Section 4.0 DEVELOPMENT OF THE BASIC EMISSION RATES

This document describes the development of basic exhaust emission rates for gasoline fueled passenger cars, light-duty trucks and medium-duty trucks (under 8500 lbs.). An emission rate represents the amount of pollutant emitted in grams per mile. The model year specific emission rate is a composite rate that accounts for variation in emissions by vehicle technology, the distribution of clean to high emitting cars and differences between the emission rates for clean and high emitting vehicles.

4.1 Introduction

The underlying assumptions in EMFAC2000 are that the vehicle fleet can be categorized into unique technology groups with each technology group representing vehicles with distinct emission control technologies, that have similar in-use deterioration rates, and respond the same to repair. Further, vehicles in each technology group can be sub-divided into emission regimes. An emissions regime is defined such that emissions from vehicles within the regime do not increase with mileage accumulation. The emission regimes are analogous to quantum energy levels. The emissions characteristic of a vehicle technology group can be represented by these emission regimes, and vehicle deterioration can be simulated by the movement of vehicles among these regimes. In EMFAC2000, vehicles in each technology group are categorized into the following five regimes:

- Normals,
- Moderates,
- Highs,
- Very Highs,
- Supers.

In general, normal vehicles are those that maintain their emission levels at or below the vehicle's certification standards (FTP-standards). Moderate vehicles have emission levels that are between one and two times the FTP standards. Highs, very highs and super emission regimes have emissions levels that may be four, six and seven times the FTP standards, respectively. As vehicles age (or accumulate mileage), their emissions increase as a result of deterioration hence they migrate from normal emitting regimes to higher emitting regimes. The movement of vehicles into the higher emitting regimes is based on an analysis of CARB's in-use vehicle data, the final product of which is called the regime growth rates. This is discussed in more detail in section 4.5.

The following example illustrates how the model calculates the without I&M[1] hydrocarbon emission rates for 1966 model year vehicles in calendar year 1990. The intent of this example is to introduce the concepts of technology groups and emission regimes. The model first determines from the technology fraction file the type of vehicles sold in 1966 model year. Table 4-1 shows that vehicles sold in 1966 were equipped with two distinct technology groups.

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[1] I&M Inspection and Maintenance or Smog Check. The intent of these programs is to lower in-use deterioration rate by identifying dirty vehicles and repairing them.

Table 4-1 Technology Groups Sold In 1966

Tech. Group	Tech. Group Description	1966 Model Year Sales
1	Non-catalyst vehicles without air injection	92%
2	Non-catalyst vehicles with air injection	8%

The model calculates the total mileage accrued by these vehicles in the1990 calendar year. In this example, it is assumed that these vehicles have accrued approximately 200,000 miles. This mileage is then used in estimating the distribution of vehicles by emissions regime. Table 4-2 shows the percentage of vehicles in technology groups 1 and 2 by emissions regime. The weighted emission rate for technology 1 and technology 2 vehicles is 10.2 g/mi. and 8.2 g/mi., respectively. These rates are then multiplied by the respective sales fractions to arrive at a weighted rate of 10.04 g/mi. This process is then repeated for all model years up to and including the 1990 model year. The model year specific emission rates are then multiplied by the mileage accrued by these vehicles in 1990 calendar year the summation of which results in an inventory for the 1990 calendar year.

Table 4-2 Regime Specific Populations and Emission Rates

Tech Group	Regime	Percent	Emissions (g/mi.)
1	Normal	0.0	3.1
	Moderate	83.3	5.9
	High	1.4	12.9
	Very High	7.8	26.6
	Super	7.5	40.9
	Weighted		**10.2**
2	Normal	34.3	4.0
	Moderate	50.5	5.3
	High	1.2	15.1
	Very High	7.1	23.8
	Super	6.9	33.6
	Weighted		**8.2**

In EMFAC2000, as in its predecessor model CALIMFAC, the without I&M emission rates are calculated first. The with I&M emission rates are calculated from the without I&M rates. Section 8.0 describes how the with I&M rates are calculated. This document only deals with the development of the without I&M rates.

This document describes the following:

1. Development of the vehicle technology groups. (Section 4.2)
2. Assessing technology groups that needed improvement. (Section 4.3)
3. Data used in developing the average emission rates for each technology group, by emissions regime. (Section 4.4)
4. Development of the emission regime boundaries and regime growth rates. (Section of 4.5)
5. Calculation of average emission rates. (Section 4.6)

6. UC based emission rates. (Section 4.7)

4.2 Vehicle Technology Groups

In MVEI7G, the CALIMFAC model was used in calculating the with and without I&M emission rates which were then used as inputs to the EMFAC model. The basic framework of EMFAC2000 is modeled after the old CALIMFAC model. The first step was to update the CALIMFAC's technology groups. In the CALIMFAC model the vehicle fleet was characterized into 16 technology groups (Table 4-3).

Table 4-3 Technology groups used in the CALIMFAC model

Technology Group	Model Years Included	Emission Control Systems
1	Pre-1975	Without Secondary Air
2	Pre-1975	With Secondary Air
3	1975 and later	No catalyst
4	1975-76	Oxidation catalyst, with secondary air
5	1975 and later	Oxidation catalyst, w/o secondary air
6	1977 and later	Oxidation catalyst, with secondary air
7	1977-79	TBI/Carb, TWC
8	1981 and later	TBI/Carb, single bed TWC, 0.7NOx
9	1981 and later	TBI/CARB, dual-bed TWC, 0.7 NOx
10	1977-80	MPFI, TWC
11	1981 and later	MPFI, TWC, 0.7 NOx
12	1981 and later	TBI/Carb, TWC, 0.4 NOx
13	1981 and later	MPFI, TWC, 0.4 NOx
14	1980	TBI/Carb, TWC
15	1993 and later	TBI/Carb, TWC, 0.25 HC and 0.4 NOx
16	1993 and later	MPFI, TWC, 0.25 HC and 0.4 NOx

During the early development of EMFAC2000, staff noted that the 1980 to approximately 1984 model year vehicles contributed disproportionately to the emissions inventory. Staff postulated that this phenomenon might be due to the introduction of prototype three-way catalysts, closed loop control, and fuel-injection systems on vehicles sold during these model years. If this hypothesis was true, then the technology groups 8, 9, 11, 12 and 13 should be further disaggregated since they encompassed 1981 and newer model years.

To prove this hypothesis, staff analyzed 1975 and later model year passenger car data from the: 2S76, 2S77400, 2S78C1, 2S79C1, 2S80C1, 2S81C1, 2S82C1, 2S83C1, 2S78C2, 2S80C2, 2S87C1, 2S88C1, 2S89C1, 2S89C2, 2S90C1, 2S92C2 and 2S93C1 light-duty vehicle surveillance projects using SAS software. The CARB routinely conduct surveillance projects in an ongoing effort to improve the motor vehicles emissions inventory. During these projects, vehicles are randomly selected from the Department of Motor Vehicles (DMV) vehicle registration database, procured, and tested as-is at baseline. Vehicles are tested using the FTP test procedure. In the surveillance projects listed above, the numbers after "S" refer to the calendar year during which the surveillance project was conducted. Since every project contains

a crossection of the vehicle fleet, the database contains emission data for vehicle model years tested at various mileages.
The entire data set, consisting of 3151 vehicles, was first disaggragted into technology groups 3 through 14. Tables 4-4 and 4-5 show the number, and mean odometer of vehicles by technology group and model year, respectively. Similarly, Tables 4-6, 4-7 and 4-8 show the mean FTP weighted HC, CO and NOx emissions by technology group and model year, respectively.

The objective of the analysis was to determine if HC, CO or NOx emissions from a given technology group vary from one model year to the next, taking into account the odometer of the vehicles when tested. Since the number of vehicles tested in each model year varied, an analysis of variance was performed using "Proc GLM" for unbalanced data sets on each technology group. The analysis of variance tests to determine if the null hypothesis (H_o) is acceptable or can be rejected in favor of an alternative hypothesis (H_a). In this analysis, the H_o is that the emissions within any technology group don't vary from one model year to the next. The H_a is that the emissions within any technology group vary from one model year to the next. If H_o is rejected then the Duncan's[2] multiple range test was performed at a 95% confidence level to determine what the differences are by model year, i.e., for a particular technology group are the mean HC emissions from 1981 to 1984 model year vehicles similar, but significantly different from 1985+ model year vehicles? Additional analyses were also performed to determine if:

a) The emissions from technology group 8 and 9 differ significantly from each other or do the emissions from combining the technology groups vary by model year.
b) The emissions from technology groups 12 and 13 differ significantly from each other or do the emissions from combining the technology groups vary by model year.
c) The emissions from technology groups 8, 9 and 11 differ significantly from each other or do the emissions from combining the technology groups vary by model year.

These analyses were performed to see if certain technology groups could be combined. The analysis indicated that vehicles in technology group 5 (1975 and later model year vehicles with oxidation catalyst and without secondary air) should be split into 1975-79 and 1980+ model year groups. The HC, CO and NOx emissions from the older model year grouping were higher than those from the newer model year grouping. Similarly, the analysis indicated that technology group 11 should be split into 1981-84 and 1985+ model year groups. Again, the HC, CO and NOx emissions from the older model year grouping were higher than those from the newer model year grouping. This analysis lent credence to the theory that there is a learning curve associated with the implementation of any new emission control technology. Following the same reasoning, staff also recommended that technology group 13 (1981 and later, MPFI, TWC equipped vehicles certified to the 0.4 NOx standard) be split into 1981-84 and 1985+ model year groups. This recommendation was based on engineering judgement and not based purely on data analysis. However, this was not done since it would have diluted the sample size, and diminished the significance of the analyses. Two analyses were performed for this technology group, one with and one without the 1987 model year vehicles since these vehicles had high emissions. Both analyses indicated that older model year vehicles (1983-84) behave differently than 1985+ vehicles, however, the results were not definitive due to insufficient data for 1985-87 model year vehicles.

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[2] Multiple comparison procedures. An Introduction to Statistical Methods and data Analysis by Lyman Ott

Additional analyses indicated that there was very little difference between technology groups 4 and 6, both incorporate vehicles equipped with oxidation catalysts with secondary air injection. Ideally, these groups should be combined, however, staff suggested that technology group 4 encompass 1975-77 model year vehicles and technology group 6 should incorporate 1978 and later vehicles. This was done based on the visual interpretation of the mean HC and CO emissions and on the suggested grouping for NOx.

Additional analyses indicated that technology groups 8 and 9 were similar, and that the HC and CO emissions did not vary by model year. However, the Duncan's test indicated that the NOx emissions from 1981-85 vehicles varied significantly from the 1986 and later model year vehicles. This result was attributable to the 1986 and newer single-bed TWC vehicles having lower NOx emissions than the older model year vehicles and the dual-bed TWC equipped vehicles. A similar analysis was also performed on the 1981 and newer 0.7 NOx TBI/CARB single- or dual-bed TWC equipped vehicles to determine if the emissions very significantly by fuel delivery system. The results indicated that the weighted emissions do not vary significantly by fuel delivery system. Both analyses indicated that technology group 8 and 9 should be collapsed to form a more robust data set for subsequent analyses.

A similar analysis was also performed to see if technology groups 12 and 13 could be combined. The results indicated that the emissions varied significantly by technology group, i.e., the emissions from 0.4 NOx TWC equipped vehicles vary by TBI/CARB and MPFI fuel delivery systems.

The final analysis was to determine if technology group 11 was significantly different from technology groups 8 and/or 9. The results indicated that technology group 11 was significantly different from technology groups 8 or 9, and as such should remain as an independent technology group.

Table 4-9 shows the final technology groups used in EMFAC2000.

Having determined the technology groups, the next step in updating the basic emission rates was to see how well the CALIMFAC program did in predicting the population of vehicles in each regime when compared to the data from the new surveillance programs.

Table 4-4 Number of Vehicles by Technology Group and Model Year

Tech	MODEL YEAR																	
Group	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	TOTAL
3	23	34	25	13	14	10													119
4	191	221																	412
5	37	47	18	22	23	9	20												176
6			216	187	137	69	27	37	44	2	1								720
7		1		6	17														24
8							109	60	82	90	67	55	44	34	16				557
9							46	94	59	90	60	23	2						374
10			4	2	9	38													53
11							38	42	45	56	79	77	48	50	20				455
12									35						13	8	3		59
13									9	13	2	1	2		29	18	5	5	84
14						118													118
																			3151

Table 4-5 Average Odometer by Technology Group and Model Year

Tech	MODEL YEAR																	
Group	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	TOTAL
3	40069	31975	43180	41114	34126	29643													36949
4	42755	35987																	39125
5	41217	29657	51327	45824	35146	42126	50669												40067
6			38044	36431	34078	49587	43700	50632	69021	74747	32160								40822
7		51725		42169	43364														43414
8							54911	64383	82462	82857	70050	58238	66618	54756	43675				67245
9							48309	43960	61682	56796	54184	34342	34403						51377
10			51724	56255	32485	65517													58517
11							57481	87348	88668	84584	60303	54117	67497	47236	55289				66413
12									65171						52665	49610	34255		58733
13									80754	61835	39612	41987	73521		52297	43567	38887	22557	52463
14						46705													46705
																			50153

Table 4-6 Mean Hydrocarbon Emissions, By Technology Group and Model Year

Tech	MODEL YEAR																	
Group	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
3	1.963	1.108	2.58	1.004	0.934	0.619												
4	1.558	1.35																
5	2.751	1.609	1.906	2.255	1.367	0.679	0.484											
6			0.978	0.966	0.851	0.972	0.708	0.419	0.784	0.909	0.308							
7		1.69		1.659	1.396													
8							1.24	0.936	1.401	0.843	0.697	0.652	0.578	0.551	0.339			
9							0.869	0.866	0.804	0.869	0.945	0.512	0.716					
10			0.963	0.508	1.722	0.996												
11							0.768	1.029	1.001	0.892	0.646	0.523	0.402	0.348	0.335			
12									0.695						0.58	0.518	0.262	
13									0.87	0.483	0.306	0.275	1.002		0.371	0.394	0.235	0.245
14						1.192												

Table 4-7 Mean Carbon Monoxide Emissions, By Technology Group and Model Year

Tech	MODEL YEAR																	
Group	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
3	18.63	12.42	20.74	11.72	8.206	8.864												
4	20.38	14.57																
5	41.32	24.04	28.647	28.87	16.35	5.781	6.604											
6			13.37	12.51	11.3	13.35	13.01	7.04	14.01	20.78	8.77							
7		6.31		21.122	18.077													
8							18.375	13.86	15.727	11.029	11.027	13.62	9.386	8.551	6.445			
9							10.735	13.248	9.454	10.679	13.162	5.506	11.725					
10			21.08	5.73	10.843	13.341												
11							11.526	14.824	14.068	12.613	7.947	6.563	4.341	3.881	4.455			
12									9.4713						9.531	8.565	3.643	
13									11.443	5.716	4.17	2.36	8.22		4.019	5.035	2.902	2.516
14						20.56												

Table 4-8 Mean Oxides of Nitrogen Emissions, By Technology Group and Model Year

Tech	MODEL YEAR																	
Group	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
3	1.635	2.116	1.93	1.745	1.686	1.304												
4	2.481	2.395																
5	2.452	2.197	1.868	2.271	1.913	1.108	0.861											
6			1.837	1.611	1.671	1.198	0.895	0.774	1.063	1.042	0.33							
7		1.26		1.373	1.44													
8							1.051	0.988	1.395	1.063	0.73	0.752	0.712	0.668	0.514			
9							1.024	0.985	1.263	1.026	1.072	0.911	0.679					
10			1.581	1.05	1.341	1.561												
11							1.066	1.306	1.283	1.222	0.954	0.695	0.752	0.56	0.49			
12									0.865						0.723	0.708	0.303	
13									1.232	0.654	0.767	0.56	1.277		0.402	0.344	0.29	0.285
14						1.295												

Table 4-9 EMFAC2000 Technology Groups

Technology Group Definitions for EMFAC2000 and Corresponding Technology groups

Old Group	Tech Group	Model Years Included	Emission Control Configurations, Fuel Metering Systems, and Applicable Emission Standards
1	1	Pre-1975	Without secondary air
2	2	Pre-1975	With secondary air
3	3	1975 and later	No catalyst
4	4	1975-1976	Oxidation catalyst, with secondary air
5	5	1975-1979	Oxidation catalyst without secondary air
	6	1980 and later	Oxidation catalyst without secondary air
6	7	1977 and later	Oxidation catalyst, with secondary air
7	8	1977-1979	Three-way catalyst with TBI/Carb
8 and 9	9	1981-1984	Three-way catalyst with TBI/Carb, 0.7 NOx
	10	1985 and later	Three-way catalyst with TBI/Carb, 0.7 NOx
10	11	1977-1980	Three-way catalyst with MPFI
11	12	1981-1985	Three-way catalyst with MPFI, 0.7 NOx
	13	1986 and later	Three-way catalyst with MPFI, 0.7 NOx
12	14	1981 and later	Three-way catalyst with TBI/Carb, 0.4 NOx
13	15	1981 and later	Three-way catalyst with MPFI, 0.4 NOx
14	16	1980 only	Three-way catalyst with TBI/Carb
15	17	1993 and later	Three-way catalyst with TBI/Carb, 0.25 HC
16	18	1993 and later	Three-way catalyst with MPFI, 0.25 HC
none	19	1996 and later	Three-way catalyst with TBI/Carb, 0.25 HC, and OBD II
none	20	1996 and later	Three-way catalyst with MPFI, 0.25 HC, and OBD II
none	21	1994-1995	Transitional Low Emission Vehicles (TLEV), **no** OBD II
none	22	1996 and later	TLEVs with OBD II
none	23	1996 and later	Low Emission Vehicles (LEV)
none	24	1996 and later	Ultra-Low Emission Vehicles (ULEV)
none	25	1996 and later	Zero Emission Vehicles (ZEV)
none	26	1996 and later	Three-way catalyst with TBI/Carb, 0.7 NOx, and OBD II
none	27	1996 and later	Three-way catalyst with MPFI, 0.7 NOx, and OBD II
none	28	All	Low Emission Vehicles (LEV II)
none	29	All	Ultra-Low Emission Vehicles (ULEV II)
none	30	All	Super Ultra-Low Emission Vehicles (SULEV)

TBI/Carb: Throttle-body injection or carburetor fuel metering system

MPFI: Multi point fuel injection system

OBD II: Second generation on-board diagnostic systems. All 1996 and later vehicles (except Mexican vehicles) are assumed to be equipped with OBD II.

*Supergroups: (A) Non catalyst, (B) Oxidation catalyst, (C) Three-way catalysts with carburetors or throttle body injection, (D) Three-way catalysts with multi point fuel injection

4.3 Comparison of Surveillance Data with EMFAC2000 Predictions for Emissions Regime

The following section details an analysis performed by Sierra Research (under contract to CARB) to determine how the distribution of vehicles by emission regime from the CALIMFAC model compared to data from newer surveillance data. The purpose of this analysis was to identify vehicle technology groups/pollutant combinations that should be revised.

The distribution of vehicles among emissions regimes found in the surveillance data was compared to the distributions predicted by CALIMFAC model. This was done using a chi-squared (χ^2) test for different population distributions. The data used were from CARB surveillance projects run between 1987 and 1994.[1] Only passenger car data were used in the comparison.

The χ^2 test was done for the following six technology groups, which had the largest sample sizes in the ARB surveillance data:

- Old technology group 6 - 1977+ Oxidation catalyst with secondary air
- Old technology group 8 - 1981+ TBI/Carb, single-bed TWC, 0.7 NOx
- Old technology group 9 - 1981+ TBI/Carb, double-bed TWC, 0.7 NOx
- Old technology group 11 - 1981+ MPFI, TWC, 0.7 NOx
- Old technology group 13 - 1981+ MPFI, TWC, 0.4 NOx

4.3.1 Test Procedures

The following test statistic was used for the χ^2 test:[3]

$$u = \sum_{i-norm}^{super} \frac{(n_i - n_{e,i})^2}{(n_{e,i})} \cdots\cdots\cdots [4-1]$$

Where the summation index, i, is taken over the five emissions regimes (normal, moderate, high, very high and super); n_i is the number of surveillance vehicles found to be in a given regime; and $n_{e,i}$ is the number expected in the regime. The expected number was found by multiplying the total number in the sample ($n = \sum_i n_i$) by the CALIMFAC predicted fraction of vehicles in the regime. In general $n_{e,i}$ is a non-integer value. This statistic and the use of the χ^2 distribution presumed a "large" sample size, but the χ^2 approximation is surprisingly good for small n when the number of regimes is greater than two (as it was here).

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[1] These surveillance tests have the following project names in the ARB data base: 2S87C1, 2S88C1, 2S89C1, 2S89C2, 2S91C1, 2S91C2 and 2S93C1.

The statistical test to determine if the observed distribution is different from the expected distribution is based on the null hypothesis that the two distributions are the same. This hypothesis is rejected if the computed test statistic is greater than a critical value determined by the desired significance level and the degrees of freedom. For this test, the significance level represented the probability that the null hypothesis would be rejected if the observed and expected distributions were, in fact, the same. The number of degrees of freedom equals the number of regimes minus one, which was four in this calculation. For the level of significance chosen, the critical value of the test statistic, u_{crit}, is found from tables of the χ^2 distribution. The statistical test is defined as follows:

$u > u_{crit}$Reject null hypothesis; distributions assumed different.

$u \leq u_{crit}$Accept null hypothesis; distributions assumed the same.

The test was done using a significance level of 0.05; the critical value of the test statistic is 9.488 for this significance level.

For small sample sizes, an alternative test can be used. This test is based on the likelihood ratio, λ , defined in terms of the actual and expected number of vehicles by the following equation:

$$\lambda = \prod_{i=norm}^{super} \left(\frac{n_{e,i}}{n_i} \right)^{n_i} \dots \qquad [4-2]$$

n_i and $n_{e,i}$ have been defined previously; Π is the continued product operator. The small-sample approach is outlined below.

1. For a given sample size, n, and EMFAC2000 expected values, compute the value of λ and the probability for each possible distribution of the (integer) $\{n_i\}$.

2. Tabulate the values of λ for various distributions and the associated probability of that distribution in order of increasing λ.

3. Compute the cumulative probability for each value of λ in the table (i.e., the probability that λ will be less than or equal to a given value).

4. Select the critical value of λ as the one whose cumulative probability has the desired significance level (0.05 in these calculations).

5. Compare the value of λ for the observed distribution in the surveillance data with the critical value of λ determined in step 4. If the observed value is less than the critical value, reject the null hypothesis that the distributions are the same.

This small sample procedure was used for sample sizes of one to twelve. The large-sample statistic, u, was also computed for these samples. In general, the small-sample procedure showed lower probabilities that the observed sample was different from the EMFAC2000 distributions than the large-sample procedure. Thus, any possible error in switching from the small-sample procedure to the large-sample procedure for samples of eight or more would reject the null hypothesis when it might otherwise be accepted by the more accurate procedure.

To compare observed and expected data, the surveillance data in which vehicle age is not recorded, but odometer readings are, were compared to the EMFAC2000 predictions of emission regimes, which are calculated based on odometer mileage but are reported as a function of vehicle age. These equivalencies are shown in Table 4-10.

For a given test year,CALIMFAC provides results only for technology groups whose age is less than the maximum possible age for the technology group (e.g., predictions for a 1987 test date for technology groups that start in 1981 will be available only for vehicle ages of 1 to 6 years). There were some surveillance data that could not be used because they had accumulated high mileage in a short time. Other vehicles did not have CALIMFAC distributions because they were too old to be included in the sales fraction. This was especially true of the oxidation catalyst vehicles in old technology group 6.

Table 4-10 Equivalencies Between Odometer Reading in Surveillance Data and Vehicle Age in EMFAC2000 Predictions

Surveillance Data Odometer Readings (miles)	EMFAC2000 Vehicle Age Range (years)
0 to 22,000	1 and 2
22,000 to 45,000	3 and 4
45,000 to 65,999	5 and 6
66,000 to 85,000	7 and 8
Greater than 85,000	9 and greater

The initial tests were performed by subdividing the surveillance data by test year and vehicle odometer reading for each technology group. There were eight test years and five odometer/age classifications, giving 40 possible distributions of vehicles among emission regimes for each pollutant in each technology group. Because some test-year/age classifications had no vehicle data and other high-mileage vehicles in early test years had no CALIMFAC projections, there were only 101 different distributions for a given pollutant: 6 for old technology group 6, 8 for old group 13, 21 for old group 9, and 33 for old groups 8 and 11. Considering all pollutants, there were 303 (3 x 101) distributions from surveillance data to be compared to CALIMFAC data. This was the most disaggregated set of data considered.

4.3.2 Results

The χ^2 test (or the small-sample alternative) was applied to each of the 303 distributions for a specified pollutant, test year, technology group and odometer/age group. Of the 303 possible tests, 260 satisfied the null hypothesis at the 0.05 level. The distributions that failed the χ^2 test are summarized in Table 4-11. In addition to showing the test statistic for the failed distributions, Table 2-2 shows the probability that the observed test statistic would be observed if the underlying distributions were, in fact, the same. For the small-sample procedure, only this probability is shown.

Table 4-11
Description of One-year Data Sets Not Satisfying Null Hypothesis of χ^2 Test at 0.05 Significance Level
Not Shown: 260 of 303 Data Sets Satisfying Null Hypothesis

Species	Old Technology Group	Test Date	Mileage Group	Sample Size	χ^2 Result	
					Test Statistic	Probability
HC	6	1993	85k+	2	-	.0067
	8	1989	85k+	62	36.53	4x10^{-7}
		1990	85k+	7	-	.0050
		1993	66-85k	8	-	.0093
		1993	85k+	16	16.69	.0014
		1994	66-85k	3	-	.0049
	9	1987	45-66k	9	-	.0465
		1989	85k+	10	-	.0002
		1990	22-45k	13	9.83	.0434
		1990	45-66k	6	32.37	2x10^{-6}
		1991	85k+	3	-	.0098
		1992	85k+	6	-	.0088
	11	1989	66-85k	19	10.75	.0295
		1989	85k+	34	13.72	.0082
		1992	66-85k	29	11.68	.0199
		1993	45-66k	4	-	.0095
		1993	85k+	16	12.98	.0114
	13	1992	22-45k	8	-	.0233
CO	6	1988	85k+	2	-	.0067
		1993	85k+	2	-	.0026

	8	1989	85k+	62	18.33	.0011
		1990	85k+	7	-	.0023
		1993	85k+	16	15.97	.0031
		1994	66-85k	3	-	.0476
	9	1988	22-45k	43	10.37	.0346
		1989	85k+	10	-	6x10^{-6}
		1990	45-66k	13	27.09	2x10^{-5}
		1991	85k+	3	-	.0108
		1992	85k+	6	-	.0342
	11	All pass for this technology group and pollutant.				
	13	All pass for this technology group and pollutant.				
NOx	6	1989	85k+	12	-	.0042
	8	1993	45-66k	6	-	.0074
	9	1987	0-22k	4	-	.0152
		1989	85k+	10	-	.0220
		1990	22-45k	5	-	.0071
		1990	85k+	6	-	.0476
		1992	85k+	6	-	.0360
	11	1989	85k+	34	33.30	1x10^{-6}
		1992	45-66k	24	16.49	.0024
		1992	66-85k	29	19.85	.0005
		1992	85k+	28	12.81	.0122
		1993	66-85k	5	-	.0113
		1994	66-85k	5	-	.0029
		1994	85k	5	-	.0022
	13	All pass for this technology group and pollutant.				
Note: The "probability" column entry represents the probability that the test statistic would be observed if the two distributions were actually the same. The test statistic column contains the result of the computation in equation [1] where the total sample was greater than 12 vehicles.						

The largest number of mismatches are in old group 9, for all pollutants, old technology group 8 for HC and CO, and old technology group 11 for HC and NOx.

Many of the distributions that did not satisfy the null hypothesis at the 0.05 significance level had small sample sizes, but one of the failed distributions had a sample size of 62, one of the larger sample sizes for this test series. Twenty-four of the 43 failed distributions were for the 85,000-mile-plus category. This category in the surveillance data fleet was compared with the nine-year-plus vehicle age in the EMFAC2000 data.

One possible reason that a large number of the distributions not satisfying the null hypothesis are in 85,000-and-above mileage range is that the actual distribution of vehicles in the surveillance fleet differs from the standard distribution predicted from EMFAC2000. To illustrate this difference, the proportion of super emitters for CO emissions from old technology group 8 in CALIMFAC was examined for each of the age ranges used to classify the odometer data in the surveillance fleet. The results are shown in Table 4-12.

Table 4-12
Proportion of Super Emitters in CALIMFAC
for CO in Old Technology Group 8

Age Range (years)	1-2	3-4	5-6	7-8	9+
Range for Supers	0	0 to .007	.007 to .0205	.0205 to .0326	.0326 to .0975

The range for the proportion of super emitters is relatively broad in the nine-year-plus age category compared to the other age bins. Thus, it is possible that this age classification does not provide a good match to the odometer data range for this regime.

The data for each technology group were further aggregated into four two-year groups based on test dates (1987-1988, 1989-1990, 1991-1992, and 1993-1994). Each of these groups should represent vehicles that have undergone a different number of visits to an I&M station in the biennial program. Each technology group could provide a maximum of 15 distributions (3 two-year blocks x 5 five-mileage bins). Because of some groups with no data, there were only 5 distributions for old technology group 6, 17 for old group 8, 12 for old group 9, 19 for old group 11, and 5 for old group 13. This gave a total of 58 distributions for each pollutant, or a total of 174 distributions for comparison to CALIMFAC data. At the 0.05 level, 142 of these satisfied the null hypothesis that the distributions are similar. Table 4-13, with the same format as Table 4-11, shows the information on the distributions that did not satisfy the null hypothesis. With the aggregation of two years of test data, the sample size for each distribution tested increases.

Sixteen of the 32 cases where the null hypothesis was not satisfied were for vehicles with odometer readings greater than 85,000 miles. Two particular group/pollutant combinations gave the largest numbers of distributions failing to satisfy the null hypothesis: (1) old technology groups 8 and 9 for HC and CO, and (2) old technology group 11 for HC and NOx.

A final level of aggregation took all the measurement years for each technology group and age classification. This gave 60 total distributions, of which 39 satisfied the null hypothesis at the 0.05 level. Nine of the 21 distributions that did not satisfy the null hypothesis were for distances greater than 85,000 miles. Details of the failed distributions are shown in Table 4-14.

Table 4-13
Description of Two-Year Data Sets Not Satisfying Null Hypothesis of χ^2 Test at 0.05 Significance Level
Not Shown: 142 of 174 Data Sets Satisfying Null Hypothesis

Species	Old Technology Group	Test Years	Mileage Group	Sample Size	χ^2 Result	
					Test Statistic	Probability
HC	6	93-94	85k+	2	-	.0067
	8	89-90	85k+	69	51.40	$2x10^{=10}$
		93-94	66-85k	11	-	.0009
		93-94	85k+	23	18.55	.0009
	9	89-90	45-66k	36	22.32	.0002
		89-90	85k+	16	49.50	$5x10^{-10}$
		91-92	85k+	9	-	.0006
	11	89-90	45-66k	31	14.35	.0060
		89-90	85k+	43	15.90	.0032
		93-94	45-66k	14	22.24	.0002
		93-94	85k+	21	12.00	.0174
	13	91-92	22-45k	9	-	.0152
CO	6	87-88	66-85k	9	-	.0058
		93-94	85k+	2	-	.0026
	8	89-90	85k+	69	19.64	.0006
		93-94	45-66k	11	-	.0081
		93-94	66-85k	11	-	.0203
		93-94	85k+	23	12.45	.0143
	9	87-88	22-45k	17	12.11	.0166
		89-90	45-66k	36	23.12	.0001
		89-90	85k+	16	99.55	$1x10^{-20}$
		91-92	85k+	9	-	.0009
	11	All pass for this pollutant and technology group combination				
	13	All pass for this pollutant and technology group combination				
NOx	6	89-90	85k+	20	11.87	.0184

	8	93-94	66-85k	11	-	.0208
		93-94	85k+	23	12.55	.0137
	9	87-88	0-22k	15	24.02	$8x10^{-5}$
		89-90	22-45k	11	-	.0007
	11	89-90	85k+	43	24.58	$6x10^{-5}$
		91-92	45-66k	28	18.90	.0008
		91-92	66-85k	30	22.17	.0002
		91-92	85k+	29	11.67	.0200
		93-94	66-85k	10	-	$9x10^{-5}$
	13	All pass for this pollutant and technology group combination				
Note: The "probability" column entry represents the probability that the test statistic would be observed if the two distributions were actually the same. The test statistic column contains the result of the computation in equation [1] where the total sample was greater than 12 vehicles.						

Table 4-14
Description of Six-Year Data Sets Not Satisfying Null Hypothesis of χ^2 Test at 0.05 Significance Level
Not Shown: 39 of 60 Data Sets Satisfying Null Hypothesis

Species	Old Technology Group	Test Years	Mileage Group	Sample Size	χ^2 Result	
					Test Statistic	Probability
HC	6	87-94	66-85k	27	63.05	$7x10^{-13}$
	8	87-94	66-85k	104	14.20	.0067
		87-94	85k+	168	59.29	$4x10^{-12}$
	9	87-94	45-66k	104	18.90	.0008
	11	87-94	85k+	112	29.94	$5x10^{-6}$
	13	All pass for this pollutant and technology group combination				
CO	6	87-94	66-85k	27	51.51	$2x10^{-10}$
	8	87-94	85k+	168	31.73	$2x10^{-6}$

	9	87-94	22-45k	82	16.25	.0027
		87-94	45-66k	104	10.60	.0315
		87-94	85k+	37	121.22	3x10^{-25}
	11	87-94	85k+	112	23.37	.0001
	13	All pass for this pollutant and technology group combination				
NOx	6	87-94	66-85k	27	54.92	3x10^{-11}
		87-94	85k+	55	10.60	.0314
	8	87-94	85k+	168	11.85	.0185
	9	87-94	0-22k	17	19.42	.0007
		87-94	45-66k	104	10.47	.0332
		87-94	85k+	37	18.44	.0010
	11	87-94	22-45k	95	12.11	.0166
		87-94	66-85k	87	24.89	5x10^{-5}
		87-94	85k+	112	20.47	.0004
	13	87-94	22-45k	23	10.45	.0033

Note: The "probability" column entry represents the probability that the test statistic would be observed if the two distributions were actually the same. The test statistic column contains the result of the computation in equation [1] where the total sample was greater than 12 vehicles.

The aggregation of the data into larger groupings of test years was done to see if larger sample sizes would improve the matching between the EMFAC2000 predictions and the surveillance data. However, just the opposite effect occurred. As the data were aggregated into more than individual year groups, the fraction of distributions that matched the EMFAC2000 predictions declined from 85.8% for one test year to 81.6% for two test years to 65.0% for all test years. Because the EMFAC2000 predictions are for individual years and because the small sample procedure is able to provide results regardless of the sample size, the comparison should rely on the single-year results.

In order to determine the direction of the difference for the distributions that did not satisfy the null hypothesis, a simple index to measure the degree of poorly performing vehicles was constructed. The index was computed by assigning each regime a score based on the midpoint of the CALIMFAC emission boundaries for the regime. For example, the very high CO emission regime, with emissions between 6 to 10 times the FTP standard, was assigned a score of 8. The scores for all pollutants and regimes are shown in Table 4-15.

HC	0.75	1.5	3.5	7	15
CO	0.75	1.5	4	8	15
NOx	0.75	1.5	2.5	3.5	6

The index is computed from the scores in Table 4-15 by the following equation:

$$\begin{aligned}\text{Index} = [\ & s_{N,species} \text{ x (Percentage of Normals)} \\ & + s_{M,species} \text{ x (Percentage of Moderates)} \\ & + s_{H,species} \text{ x (Percentage of Highs)} \\ & + s_{V,species} \text{ x (Percentage of Very Highs)} \\ & + s_{S,species} \text{ x (Percentage of Supers)}\ ] / s_{S,species}\end{aligned}$$

This would range from a low score* for 100% normal vehicles to 100 for 100% super emitters. This index was computed for both the CALIMFAC distribution and the surveillance data in the cases where the null hypothesis was not satisfied. In most of the cases, the index was higher for the surveillance fleet than for the CALIMFAC cases. This indicates that the cases where there is a significant difference between the CALIMFAC predictions and the surveillance data are cases where CALIMFAC is underpredicting the actual emissions. The details of this comparison are given in Table 4-16. The occurrence of dirtier distributions is truer for HC and CO than it is for NOx. The one exception to this general trend was for old technology group 13. The vehicles from this group used in CALIMFAC comparisons were generally newer cars with no vehicles over 66,000 miles. The 94 vehicles in the surveillance data had no very high or super regime vehicles for HC, two very high and no super regime vehicles for CO, and two very high and five super regime vehicles for NOx. For this technology group, all the distributions that did not meet the statistical criterion for similarity had cleaner emissions than the CALIMFAC predictions.

Table 4-16
Number of Different Cases That Have "Dirtier" Vehicles in Surveillance Fleet than in EMFAC2000 Predictions
Compared to Total Cases with Different Distributions

Years of Test Data in Group	Total Cases	Dirty Cases	Total Cases	Dirty Cases	Total Cases	

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*The lowest scores are 100 s_N/s_S for each pollutant. These minimum values are 5 for HC and CO and 12.5 for NOx.

One year	18	16	11	11	13	8
Two years	12	11	10	9	10	5
Six years	5	5	6	6	10	6

In this table, "Total Cases" refers to total cases with different distributions. For example, the one-year data set for HC had 18 cases where the surveillance data had a significantly different distribution than the EMFAC2000 predictions (out of a possible 101 cases tested). Of these 18 cases, 16 had a "dirtier" distribution in the surveillance data than in the CALIMFAC predictions.

The comparisons made here included data from the "Surveillance-9" study (2S87C1). These data were also used in the derivation of CALIMFAC regime boundaries and regime growth functions. It was included in the comparisons here as a check on how good a match could be expected by the χ^2 comparison. The Surveillance-9 data were all taken in 1987 and 1988; no other data were taken in those years. The single-year comparisons in Table 3 show that four technology group/mileage/pollutant combinations do not show a match between CALIMFAC predictions and the Surveillance-9 data. This shows that the statistical fits to the data used in CALIMFAC have some residual error and it is not surprising that data, which were not used in the fit, do not match the CALIMFAC data completely. However, the fits for the Surveillance-9 data are better than those for other years. If the 43 distributions that did not match were evenly distributed among the study years, the number of mismatched distributions for 1987 and 1988 would be expected to be about ten instead of the four actually found.

Based on the comparison, the following conclusions were reached:

- CALIMFAC predictions are consistent with surveillance data for 86% of the cases evaluated.
- Significant differences exist and particular attention was paid to the following technology groups in subsequent development of emission rates for EMFAC2000:

    - vehicles with more than 85,000 miles;
    - HC and CO emissions from old technology group 8;
    - all emissions from old technology group 9; and
    - HC and NOx emissions from old technology group 11.

- In general, the differences occurred because the vehicles in the sample were dirtier than the CALIMFAC predictions. The exception to this was old technology group 13.

Having determined that there were several shortcomings of the then CALIMFAC model, staff decided on data to be used in updating the EMFAC2000 model. The model is driven by data from vehicles that have not been subject to I&M programs. Further, even the data from CARB's surveillance projects could not be simply added to the "EMFAC2000 master" data set without making sure that the data was indeed representative of the failure rates found during BAR's random roadside surveys. The following section details the data used in EMFAC2000.

4.4 Data Used in the Development of EMFAC2000

Several data sets were available for use in developing EMFAC2000:

1. The data used in the development of the original CALIMFAC model, consisting of ARB data up to Surveillance set 9, augmented by vehicles from early I&M data sets to adjust the component malperformance rates.
2. New ARB data from studies 2S88C1, 2S89C1, 2S89C2, 2S91C1, and 2S91C2.
3. New ARB data from I&M evaluation studies.
4. EPA data obtained at Hammond and Ann Arbor to develop correlations between IM240 and FTP results.

This section discusses the selection of particular data sets to be used in the determination of EMFAC2000 regime and emission rate information and the quality control procedures used on the data. Data sets were selected in consultation with CARB staff. The goal was to obtain representative data sets, which would have a sufficient number of vehicles to give statistical significance. Data sets obtained in studies of I&M programs contained only vehicles which were expected to fail the I&M program. Such data sets were not considered representative of the entire fleet and were not used (with some exceptions noted below) in CALIMFAC or EMFAC2000. One important restriction was placed on the data used to determine regime growth functions in the absence of an I&M program. Only data on vehicles which had never been through an I&M program could be used for this purpose.

4.4.1 ARB Data

The data previously used to develop the CALIMFAC model contained results from CARB surveillance and high-mileage tests up to and including Surveillance 9 (2S87C1). That data set used selected data from the original 1987 study of the California I&M program to provide a data set that was representative of actual vehicle malperformance rates. This was done by adding vehicles from the I&M data set to match vehicle component malperformance rates from the BAR random roadside tests. This entire data set, referred to as the old master data set, was used in the development of CALIMFAC and was used again for EMFAC2000. For both CALIMFAC and EMFAC2000 this data set was assumed to have vehicles which had not been through an I&M program. These data were used in the development of regime boundaries, regime emission rates, and regime growth functions. The vehicles in the Surveillance 9 data set had actually been through the initial biennial I&M program in California, but the effects of this single program step were assumed to have a negligible impact on the distribution of vehicles among regimes.

Recent surveillance and high-mileage data studies by ARB (2S88C1, 2S89C1, 2S89C2, 2S91C1 and 2S91C2) were done on vehicles that had been through one or more I&M cycles. These data were used to develop the definition of regime boundaries, because the same regime boundaries are applied in the model to both I&M and non-I&M vehicles.

However, these data could not be used to determine the regime growth functions[*] in the absence of I&M. Development of these functions is discussed in the next section.

4.4.2 Quality Control Checks with ARB Data

The following series of quality control checks were used on the new CARB data sets:

- The weighted FTP emission rates were calculated from individual bag data and compared to the weighted FTP emission value in the data set.
- The model year and emission standard fields were checked to ensure that the emission standards were appropriate for the model year.
- The reference table developed for the California Bureau of Automotive Repair (BAR) was used to check the description of the vehicle emission control system.

Details of the discrepancies found in these quality control checks were sent to CARB staff and the appropriate corrections were made in the database.

4.4.3 Comparison of Malperformance Rates in ARB and BAR Data

An important measure of the representativeness of the data set is the observed occurrence of vehicles with emission control components that are not functioning properly. The BAR maintains a random roadside survey, which stops vehicles on the road and observes the performance of emission control components. The malperformance rates for the ARB surveillance data were compared to those from the BAR random roadside surveys. Two separate sets of vehicles were examined: (1) gasoline-powered, California-certified passenger cars; and (2) all vehicles in the data set. Details on this comparison are provided below.

4.4.3.1 Analysis of ARB Data

Two files from the CARB data set were used in the analysis. The vehicle description (VEHDESC) file contained basic information about the vehicle the diagnostic and repair code (DRCODE) file contained information on malperforming components.[*] The first step in the analysis was to determine the particular emission control components that should be present on a given vehicle. That information was taken from specific fields in the ARB data set shown in Table 4-17. The specific codes used to identify system components in the DRCODE file were taken from an ARB analysis.[**] These also are shown in Table 4-17.

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[*] This is the name of the regression equations giving the population of the various regimes as a function of some parameter (typically vehicle age and/or odometer reading).

[**] Preliminary draft memo from Dilip Patel to Mark Carlock at ARB, "Analysis of 2S88C1, 2S89C1, 2S89C2 and 2S91C1/C2 programs," received at Sierra Research on December 20, 1993. Final results are presented in Table 2 of that memo.

Table 4-17 Identification of Components		
Emission Control System	System Component Codes	Presence of Emission Control System Determined by
Exhaust Gas Recirculation (EGR)	600, 606, 608	Variable EGR in VEHDESC file equal to 'Y'
Spark Ignition System	306, 309, 314	Assumed to be present on all vehicles
Evaporative Controls	406, 408, 409, 410	Assumed to be present on all vehicles
Thermostatic Air Cleaner	206, 208, 209, 211	Assumed to be present on all vehicles
Positive Crankcase Ventilation (PCV)	506, 508	Assumed to be present on all vehicles
Air Injection System	700 to 799	Variable AIR_INJ in VEHDESC file equal to 'A' or 'P'
Catalyst	811	Variable REACTOR in VEHDESC file equal to 'C', 'T', 'D', 'O', or 'E'
Oxygen Sensor	813	Variable O2_SENS in VEHDESC file equal to 'Y'

Records in the DRCODE file contain fields that identify the vehicle and system component and contain a one-character diagnostic code (DICODE) and a yes/no flag to indicate tampering (TAMPER). A malperforming vehicle is recognized when the tamper flag indicates yes or when a malperforming part is indicated by one of the following values in the DICODE field: plugged (‘B’), disconnected (‘D’), electrical defect (‘E’), defective (‘F’), leaking (‘L’), missing (‘M’), off specification (‘O’), or misrouted (‘R’). Records in the DRCODE file also have a diagnostic and repair sequence (DR_SEQ) field that identifies a particular test in a sequence of tests. Malperformance for a given vehicle and system component may be noted at any value of DR_SEQ. If none of these conditions were met, or if none of the component codes for a particular system were listed in the DRCODE file, it was assumed the system was performing properly.

The malperformance analysis for a particular system identified in Table 14-17 examined all the component codes corresponding to the system. If any of the component codes for a given system indicated malperformance, then the system was classified as malperforming. (For example, evaporative system malperformance would be detected by a tamper flag set to yes, or a DICODE value indicating malperformance, for system

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[***] Vehicle 380 in project 2S89C2, a 1989 Toyota P/U LB, had a 'W' in the O2_SENS field. It was assumed the vehicle had an O_2 sensor, as did the other vehicle in the same engine family.

components 406, 408, 409, or 410.) No distinction was made between tampering and other malperformance.

4.4.3.2 Analysis of BAR Random Roadside Data

Following the BAR method of analyzing random roadside data, the following test records were deleted:

- vehicles with a gross vehicle weight rating (GVWR) greater than 8500 pounds;
- vehicles with aborted emission test results indicated by a blank in the emission results field ('TSTEMS'), and by a code of 1 in the aborted test field ('ABORT'); and
- vehicles sent to a referee station to confirm aborted tests. These are determined by a value of 9 in the 'ABORT' field and an indication that the referee station has not overridden the aborted test (a value of 'N' in the referee override field, 'REFOVRD').

The BAR data analysis excluded the most recent model year vehicles because BAR did not want to analyze vehicles that could never have been to an inspection and maintenance (I&M) test station. This analysis, however, did include the most recent model year vehicles.

The analysis was done for two sets of 1980 and later model year vehicles: all vehicle types in the data set, and California-certified, gasoline-powered passenger cars. This second set was extracted from all data by selecting only those records with the following values:

Variable	Value used for Selection
VHCLTYP	'P' (passenger vehicle)
FUELTYP	'G' (gasoline)
MDLYR	80 (model year 1980 and later)
CERTYP	'C' (California-certified)

The malperformance codes were those used in an ARB analysis[*] of the BAR data. It was considered a malperformance if the system variable had a value of 'M' (modified), 'S' (missing), 'D' defective, 'F' (fail), 'T' (tamper), 'B' (missing/nonconforming) or 'C' (disconnected/nonconforming). Most systems examined had a single data entry. Others required an analysis of two or more data fields. The following variables in the BAR data set were examined in this analysis:

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[*] Preliminary draft memo from Dilip Patel to Mark Carlock, "CALIMFAC Random Roadside Analysis," received at Sierra Research December 20, 1993. Table 1 in that memo contains the malperformance codes; Table 3 contains the tampering, malmaintenance and malperformance rates for BAR 1990, 1991 and 1992 random roadside inspections for vehicle model year groups, Pre-1975, 1975-79 and 1980-Plus.

System	BAR Variable(s)	System Name
PCV	PCV & PCVFNCT	Positive Crankcase Ventilation
TAC	TAC	Thermostatic Air Cleaner
Evap	FEC	Fuel Evaporative Controls
CAT	CAT	Catalyst
EGR	EGR & EGRVLV	Exhaust Gas Recirculation
AIR	see below	Air Injection System
Spark	ISC	Ignition Spark Control
O2S	OXS	Oxygen Sensor

For 'EGR' and 'PCV', visual tests (variables EGR and PCV) and functional tests (variables EGRVLV and PCVFNCT) were analyzed; if either of these two tests failed, then the system was considered malperforming.

The other possible values stored in the BAR variables for the system components listed above are 'P' (pass), 'N' (not applicable), 'A' (aborted test) or missing/blank. Only vehicles with a 'P' for pass were considered passing vehicles; those vehicles with 'N', 'A' or missing values were not included in the analysis of that particular system. The total number of vehicles with a particular system, used to determine the malperformance rate, was calculated as the sum of the malperforming vehicles plus the passing vehicles for the system under consideration.

There are a series of variables related to the components of an air-injection system which require a separate analysis for this system. An initial variable, AIS, determines if the system is pulse air ('P'), not applicable ('N'), or an air pump ('A'). The total number of air injection systems was taken as the number of vehicles with a 'P' or an 'A' value in the AIS variable. The number of malperforming air injection systems was determined as the number of vehicles with any malperformance code (as listed above) in any of the following variables:

Variable	Component Name
AIP	Air Injection Pump
APB	Air Pump Belts
AIB	Air Injection Plumbing
ADV	Air Diverter Valve
ARV	Air Reed Valve
PAI	Pulse Air Injection

4.4.3.3 Comparison of ARB and BAR Data

The malperformance rates between ARB and BAR data were compared based on the ARB and BAR data sets developed as described above. Results of this comparison for all vehicles in the survey data are shown in Table 4-18. As the table shows, the percent failures in the ARB surveillance data are higher than those found in the BAR data for each emission control system. This is similar to the result found in the original development of the CALIMFAC model: the malperformance rates for ARB surveillance data on 1980 and later model year vehicles were higher than those calculated in the BAR roadside surveys.

Table 4-18
Component Malperformance Rates from ARB Surveillance Data and BAR Roadside Survey Data for 1980 and Later Model Year Vehicles
Data for All Vehicles in Survey

Emission Control System	ARB Surveillance Data			BAR Roadside Data		
	Total	Bad	% Bad	Total	Bad	% Bad
PCV Valves	1096	91	8.3%	4072	109	2.7%
Thermostatic Air Cleaner	1096	92	8.4%	2447	177	7.2%
Evaporative System	1096	83	7.6%	4070	44	1.1%
Catalyst	1096	128	11.7%	4050	27	0.7%
Exhaust Gas Recirculation	949	161	16.9%	3678	205	5.6%
Ignition System	1030	134	13.0%	4013	31	0.8%
Air Injection	592	61	10.3%	2338	68	2.9%
Oxygen Sensor	1035	442	42.7%	3651	9	0.2%

The same comparison is shown in Table 4-19, based on California-certified, gasoline-powered, passenger cars only. The BAR data generally show a very slight decrease in the malperformance rates as compared to the entire vehicle fleet, whereas the ARB surveillance data show both slight increases and decreases when compared to the entire vehicle fleet. Therefore, excluding federal vehicles and trucks does not significantly change the malperformance rates.

Table 4-19
Component Malperformance Rates from ARB Surveillance Data and BAR Roadside Survey Data for 1980 and Later Model Year Vehicles
Data for California-Certified Passenger Cars Only

Component	ARB Surveillance			BAR Roadside		
	Total	Bad	% Bad	Total	Bad	% Bad
PCV Valves	758	67	8.8%	2742	67	2.6%
Thermostatic Air Cleaner	758	61	8.0%	1489	94	6.3%
Evaporative System	758	56	7.4%	2742	13	0.5%
Catalyst	758	89	11.7%	2728	8	0.3%
Exhaust Gas Recirculation	643	117	18.2%	2447	115	5.0%
Ignition System	716	101	14.1%	2700	12	0.4%
Air Injection	397	45	11.3%	1439	27	1.9%
Oxygen Sensor	718	291	40.5%	2513	4	0.2%

4.4.3.4 Comparisons with Previous Analysis

Sierra staff compared BAR random roadside data from the 1992 survey with data from vehicles recruited for the last evaluation of the California I&M program (Project 2S91V1). Because the I&M data set included only vehicles that should have failed an I&M test, the BAR data were adjusted to include only that subset of vehicles. In addition, the numbers of vehicles used in the analysis of BAR data were adjusted so that both the BAR data set and the I&M data set would have the same distribution of vehicle model years.

The results of the earlier analysis found the defect rates to be similar for the CARB and BAR data sets except for missing catalysts and, to a smaller degree, for missing air-injection system components. Catalysts and air-pump hardware were missing at a higher rate in the BAR database as compared to the I&M database. In contrast to these results from the remote-sensing report, the analysis presented here found higher malperformance rates in the BAR data as compared to the ARB surveillance data. However, even if the malperformance rates in the BAR roadside and ARB surveillance data were the same, it would not be necessary to seek modifications to the ARB surveillance data to properly represent malperforming vehicles. The significant concern raised by the remote-sensing report is its conclusion that missing catalysts and air pump components occur at a higher rate in the BAR data as compared to the <u>I&M evaluation data</u>. In order to ensure that the <u>ARB surveillance data</u> were not under-representing missing catalyst and air-injection components, a separate analysis was made looking only at missing components. This comparison of missing catalysts and air-pump components was done for California-certified passenger cars using the same data sets that were used for the comparison shown in Table 4-17. The comparison of missing component rates is presented in Table 4-20. As the table shows, the rate for missing air-injection components is slightly higher in the BAR data, as compared to the ARB surveillance data. This is similar to the conclusion reached in the remote sensing report, but the difference between the BAR data and ARB surveillance data shown in Table 4-20 is not statistically significant.

Table 4-20
Missing Rates from ARB Surveillance Data and BAR Roadside Survey
1980 and Later Model Year California-Certified Passenger Cars

Component	Data	Total	Missing	Percent Missing		
				Obs.	LCL	UCL
Catalyst	ARB	758	1	0.1%	0.0%	0.4%
	BAR	2728	4	0.1%	0.0%	0.3%
Air Injection	ARB	397	3	0.8%	0.0%	1.6%
	BAR	1439	16	1.1%	0.6%	1.7%

Note: The entries in the percent missing column represent the observed percentage (obs) missing as well as the lower and upper 95% confidence limits (LCL and UCL).

These results compare not only the observed percent missing but also the upper and lower 95% confidence limits for the observed percentage. These confidence limits are computed from the cumulative binomial distribution. They represent the boundaries within which the missing rate is expected to fall, with 95% confidence, assuming the observed missing rate is the true missing rate for the population. Based on this comparison, there does not appear to be any statistically significant difference between the rate of missing catalysts or missing air pump components for the ARB surveillance and BAR random roadside data sets analyzed in this survey.

The difference between this conclusion and the one reached in the remote-sensing report, which found a significant difference in the rate for missing catalysts, may be due to the differences in the model years analyzed. The remote-sensing report analysis covered all model years, while the current analysis looks only at 1980 and later model years. When all model years are considered, the missing catalyst rate in the BAR database 0.5%, with a 95% confidence interval of 0.3% to 0.8%. The ARB data, for all model years, have a missing catalyst rate of 0.1%, with a confidence interval of 0.0% to 0.2%. Thus, when all model years are considered, the missing catalyst rate in the ARB surveillance data is higher than that in the BAR data and the difference is statistically significant. This is consistent with the conclusion in Sierra's CALIMFAC report that the ARB surveillance data underrepresented vehicle malperformance for pre-1980 model-year vehicles. This under-representation was corrected in the CALIMFAC database, which was used as the old master data set in this work.

4.4.4 Available EPA Data

The initial comparison of measured regime populations and CALIMFAC predictions discussed in the previous section showed that the largest disagreement was for high-mileage vehicles. Sierra examined various possible data sets that could be used to extend the ARB data and selected data used by EPA to correlate FTP and IM240 results as a good source of non-I&M data. As described below, this data set was corrected to a realistic pass-fail distribution for IM240 tests, and provided a source of late-model, non-I&M data that were not available in the ARB database.

During the development of MOBILE5, EPA compiled a very large database of vehicles (approximately 7,000 records) tested during the first two years of the Hammond, Indiana, I&M program (thus representing a non-I&M fleet of vehicles). Although the testing was performed over the IM240 cycle, EPA developed a set of correlation equations that "converted" the lane IM240 results (conducted on tank fuel) to an FTP/Indolene basis. The data used for this conversion were obtained from approximately 650 vehicles; 425 of these were a subset of the Hammond data, while 225 were tested at EPA's facilities in Ann Arbor. Because the data set was based on correlations, rather than actual FTP data, it was not used in the development of EMFAC2000. Instead, the FTP data collected for the correlation between FTP and IM240 results were used to bolster the existing non-I&M California data set. However, because the vehicles that received FTP tests were not randomly selected, the data first had to be weighted.

EPA staff has indicated that the vehicles recruited for FTP testing at the Hammond site were skewed toward higher emitting vehicles. In addition, the vehicles tested at the Ann Arbor site were pre-screened to eliminate tampered vehicles, and they likely under-represented the fraction of high emitters in an in-use, non-I&M fleet of vehicles. Thus, it was necessary to weight (i.e., add or subtract) vehicles in the 650-vehicle FTP data set so that it correctly represented the fraction of high-emitting vehicles in a non-I&M fleet. The FTP data set was weighted so that it had the same pass/fail rate for IM240 as the 7,000-car I&M fleet. Summarized below is the process used for this weighting.

- Pass rates were determined for technology-group and mileage-bin combinations in each fleet using IM240 cutpoints of 0.8 g/mi. HC, 15.0 g/mi. CO, and 2.0 g/mi. NOx (these are standard IM240 cutpoints used in many of EPA's analyses).

- EPA technology groups were used for this analysis because this was the only technology classification available in the I&M fleet; these were closed-loop multi-point fuel-injection (MPFI), throttle-body injection (TBI), and carburetted.

- Mileage bins consisted of 0-22,000, 22,001-45,000, 45,001-66,000, 66,001-85,000, and over 85,000 miles (as used in previous comparisons of CALIMFAC predictions and ARB data discussed in Section 2).

- The analysis was done for 1981 and later light-duty gas vehicles (LDVs); light-duty trucks were not considered.

- Because analyses were made on specific technology groups, no adjustment was made for the difference in the manufacturer fractions between the EPA data set and the California vehicle population.

4.4.4.1 Non-I&M IM240 Failure Rates from the Hammond Data

Vehicles were selected from the 7,000-vehicle I&M fleet to match the selection criterion outlined above. Additional selection criteria, consistent with EPA's selection of vehicles for developing MOBILE5 emission factors, were as follows:

1. vehicles that had odometer readings of 0 or of greater than 300,000 were deleted;
2. data collected on 14 test dates in March and April where the ambient temperature exceeded 75 F were deleted; and
3. only data for vehicles in an as-received condition were considered.

The number of vehicles in each technology group and mileage bin is summarized in Table 4-21, and the fraction of IM240 failures (for HC, CO, and NOx, independently) by technology group and mileage bin is given in Tables 4-22a to 4-22c. The fractions contained in Tables 4-22a to 4-22c was used as the basis for modifying the distribution of vehicles in the FTP database.

Table 4-21
Number of Vehicles in the Hammond IM240 Database
by Technology and Mileage Bin

Mileage Bin	Technology Group		
	MPFI	TBI	CARB
0-22K	818	448	130
22-45K	656	518	326
45-66K	372	410	436
66-85K	230	322	468
Over 85K	174	354	739

4.4.4.2 Converting Lab/Indolene IM240 Results to a Lane/Tank Fuel Basis

Because only IM240 scores based on Indolene were available for the Ann Arbor FTP data, it was not appropriate to use those values directly when establishing the fraction of IM240 failures. Vehicles tested at both the Hammond I&M lane and at a local lab had different IM240 results when comparing the lane results (on tank fuel) to the lab results on Indolene. EPA accounted for this difference prior to performing the IM240-to-FTP conversion. Sierra accounted for this difference prior to segregating the Ann Arbor data according to the pass-fail rate, as described below.

The Hammond data for which both lane IM240 and lab IM240 (on Indolene) tests are available were used to develop adjustments to account for emissions differences between the lane and the lab. In general, this analysis indicated that vehicles with low Indolene/lab IM240 scores have much higher lane IM240 scores (i.e, up to 80% higher, depending upon pollutant), whereas those vehicles with relatively high IM240 scores (i.e., higher than the above cutpoints) have lane IM240 scores that more closely match the lab. Because of this, the data were segregated according to whether the IM240 cutpoints were met, and regressions were performed (i.e., lane/tank fuel versus lab/indolene). The regression results are summarized in Table 4-23.

Table 4-22a
HC Failure Rate in IM240 Database
by Technology and Mileage Bin

Mileage Bin	Technology Group		
	MPFI	TBI	CARB
0-22K	1.1%	2.0%	11.5%
22-45K	2.7%	6.0%	15.3%
45-66K	6.2%	12.4%	21.3%
66-85K	13.9%	21.4%	31.6%
Over 85K	27.0%	31.9%	44.8%

Table 4-22b
CO Failure Rate in IM240 Database
by Technology and Mileage Bin

Mileage Bin	Technology Group		
	MPFI	TBI	CARB
0-22K	1.0%	0.9%	13.1%
22-45K	2.6%	4.1%	15.6%
45-66K	4.6%	9.8%	18.6%
66-85K	11.7%	13.4%	29.3%
Over 85K	16.1%	16.4%	40.2%

Table 4-22c
NOx Failure Rate in IM240 Database
by Technology and Mileage Bin

Mileage Bin	Technology Group		
	MPFI	TBI	CARB
0-22K	1.3%	2.0%	15.4%
22-45K	4.3%	6.0%	16.6%
45-66K	7.8%	12.4%	28.2%
66-85K	25.2%	21.4%	39.7%
Over 85K	37.4%	31.9%	47.4%

Several differences between Sierra's analysis and EPA's analysis are worth noting with respect to the fuel adjustments. First, only two "seasons" were considered in this analysis: summer, which was based on the five-month (May - September) volatility control period required by EPA's volatility rule; and winter, which consisted of the remaining months of the year. EPA considered four seasons in its analysis; however, the number of vehicles within each emitter group and season is fairly small in some cases, leading to questions of whether the effect is real or an artifact of a small sample size. Second, EPA did not use a regression approach in its analysis; it simply took the ratio of the mean emission level for each season and emitter group. Finally, the definition of emitter groups was slightly different. Sierra based emitter groups on the Indolene scores with the IM240 cutpoints listed above, while EPA's cutpoints were 1.64 g/mi. HC, 13.6 g/mi. CO, and 2.0 g/mi. NOx based on the lane scores. (The HC and CO cutpoints were considered together in EPA's analysis, i.e., a vehicle was considered a "high" if it failed either the HC <u>or</u> CO cutpoints.)

The regression coefficients in Table 4-23 were used to adjust the IM240 results for the Ann Arbor tests prior to using those results to determine the pass/fail status of the Ann Arbor vehicles. The net result of this procedure was a slight increase in the failure rate for the Ann Arbor vehicles.

Table 4-23
Summary of Fuel/Lane Correction Regression Analysis

Month/ P-F Status	HC			CO			NOx		
	Int	Slp	R^2	Int	Slp	R^2	Int	Slp	R^2
May-Sep									
Pass	0.162	1.060	0.42	3.04	0.847	0.33	0.201	1.210	0.56
Fail	1.113	0.514	0.56	12.14	0.665	0.54	2.361	0.508	0.11
Oct-Apr									
Pass	0.014	1.778	0.44	1.62	1.183	0.39	0.285	1.130	0.61
Fail	0.995	0.624	0.62	10.54	0.734	0.60	0.449	0.932	0.72

Note: Intercept (Int) and slope (Slp) are for regression equations predicting the IM240 result (in g/mi.) on tank fuel in a lane test from corresponding IM240 result (also in g/mi.) on indolene in a laboratory test.

4.4.4.3 Adjustments to the FTP Database

As alluded to above, the FTP database was modified so that the IM240 pass-fail rates matched, as closely as possible, those observed in the complete Hammond database. This was done by comparing not only the overall pass-fail rate for the IM240 tests, but also the pass-fail rate for individual species. The comparisons of CALIMFAC predictions with recent ARB data in Section 2 indicated that the CALIMFAC predictions tended to produce slightly "cleaner" distributions than those actually observed for some technology groups and mileage bins. Because of this, the adjustment of the database was done by removing or adding clean vehicles. This kept all failing vehicles in the database while providing a representative pass-fail distribution.

A Monte Carlo selection technique was used in determining the vehicles to be eliminated or double-counted. This analysis was applied separately to each subfleet for a particular technology group and mileage bin combination. Each vehicle in the subfleet was considered, and the decision to retain, eliminate or double count a vehicle was made randomly. After each vehicle was considered, the IM240 pass rate for the resulting subfleet was computed for each species as well as the overall pass rate. This random analysis was repeated 50,000 times, and the subfleet which produced the minimum value in the square-difference in pass rate, defined as

$$\sum_{i=HC,Co,NOx and Overall}\left[(lane\ passrate)i-(FTP\ fleet\ pass\ rate)i\right] \qquad [4-3]$$

was used as the final subfleet from the EPA correlation data.

The result of the analysis for the different technology groups and mileage bins is shown in Tables 4-24a to 4-24d for overall results, HC, CO and NOx. The closest agreement is found in the overall failure rate for the adjusted fleet. Individual species results do not show as good agreement although there is an improvement for almost all technology/-mileage combinations. The closeness of the failure rates between the adjusted FTP fleet and the I&M fleet justifies the use of the adjusted FTP fleet data as a representative data set.

These additional data provided needed information on late-model non-I&M vehicles for use in determining regime sizes, mean emission rates of regimes, and regime growth functions. The fact that the vehicles were certified to federal standards rather than California standards was not a problem since the definition of regimes is based on the ratio of the actual emissions to the standard. However, because the EPA data set did not contain information on I&M repairs, which is needed for development of the normal regime, it could not be used in determing regime boundaries for “normal” vehicles.[*]

Table 4-24a

Overall Failure Rates in IM240 by Technology and Mileage Bin
Comparison of IM data, FTP data and adjusted FTP data

Mileage Bin	Fleet	Technology Group		
		MPFI	TBI	CARB
0-22K	I&M Fleet	3.0%	4.5%	24.6%
	Original FTP	0.0%	18.3%	0.0%
	Adjusted FTP	0.0%	10.4%	0.0%
22-45K	I&M Fleet	8.2%	12.2%	31.9%
	Original FTP	14.1%	27.3%	43.5%
	Adjusted FTP	7.6%	15.8%	29.2%
45-66K	I&M Fleet	13.4%	30.0%	46.3%
	Original FTP	22.7%	45.6%	62.5%
	Adjusted FTP	13.4%	29.5%	45.4%
66-85K	I&M Fleet	38.7%	45.0%	60.0%

	Original FTP	35.4%	50.0%	69.3%
	Adjusted FTP	37.0%	38.9%	57.4%
Over 85K	I&M Fleet	51.7%	56.5%	71.6%
	Original FTP	44.2%	61.1%	81.0%
	Adjusted FTP	51.5%	54.1%	68.1%

Adjustments to FTP fleet are set to get the best possible match for all pollutants and for overall failure rate.

Table 4-24b

HC Failure Rates in IM240 by Technology and Mileage Bin
Comparison of IM data, FTP data and adjusted FTP data

Mileage Bin	Fleet	Technology Group		
		MPFI	TBI	CARB
0-22K	I&M Fleet	1.1%	2.0%	11.5%
	Original FTP	0.0%	6.3%	0.0%
	Adjusted FTP	0.0%	3.4%	0.0%
22-45K	I&M Fleet	2.7%	6.0%	15.3%
	Original FTP	9.4%	12.1%	25.0%
	Adjusted FTP	5.0%	7.0%	16.7%
45-66K	I&M Fleet	6.2%	12.4%	21.3%
	Original FTP	16.7%	29.5%	55.2%
	Adjusted FTP	9.4%	19.0%	39.4%
66-85K	I&M Fleet	13.9%	21.4%	31.6%
	Original FTP	20.8%	35.7%	43.6%
	Adjusted FTP	21.7%	27.8%	36.2%
Over 85K	I&M Fleet	27.0%	31.9%	44.8%

	Original FTP	27.1%	46.3%	60.4%
	Adjusted FTP	32.4%	41.0%	50.7%

Adjustments to FTP fleet are set to get the best possible match for all pollutants and for overall failure rate.

Table 4-24c

CO Failure Rate in IM240 by Technology and Mileage Bin
Comparison of IM data, FTP data and adjusted FTP data

Mileage Bin	Fleet	Technology Group		
		MPFI	TBI	CARB
0-22K	I&M Fleet	1.0%	0.9%	13.1%
	Original FTP	0.0%	12.5%	0.0%
	Adjusted FTP	0.0%	6.9%	0.0%
22-45K	I&M Fleet	2.6%	4.1%	15.6%
	Original FTP	9.4%	15.1%	18.7%
	Adjusted FTP	5.0%	8.8%	12.5%
45-66K	I&M Fleet	4.6%	9.8%	18.6%
	Original FTP	15.1%	29.4%	45.8%
	Adjusted FTP	8.5%	20.0%	33.3%
66-85K	I&M Fleet	11.7%	13.4%	29.3%
	Original FTP	14.6%	33.3%	41.0%
	Adjusted FTP	15.2%	25.3%	34.0%
Over 85K	I&M Fleet	16.1%	16.4%	40.2%
	Original FTP	16.3%	24.1%	56.9%
	Adjusted FTP	18.1%	21.3%	47.2%

Adjustments to FTP fleet are set to get the best possible match for all pollutants and for overall failure rate.

Table 4-24d

NOx Failure Rates in IM240 by Technology and Mileage Bin
Comparison of IM data, FTP data and adjusted FTP data

Mileage Bin	Fleet	Technology Group		
		MPFI	TBI	CARB
0-22K	I&M Fleet	1.3%	3.1%	15.4%
	Original FTP	0.0%	12.5%	0.0%
	Adjusted FTP	0.0%	6.9%	0.0%
22-45K	I&M Fleet	4.2%	6.6%	16.6%
	Original FTP	4.7%	9.1%	31.3%
	Adjusted FTP	2.5%	5.3%	20.3%
45-66K	I&M Fleet	7.8%	19.5%	28.2%
	Original FTP	7.6%	16.2%	12.5%
	Adjusted FTP	4.3%	10.5%	9.1%
66-85K	I&M Fleet	25.2%	31.1%	39.7%
	Original FTP	12.5%	20.0%	43.6%
	Adjusted FTP	13.0%	14.8%	36.2%
Over 85K	I&M Fleet	37.4%	46.1%	47.4%
	Original FTP	25.6%	42.6%	44.2%
	Adjusted FTP	29.3%	37.7%	37.7%

Adjustments to FTP fleet are set to get the best possible match for all pollutants and for overall failure rate.

The EPA data were used in the development of regime growth functions, which are discussed in the next section.

4.5 Definition of Emission Regime Boundaries

In the old CALIMFAC model there was only one set of regime boundaries (Table 4-25) which did not change by model year groupings. In EMFAC2000, Sierra staff was asked to analyze the entire data set to determine if it was appropriate to continue with one set of regime boundary definitions or have them change by model year groupings.

Table 4-25 Regime boundary Definitions used in the CALIMFAC Model

Regime	HC	CO	NOx
Normal	≤ 1x	≤ 1x	≤ 1x
Moderate	>1-≤ 2x	>1-≤ 2x	>1-≤ 2x
High	>2-≤ 5x	>2-≤ 6x	>2-≤ 3x
Very High	>5-≤ 9x	>6-≤ 10x	>3-≤ 4x
Super	>9x	>10x	>4x

In addition, Sierra staff was also charged with the task of determining if the super emission regime should be further sub-divided into super and super-super emission regimes. Following is the regime boundary analysis.

4.5.1 Regime Boundaries

This section discusses the steps used to determine the final regime boundaries for EMFAC2000. This is the first step in the development of a regime-based emission model. The following data sets were used in this analysis:

- The old master data used for CALIMFAC,
- The new ARB surveillance data set, and
- Data from the I&M recapture fleet obtained in 1991 (2S91V1 and 2S91V2).

The regime boundaries apply to both the non-I&M and the with I&M fleet. Thus, it is appropriate to use the new ARB surveillance data set, which has vehicles, which have been through one or more I&M cycles. The I&M recapture data set was used at the suggestion of ARB staff as an additional data set that would be representative of fleet data in the determination of regime boundaries. In order to obtain large sample sizes for this analysis the regime boundaries were not determined for individual technology groups. Instead the analyses were done for three model-year groups: pre-1975, 1975 to 1979, and 1980 and later. These model year groups are surrogates for three broad classes of emission control technology: non-catalyst (pre-1975), oxidation catalyst (1975-1979), and three-way catalyst (1980-and-later). The regime boundaries are determined on the basis of emission ratios. These are the ratio of the measured emissions to the corresponding emission standard for the vehicle. This allows the consideration of vehicles with different emission standards in a given model year group.

Vehicles were grouped into regimes ranging from normal vehicles (the lowest emission group) to super emitters (the highest emission group). Specific steps required determining each of the following:

1. the upper boundary for normal vehicles,
2. the lower boundary for super emitters,
3. the number of regimes between normals and supers,
4. the boundaries of the regimes between normals and supers,
5. the adjustment of regime boundaries to provide "zero" slopes of regression lines within each region (except normals), and

The descriptions provided below detail the specific data sets and methods used in each step.

4.5.1.2 Determination of the Upper Limit for the Normal Regime

Normal vehicles are defined as those whose emissions, on average, do not improve as a result of I&M repair. To determine this boundary, the emissions ratio where the I&M repairs have no effect on emissions had to be determined. This analysis was based on only the old master data set and the new ARB data. No data from the I&M recapture fleet were used in this step because the necessary I&M repair data were not available for this data set.

The emission results were taken from the CVS data file (fields WT_HC, WT_CO and WT_NOX for HC, CO and NOx, respectively). The only vehicles considered in this analysis were California-certified, gasoline-powered passenger cars. Each vehicle could have several records with emission results in the CVS file. For each vehicle, the pre-I&M emission results were taken from the CVS record for which the field REASON was equal to 'B' (baseline) and the field LAST did not equal 'N' (not the last in a series; the value 'N' in the field LAST could represent a test which had some problems and therefore another baseline test was needed). The post-I&M emission results were taken from the record for which the field LAST was equal to 'Z' (last test for the vehicle).

The initial emission tests and the results after final repair were grouped into ½ emission standard ratio groups for this analysis. These groups are characterized by the lower boundary of their range. For example, vehicles with emissions between 0.0 and 0.5 times the emission standard are labeled as the 0 group; 0.5 to 1.0 is the 0.5 group, etc. If the emissions were reduced after the repair work, then that vehicle was labeled as “better.” If the emissions after repair were increased, then the vehicle was labeled as “worse.” (Vehicles with no change in emissions did not have to be considered in this analysis.) The sum of the change in emissions (in grams per mile) is computed for each group. The breakpoint is determined when the emission decrease for the better group is greater than the emission increase for the worse group.

The results of this analysis are shown in Tables 4-26 and 4-27. Table 4-26 shows the breakpoints at which the emissions improved by the I&M repairs. Table 4-27 shows the results for emission increases and decreases for this group and the lower group where emission increases were greater than decreases. These breakpoints were usually near an emission ratio of 1.0 where the measured emissions equal the FTP standard. This range is intuitively reasonable in that the vehicles were designed to operate below the emission standard limit. In addition, the analysis for CALIMFAC also selected an emission ratio of 1.0 for the upper limit of normals.

There is no consistent pattern suggesting a change in the choice for the limit on normals. Accordingly, the boundary ratio for normal vehicles was retained at an emission ratio of 1.0 for all pollutants and all model years.

Table 4-26
Normal Regime Breakpoints

Model Years	HC	CO	NOx
Pre-1975	1.0	1.5	1.5
1975-1979	1.5	1.5	1.0
1980 and Later	1.0	1.0	1.0

Table 4-27
Emission Increases and Decreases Surrounding Where Point Emissions Change from Net Increase to Net Decrease*

Model Years	Species	Net Increase in Emissions			Net Decrease in Emissions		
		Ratio	Increase	Decrease	Ratio	Increase	Decrease
Pre-1975	HC	0.5	215	19	1.0	6	57
	CO	1.0	994	781	1.5	16	458
	NOx	1.0	198	41	1.5	1	17
1975-1979	HC	1.0	109	28	1.5	13	26
	CO	1.0	1040	481	1.5	12	471
	NOx	0.5	260	27	1.0	18	90
1980 and Later	HC	0.5	5	4	1.0	6	13
	CO	0.5	160	148	1.0	110	310
	NOx	0.5	22	7	1.0	18	32

*Values for increase/decrease are the sum of grams/mile for all vehicles in that group.

4.5.1.3 Determination of the Lower Boundary for Super Emitters

Super-emitting vehicles are those vehicles that are the outliers from the rest of the group. All data sets were used for this analysis, and normal vehicles were excluded. A separate analysis was conducted for each pollutant and each model-year group.

The procedure for identifying the outliers was adapted from a suggested procedure in the SAS manual.[1] The initial step uses the SAS procedure FASTCLUS to create ten clusters for each pollutant/model-year group. This is done by setting the maximum clusters to ten and zero iterations (MAXC=10 and MAXITER=0).

The high-frequency clusters (i.e., those with the highest number of vehicles) that are found in the FASTCLUS procedure are less likely to contain the outlying data points. A cut point for "high-frequency" clusters is determined by examining the distribution of the number of vehicles in each cluster shown in the FASTCLUS output. This cutpoint

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[1] SAS/STAT User's Guide, Vol. 1, Version 6, Fourth Edition, page 842. Example 2: Outliers.

typically includes 60-80% of the vehicles. The means from this group of high-frequency clusters are used as input to the next clustering step.

The next step also uses the FASTCLUS procedure. The same set of vehicle emission data is input, as well as the means of the high frequency clusters determined from the initial step. In this step, the number of clusters is set to two and the maximum cluster radius (the STRICT parameter) is specified. The specification of two clusters and the input of the high-frequency cluster means causes FASTCLUS to select the minimum and maximum values of the initial high-frequency cluster means as the seeds for the two clusters. The value specified for the STRICT parameter is determined from an examination of the output from the initial step. This output includes a plot of the distances between the clusters and cluster radii. The "typical" size of a cluster in this plot is used to establish the value used for the STRICT parameter.

The two clusters that are formed about the selected cluster seeds within the cluster radius set by the strict parameter contain the majority of the vehicles. The outlying vehicle with the lowest emissions ratio is taken as the boundary value for super-emitters.* A bar graph of the emissions grouped around multiples of the FTP standard is used to visually check the relation of the super emitters to the rest of the emissions distribution.

The boundary values for the super regime are shown in Table 4-28. In contrast with the regime boundaries in CALIMFAC, Table 4-28 shows a separate super regime breakpoint for each model-year subgroup.

Table 4-28
Super Regime Breakpoints

Model Years	Species		
	HC	CO	NOx
Pre-1975	7	5.5	2.5
1975-1979	13	10	3.5
1980 and Later	12	10	4.5

4.5.1.4 Determination of Middle Regime Boundaries

This step used all the available data sets to determine the number and boundaries of the middle regimes. The data were divided into the same technology subgroups by pollutant and model year. The number of intermediate regimes was determined by using the SAS procedure CLUSTER. The procedure for identifying the number of clusters was adapted from a procedure in the SAS manual.[2] The only non-default input parameter is the specification of Ward's method (METHOD=WARD).[*]

The output of this procedure includes the cubic clustering criterion (CCC), and the pseudo F and pseudo t^2 statistics for the number of potential clusters. Starting from one potential cluster and then analyzing larger number of clusters, the first relatively higher value (peak) of the CCC or pseudo F statistic determines the number of clusters. For the pseudo t^2 value, the first low value (valley) provides the likely number of clusters. If all three statistics give the same value for the number of potential clusters, then it is easy to determine the number of clusters. With the data used in this project, rarely do the three statistics yield the same value.[3]

There are no satisfactory methods for determining the number of population clusters for any type of cluster analysis. ... The number-of-clusters problem is, if anything, more difficult than the number-of-factors problem. Table 4-29 lists the values interpreted from these three clustering statistics. Typically, the range of possible clusters is between 2 and 5. Because none of the three methods is any more significant than the others, the average of the three methods is chosen for a particular model year and pollutant. Table 4-29 shows these average values as well as the following averages:

- the average over model-year groups for each method and pollutant,
- the average over method and model-year group for each pollutant, and
- the average over method and pollutant for each model-year group (in the final column labeled "grand average").

The average of all nine pollutant/model-year groups was 3.26. This was rounded down to three groups and this number of intermediate clusters was used for all pollutants and model-year groups. The next step in the analysis was to locate the regime boundaries for these three intermediate groups.

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[2] SAS/STAT User's Guide, Vol. 1, Version 6, Fourth Edition, page 588. Example 3: Cluster Analysis of Fisher Iris Data.

Table 4-29
Middle Regimes Results for the Number of Clusters

Model Years	HC				CO				NOx				Grand Average
	CCC	F	t^2	Avg	CCC	F	t^2	Avg	CCC	F	t^2	Avg	
Pre-1975	6	5	2	4.3	4	4	3	4.0	3	3	4	3.3	3.8
1975-1979	4	4	2	3.3	4	4	2	3.3	3	3	2	2.7	3.1
1980+	3	3	2	2.7	2	4	3	3.7	3	3	3	3.0	2.9
Average	4.3	4.0	2.0	3.4	3.3	4.0	2.7	3.7	3.0	3.0	3.0	3.0	3.3

The FASTCLUS procedure was used to find the breakpoints for the three intermediate regimes determined by the cluster analysis. Again, the analysis was run for each model-year and pollutant group, using the FASTCLUS procedure with three clusters and ten iterations (MAXC=3 and MAXITER=10). The boundaries found by these cluster analyses are shown in Table 4-30.

Table 4-30
Middle Regimes Breakpoints Using All Data

Model Years	HC			CO			NOx		
	Moderate	High	Very High	Moderate	High	Very High	Moderate	High	Very High
Pre-1975	1 - 2.5	2.5 - 4.5	4.5 - 7.0	1 - 2.0	2.0 - 2.5	2.5 - 5.5	1 - 1.5	1.5 - 2.0	2.0 - 2.5
1975-1979	1 - 3.5	3.5 - 7.5	7.5 - 13	1 - 3.0	3.0 - 6.0	6.0 - 10.0	1 - 1.5	1.5 - 2.5	2.5 - 3.5
1980+	1 - 3.5	3.5 - 7.0	7.0 - 12	1 - 3.0	3.0 - 6.5	6.5 - 10.0	1 - 2.0	2.0 - 3.0	3.0 - 4.5

4.5.1.5 Final Adjustment of Regime Boundaries

The regime model of vehicle emissions presumes that vehicles move into higher regimes because of broken, tampered or defective parts, because of normal odometer-related deterioration. Thus the emission rates in the higher regimes should be independent of the odometer reading. Before accepting the boundaries shown in Table 4-31, a regression analysis of the emission ratio as a function of odometer reading was done for each species and model-year in all the regimes from moderate to super. These regressions should show a zero slope if emissions do not depend on odometer reading. For this check a slope was considered to be "zero" if at least one of the following results was obtained in the regression analysis:

- the hypothesis that the slope is zero was not rejected at the 0.05 level by a two-tailed t-test; or

- the emission increase was less than 10% of the certification standard for 50,000 miles.*

The results of this analysis are shown in Table 4-32. Because some slopes did not meet one of the two criteria listed above, the boundaries determined by the cluster analysis were adjusted to achieve the desired result of an essentially zero slope. The regime boundaries were adjusted by trial and error, changing boundaries by ± 0.5 emission ratio and recomputing the slope, in order to obtain a set of regimes (above the normal regime) where the emissions did not depend on the odometer reading. If a "zero" slope still was not found, then the boundaries were changed by ± 0.1 emission ratio. The regime boundaries determined following this adjustment of the slopes are shown in Table 4-33 and the resulting slopes are shown in Table 4-34.

All of the slopes, except in two instances, meet at least one of the criteria for a zero slope. The exceptions are (1) the very-high regime for NOx from 1975-1979 model-year cars which has a significant slope corresponding to an emissions increase which is 10.05% of the certification standard in 50,000 miles, and (2) the moderate regime for HC emissions from 1980 and later cars which has a significant slope which is 11.7% of the certification standard in 50,000 miles. The 1975-1979 NOx Very Highs regime boundaries are reasonably spaced and the slope is very close to the zero slope limit of 10%, so no further adjustment of these NOx regimes seems necessary. The 1980-and-later HC Moderates boundaries were accepted after examining many potential definitions of regime boundaries. One set of boundaries which allowed the zero slope criteria to be satisfied in all regimes would have set the upper limit for the normals to 1.1 leaving all the other regime boundaries the same as shown in Table 4-32. This fine adjustment to the normal boundary did not seem justified by the small deviation from the zero slope criteria that was present in this regime and the upper limit for the normals for 1980-and-later HC emissions was left at 1.0.

Table 4-31
Initial Regime Regression Slopes

Model Years	HC				CO				NOx			
	Moderate	High	Very High	Super	Moderate	High	Very High	Super	Moderate	High	Very High	Super
Pre- 1975	N	N	N	N	N	Y	N	N	N	N	N	N
1975-1979	S 0.31	N	N	N	Z	N	N	N	N	N	S 0.1005	N
1980+	S 0.23	N	N	S 18.4	S 0.17	N	N	N	Z	Z	N	N

N = No statistical significance to non-zero slope.
S = Slope is significant and not zero. The slope is printed as the increase in emissions ratio per 50,000 mile change in odometer reading. This should be less than 0.10.
Z = Slope is statistically different from zero but considered zero because it is less than 10% change of emissions ratio in 50,000 miles.

Table 4-32
Final Regime Breakpoints

Model Years	HC			CO			NOx		
	Moderate	High	Very High	Moderate	High	Very High	Moderate	High	Very High
Pre-1975	1 - 2.5	2.5 - 4.5	4.5 - 7.0	1 - 2.0	2.0 - 3.3	3.3 - 5.5	1 - 1.5	1.5 - 2.0	2.0 - 2.5
1975-1979	1 - 2.0	2.0 - 7.5	7.5 - 13.0	1 - 3.0	3.0 - 6.0	6.0 - 10.0	1 - 1.5	1.5 - 2.5	2.5 - 3.5
1980+	1 - 2.3	2.3 - 6.5	6.5 - 13.5	1 - 2.0	2.0 - 6.5	6.5 - 10.0	1 - 2.0	2.0 - 3.0	3.0 - 4.5

Note: For each species and model-year group, the normal regime consists of all emission ratios below the lower boundary of the moderate regime. The super-emitter regime consists of all emission ratios above the very-high regime.

Table 4-33
Final Regime Regression Slopes

Model Years	HC				CO				NOx			
	Moderate	High	Very High	Super	Moderate	High	Very High	Super	Moderate	High	Very High	Super
Pre-1975	N	N	N	N	N	N	N	N	N	N	N	N
1975-1979	Z	N	N	N	Z	N	N	N	N	N	S 0.1005	N
1980+	S .117	N	N	N	Z	N	N	N	Z	Z	N	N

N = No statistical significance to non-zero slope.
S = Slope is significant and not zero. The slope is printed as the increase in emissions ratio per 50,000-mile change in odometer reading.
Z = Slope is statistically different from zero but considered zero because it is less than 10% change of emissions ratio in 50,000 miles.

4.5.2 Regime Growth Rates

This section outlines the approach taken in the development of regime growth functions. The EMFAC2000 model is based on the distribution of vehicles among the various emission regimes. This distribution is determined in two steps. First, the change in regime populations as vehicles age, without an inspection/maintenance (I&M) program, is modeled. This aging process results in a shift of vehicles from the normal regime into regimes with higher emissions. The growth in the population of the higher-emitting regimes is described by the regime growth functions discussed in this section.

There are two potential measures of vehicle "age": the odometer reading, and the estimated time the vehicle has been in customer service as determined from the difference between the test date and model year. Both of these variables play a role in the regime growth. To the extent that some deterioration of emission control systems is due to weathering effects, the regime growth would be best characterized by vehicle age. To the extent that deterioration is due to vehicle use, the regime growth would be best characterized by the odometer reading. EMFAC2000 uses a fixed distribution of vehicle age to odometer reading so only one of these variables can be used in determining the population of the various regimes. The average relation between vehicle age and odometer reading shows that the average vehicle is driven fewer miles per year as it ages. Consequently, a nonlinear relation between either of these variables and regime population sizes would represent the combined effects of both.

A major issue in the development of regime growth functions is the data requirement for different regime populations as a function of vehicle age or odometer reading. The data analysis problems can be illustrated by considering a hypothetical technology group with 500 vehicles. This would appear to present enough data points, but these 500 vehicles are distributed into each of the five emission regimes. Although this provides an average of 100 vehicles in each regime, there is usually a high concentration of vehicles in the normal and moderate regimes and a much smaller number in the very high and super regimes. The average of 100 vehicles per regime for the hypothetical technology group must next be subdivided into odometer (or age) groups. Typically intervals of 10,000 miles or one year are used to group the variables. This typically provides 20 mileage bins or 10 year bins with an average of five or ten vehicles per bin. These final five or ten vehicles are then used to compute the individual regime population data points used in the regression equations.

4.5.2 Analysis

The regime growth functions represent the movement of vehicles among emission regimes in the absence of an I&M program. Consequently, the derivation of these functions uses only data for vehicles that have not been through an I&M program. The data used in this analysis are the same data used for the regime growth functions in

CALIMFAC, augmented by some EPA data for 49-state vehicles. None of the recent ARB surveillance data, which were for vehicles that had been through I&M, were used.

In CALIMFAC, linear regression equations between mileage and regime population sizes were used for the regime growth functions. As an initial step in developing regime growth functions for EMFAC2000, the regime populations for the technology groups with the largest number of vehicles (old technology groups four, six, eight, nine, and eleven) were plotted on a series of charts for visual detection of any apparent relations with mileage and age. The regime populations were determined using 10,000-mile bins, 25,000-mile bins, and one-year bins. A separate chart was prepared for each regime and each pollutant. Each chart contained 15 graphs showing all three methods for binning the data for each of the five technology groups selected. Although there was significant scatter in these charts, a general nonlinear trend was evident in both the mileage- and age-based plots. Accordingly, nonlinear functions were used for regime growth functions of all technology groups, and some preliminary efforts were made to examine different nonlinear regime growth functions.

The regime growth functions were determined based on the vehicle odometer reading. (Since vehicle emission factor models use a fixed relationship between vehicle age and odometer, either parameter can be used in a nonlinear relation.) For a given pollutant and technology group, the following procedure was followed in obtaining population data for the regime growth functions.

1. The data were grouped into 10,000-mile "bins": (0-10,000), (10,001-20,000) etc. The mileage for each bin was represented by its midpoint odometer value. The total number of vehicles in each bin was determined. This number was used to weight the data in the following step.
2. For each bin, the number of vehicles in each regime (normal, moderate, high, very high, and super) was determined. This number was then divided by the total number in that bin to get the fraction of vehicles in each regime in the bin.
3. Regression analysis was applied to data on the population fraction of each regime as a function of odometer reading at the midpoint of the population bin. (For convenience, the reading was divided by 10,000 miles.)

A simplified example of this procedure is provided below to clarify the individual steps in computing the population distributions and regression weights. For purposes of this example, 25,000 mile bins are used in place of 10,000 mile bins and an upper limit of 100,000 miles is used. The normal upper limit was the maximum odometer reading observed in the sample.

Table 4-34 contains the hypothetical distribution, for a particular pollutant and technology group, of the number of vehicles over regime and odometer range. These data are used to compute the population distributions as a function of the midpoint of the odometer range as shown in Table 4-35. The data in this table were used in the regression analysis for regime growth functions.

Table 4-34
Hypothetical Distribution of Vehicles by Regime and Odometer Range

	Odometer Range (miles)			
Regime	0-25,000	25,001-50,000	50,001-75,000	75,001-100,000
Normal	24	98	11	1
Moderate	2	7	13	4
High	0	2	11	5
Very high	0	0	4	2
Super	0	1	6	4
Total	26	108	45	16

The regime growth function used a weighted analysis where the weight for each mileage bin (i.e., the last row in Table 4-34) was taken as the total number of vehicles in the mileage bin. This step of the procedure was independent of the regression approach used; it simply provided the basic data for those regressions.

Table 4-35
Hypothetical Regime Populations Distributions as a Function of Mileage

	Bin Midpoint Mileage (miles/10,000)			
Regime	1.25	3.75	6.25	8.75
Normal	92.3%	90.7%	24.4%	6.3%
Moderate	7.7%	6.5%	28.9%	25.0%
High	0.0%	1.9%	24.4%	31.3%
Very high	0.0%	0.0%	8.9%	12.5%
Super	0.0%	0.9%	13.3%	25.0%

Two basic approaches were used to model nonlinear regime growth functions: the first examined the use of functions that could not be transformed into a linear function, and the second was based on linear regression. For the first approach, the SAS procedure, NLIN, was used to determine the regression coefficients A, B, C, and D in the following relation between regime-i population, p_i, and the odometer reading, (odo).

$$P_i = A + B^*(odo) + C^*e^{D(odo)} \qquad [4\text{-}4]$$

The regression equations produced by this approach did not provide statistically significant values for C or D. In general, the values for C were small and/or the values for D were large negative numbers. The resulting equations amounted to little more than a linear equation with a slight correction at lower mileage. This approach was not used for the final regime growth functions.

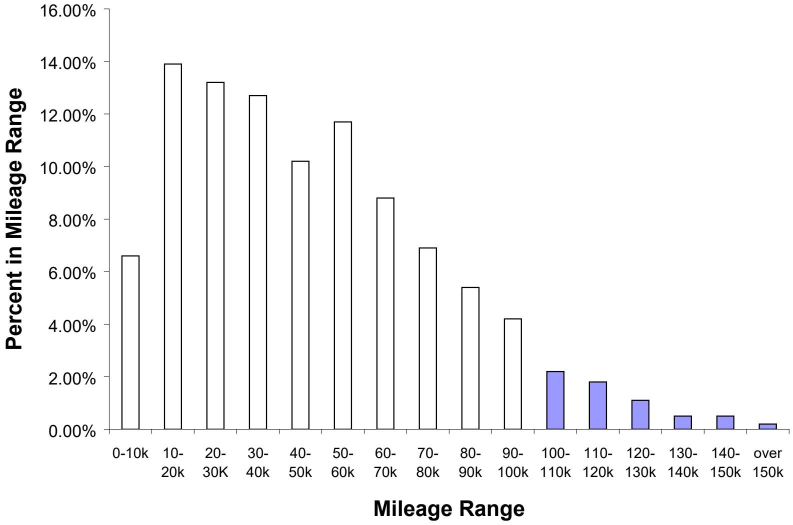
A second set of preliminary studies used the stepwise regression procedure of the SAS procedure REG. In order to allow for different possible regression lines, including a linear relation (i.e., one with constant slope) and nonlinear curves with either increasing slope or decreasing slope, the following regression equation was used:

$$P_i = A + B^*(odo) + C^*\,(odo)^2 + D^*(odo)^{1/2} \qquad [4\text{-}5]$$

Initially two sets of regressions were performed. One set used bins with a constant mileage interval. A second set of regressions used variable width bins with the same number of vehicles in each bin.[*] For this process, an ideal bin population of fifty vehicles was selected. However, if necessary due to data limitations, regressions were carried out with as few as four bins containing at least twenty vehicles per bin. As noted above, weighted regressions were used for the constant width bins to account for the different number of vehicles in each bin. Such weighting was not required for the variable width bins. A comparison of these two approaches showed no difference in the results and the constant width bin regressions were used in the final analysis.

One additional regression procedure was evaluated to overcome a major problem with the development: the lack of data at high mileage. This is illustrated in Figure 4-1 which shows the distribution of vehicle odometer readings in the total data set used for determining regime growth functions. Although there were variations from this overall distribution in each technology group, the general pattern of this figure--a sharp drop in available data with increasing mileage--was observed in all technology groups.

Figure 4-1 **Odometer Distribution in Regime Growth Function Data**



The attempted improvement in regressions at high mileage used the following approach. Appropriate aggregations ("super-groups") of technology groups, with similar characteristics, were formed, and regressions were developed for these super groups. These regressions were then used to obtain the high mileage regime populations for each technology group within the super-group. In this approach, the usual regime growth function for the technology group, $p_{i,G}$(odo) was used for odometer readings below 100,000 miles. Above 100,000 miles, the regime growth was found from the regression for the super-group using the following equation:

$$P_{i,G}\,(\text{odo}) = P_{i,G}\,(100{,}000\text{ mi}) + P_{i,G}\,(\text{odo}) - P_{i,SG}(100{,}000\text{ mi}) \qquad [4\text{-}6]$$

where $p_{i,SG}$ is the regime growth function for the super-group. This approach did not provide any apparent improvement over the regressions using all the data and was not pursued further.

Regressions were carried out for all regimes. In the CALIMFAC model, the population of the normal regime is not found from regression equations; instead, it is determined by subtracting the populations of all other regimes from 100%. With the use of nonlinear regression functions, the regression curve for normals was typically proportional to the square root of the odometer reading. This gave a steep initial drop, with a declining slope. The population of normals persisted longer than was the case when it was computed as the difference between 100% and the populations of all other regimes. A rough check on the persistence of normals was done by examining the combined data for all technology groups with odometer readings above 140,000 miles. The regime populations for the 24 vehicles in this highest mileage range are shown in Table 4-36.

Table 4-36 Regime Populations at High Mileage for Combined Data Set					
Species	Percent of Vehicles in the Following Regimes				
	Normal	Moderate	High	Very High	Super
HC	8.3	54.2	20.8	4.2	12.5
CO	16.7	45.8	16.7	8.3	12.5
NOx	29.2	50.0	12.5	8.3	0.0

The persistence of a significant population of normals, even in the highest mileage bin, is best accounted for by always using the regression equation for normals and then adjusting the population of all regimes so that they total 100%. This change was made in EMFAC2000 so that the overall approach for computing the regime populations was done in the following steps.

1. Regression equations were used to compute the raw regime populations for all five regimes.
2. Any negative regime fraction was set to zero. Any regime fraction greater than one was set to one.
3. The regime fractions determined in step 2 were summed. This sum was then divided into each regime fraction from step 2 to obtain a final set of regime fractions, which summed to one.

A similar approach was used to determine the regression equations for the raw regime population data.

4.5.2.1 Final Regime Growth Functions

The final regime growth functions were determined using the SAS regression procedure, REG, using the "adjusted R-squared" method. This method computes regression results for all possible combinations of variables. For the regression equation considered here [$A + B(\text{odo}) + C(\text{odo})^2 + D(\text{odo})^{1/2}$], seven different regression equations are possible. These are listed below with the abbreviations for each regression and a list of the terms set to zero.

Linear term only (Linear: $C = D = 0$)
Quadratic term only (Quadratic: $B = D = 0$)
Square-root term only (SQRT: $B = C = 0$)
Linear and quadratic terms (L/Q: $D = 0$)
Linear and square-root terms (L/SQRT: $C = 0$)
Quadratic and square-root terms (Q/SQRT: $B = 0$)
All terms

Prior to a selection of the final regression equation plots were made which overlaid all the regression equations and the data used as the basis of those equations. The population data points used to form the regressions generally show a large scatter, especially at high mileage where there were very few vehicles. In the high-mileage region, there might be only one vehicle in a particular 10,000-mile bin. The population of whatever regime in which this vehicle happened to lie was 100%; the population of all other regimes was zero. This variation did not have a significant effect on the regressions because the weight assigned to these points (i.e., the ratio of vehicles in this mileage bin compared to the total number of vehicles) was small.

Comparison of various regression equations showed a region between approximately 20,000 and 120,000 miles where the populations predicted by different regression results were very close. In this region, the variation in the predictions was less than the scatter in the data points. The regression, which resulted from using all variables typically, has both a minimum and a maximum did not seem to represent real vehicle behavior. In addition, this curve often extends well above 100% and well below zero. Similar eccentric behavior was noted for regression results with two variables.

The adjusted R^2 was used as a measure to compare various regression fits because this variable is a measure of the explanatory power of the model adjusted for the number of parameters in the regression equation.[*] In most cases the regression results with more than one variable had a somewhat higher value for R^2 than the one-variable equations, but they had a lower value for R^2_{adj}. In general, the equations, which had the highest value of the adjusted R2, appeared to have the most plausible physical behavior. Consequently the initial choice of a regression equation (from the seven possible alternatives) was the one with the highest value of the adjusted R^2.

The initial choice of a regression equation for each regime produced the “best” equation for that regime. Once an initial set of regression equations was selected for each regime the full EMFAC2000 calculation procedure was applied to the regression results. (Initial regression values less than zero were set to zero; values greater than one were set to one; the resulting regime fractions were renormalized so that the sum of all regime populations was one.) The resulting regime populations were then compared to the actual data on regime populations. For example, Figure 4-2 shows the results of the initial selection of regime growth functions for technology group nine. In this case the agreement between the population data and the regime growth functions (as used in EMFAC2000) was considered adequate and no modifications were made. Another example is shown in Figure 4-3: the initial regime growth functions for technology group thirteen. Some slight changes were made in the selection of regime growth functions shown in this figure. These substitutions are shown in Table 4-37. The regime growth functions for each pollutant are shown in Figures 4-4 to 4-6.

Table 4-37
Adjustments Made in Regime Growth Functions for Technology Group Thirteen

Pollutant	Regime	Initial Equation		Final Equation	
		Type	Adjusted R^2	Type	Adjusted R^2
HC	Moderate	Linear/Sqrt	0.73	Linear	0.59
HC	High	Sqrt	0.49	Quadratic	0.38
CO	Moderate	Sqrt	0.48	Linear	0.45
NOx	Normal	Quadratic	0.43	Linear	0.36

The procedure illustrated here for technology groups eight and thirteen was repeated for all other technology groups. In some cases where the number of vehicles in a particular technology group/regime combination was small aggregation of technology groups were used to derive the regime growth functions. For example, the regime growth functions for the very high and super regimes in technology groups one, two and three (non-catalyst vehicles) were obtained by aggregating the data for all three technology groups.

Figure 4-2 Comparisons of Initial Predicitions (--) with Data ( ) for vehicles in Technology group 9

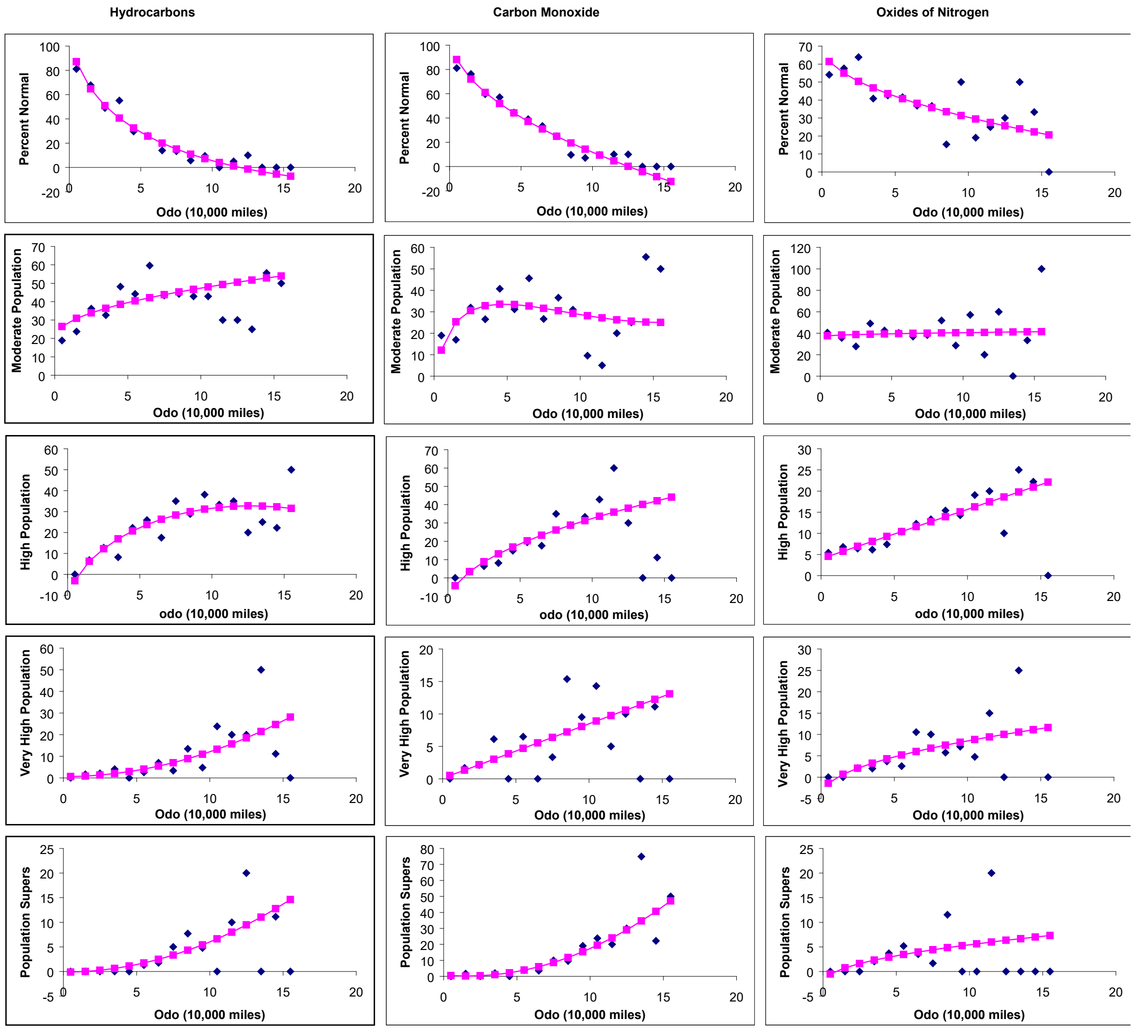


Figure 4-3 Comparisons of Initial Predictions (--) with Data ( ) for vehicles in Technology group 13

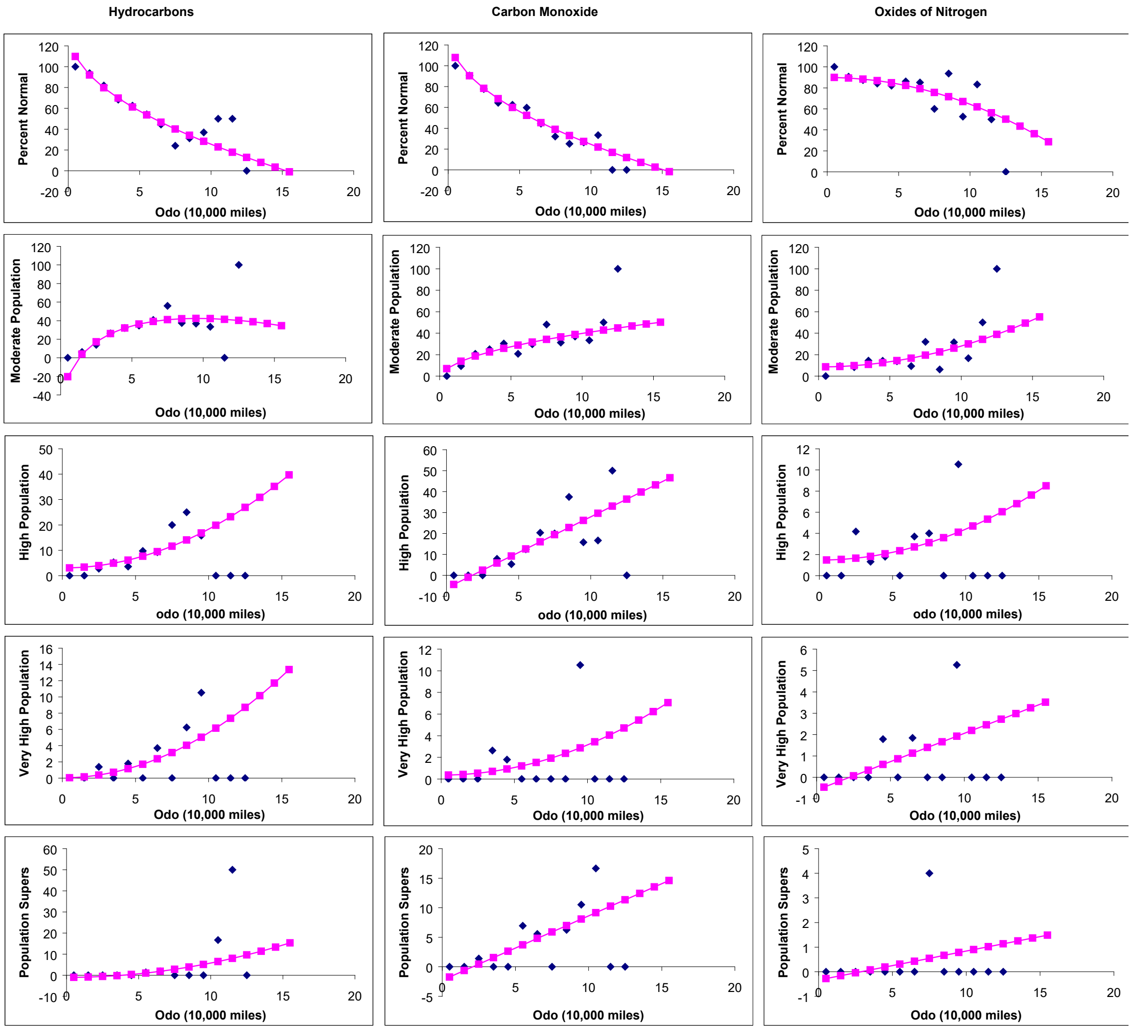


Figure 4-4 **Hydrocarbon Regime Populations for Technology Group 13 Best fit**

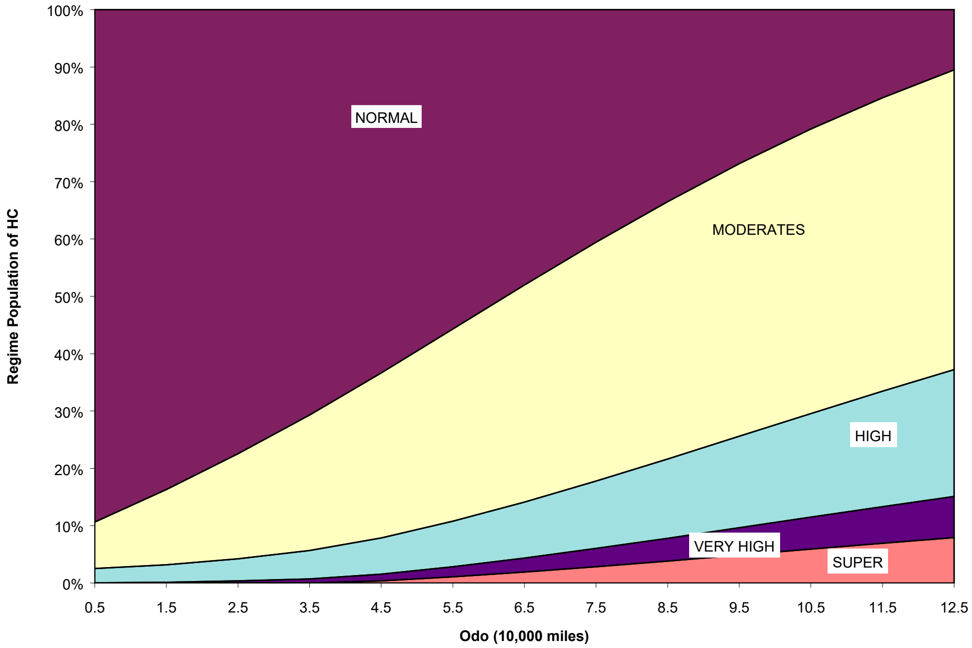


Figure 4-5 **Carbon Monoxide Regime Populations for Technology Group 13 Best Fit**

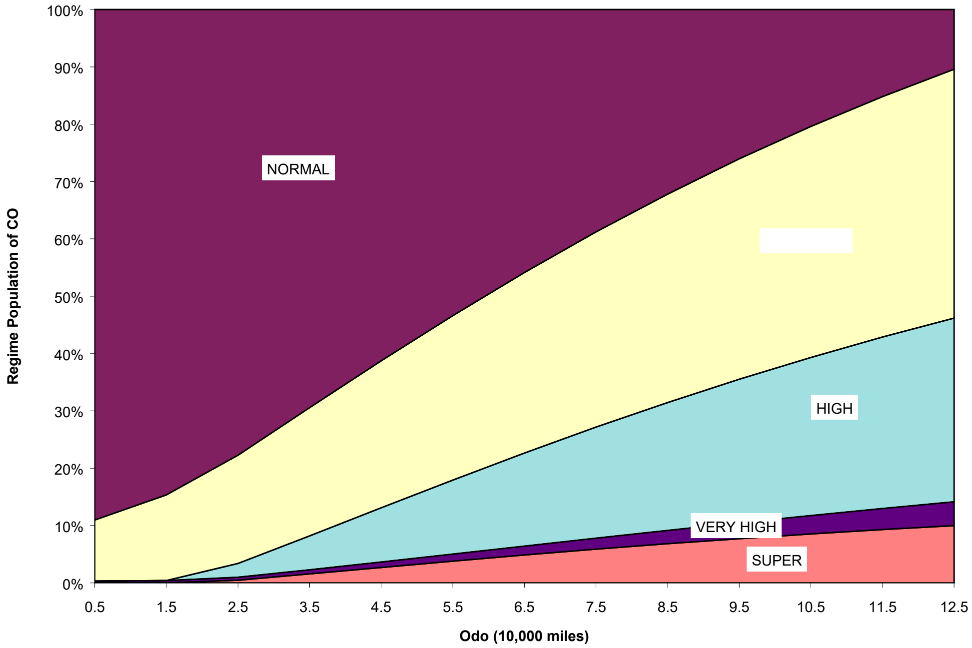


Figure 4-6 Oxides of Nitrogen Regime Populations for Technology group 13 Best Fit

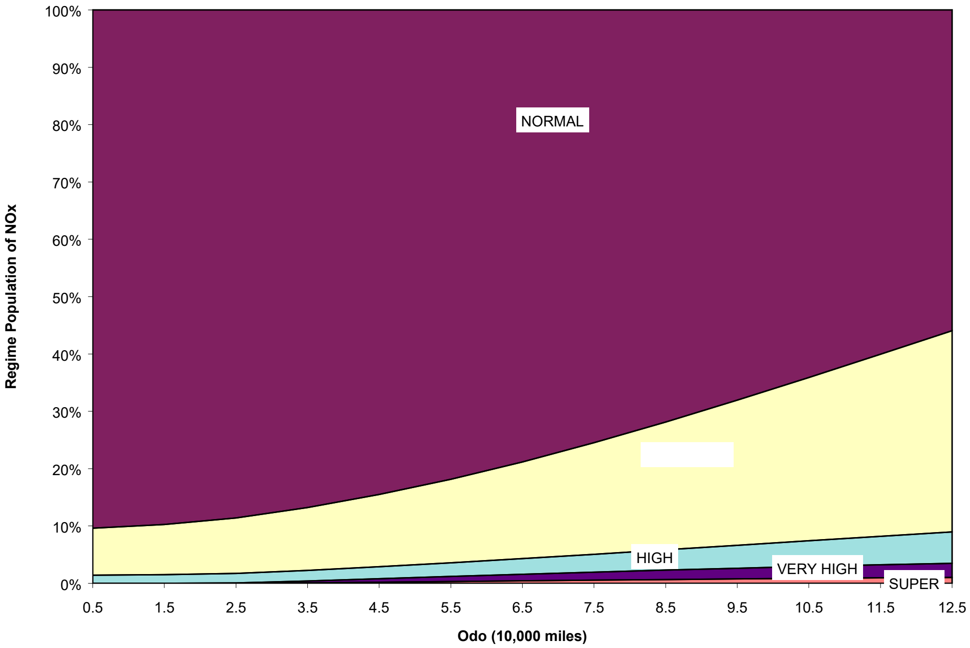


Table 4-38
Coefficients in Regime Growth Functions
Regime Population = A + B(odo) + C(odo)^2 + D(odo)$^{1/2}$
Population in percent; odo is odometer reading divided by 10,000

Technology Group	Species	Regime	Constant Term, A	Linear Term, B	Quadratic Term, C	Square Root Term, D
1	HC	Super	0.428	0	0.01767	0
		Very High	-3.389	0	0	2.4998
		High	0	0	0	0.3052
		Moderate	43.647	1.9853	0	0
		Normal	52.174	-3.1158	0	0
	CO	Super	0	0	0	0.402
		Very High	-3.868	0	0	3.138
		High	7.927	0	0	0.159
		Moderate	33.227	0	0	0.891
		Normal	61.436	0	0	-3.977
	NOx	Super	0	0	0	0.6758
		Very High	-3.8676	0	0	3.1384
		High	0	0	0	1.0158
		Moderate	32.474	0	0	-1.266
		Normal	60.907	0	0	1.307
2	HC	Super	0.428	0	0.01767	0
		Very High	-3.389	0	0	2.4998
		High	0	0	0	0.3052
		Moderate	17.451	0	0	8.424
		Normal	64.159	-1.3339	0	0
	CO	Super	0	0	0	0.402
		Very High	-3.868	0	0	3.138
		High	0	1.058	0	0
		Moderate	27.983	0	0.02441	0
		Normal	48.913	0	0	3.776
	NOx	Super	0	0	0	0.6758
		Very High	0.707	0	0	3.722
		High	4.603	0	0	2.236
		Moderate	33.022	0	0	-3.725
		Normal	44.045	0.999	0	0
3	HC	Super	0.428	0	0.01767	0

		Very High	-3.389	0	0	2.4998
		High	2.714	7.5129	0	0
		Moderate	54.365	0	0	-11.368
		Normal	50.068	-4.8012	0	0
	CO	Super	0	0	0	0.402
		Very High	-3.868	0	0	3.1381
		High	9.967	0	0	0
		Moderate	32.902	0	0	2.231
		Normal	77.119	0	0	-14.626
	NOx	Super	0	0	0	0.6758
		Very High	-3.8676	0	0	3.1384
		High	7.102	0	0	4.8558
		Moderate	36.525	-1.6606	0	0
		Normal	57.83	0	0	-3.138
4	HC	Super	-0.696	0	0	0.782
		Very High	-0.241	0.3179	0	0
		High	-3.648	6.061	-0.10103	0
		Moderate	2.534	0	0	10.124
		Normal	116.492	0	0	-30.979
	CO	Super	-0.058	0	0	1.3703
		Very High	0.412	1.3588	0	0
		High	2.615	1.3583	0	0
		Moderate	-5.035	0	0	17.3458
		Normal	110.81	0	0	-29.2072
	NOx	Super	0.061	0	0	0.2342
		Very High	0	0	0	2.6151
		High	10.189	0	0	4.8623
		Moderate	10.502	0	0	8.4388
		Normal	78.378	0	0	-15.736
5	HC	Super	-0.939	1.264	0	0
		Very High	-1.391	1.392	0	0
		High	-11.254	-2.41	0	34.947
		Moderate	40.265	0	0	-8.405
		Normal	144.998	34.7909	-0.85724	-127.941
	CO	Super	-5.251	0	0	5.341
		Very High	-1.745	0	0	7.334

		High	-15.135	0	0	18.849
		Moderate	41.129	0	0	-4.1292
		Normal	96.069	4.9052	0	-45.6392
	NOx	Super	-1.997	0.7657	0	0
		Very High	0	0	0	2.4872
		High	4.9742	0	0	8.3095
		Moderate	14.2364	2.9509	0	0
		Normal	82.7382	0	0	-18.8475
6	HC	Super	-0.896	1.142	0	0
		Very High	-1.286	1.255	0	0
		High	-11.562	-1.884	0	31.237
		Moderate	36.608	0	0	-5.121
		Normal	78.357	0	0	-27.825
	CO	Super	-4.785	0	0	4.816
		Very High	-2.175	0	0	6.822
		High	-0.363	4.7024	0	0
		Moderate	33.511	0	0	-2.3115
		Normal	100.37	4.1974	0	-42.001
	NOx	Super	-1.74	0.6785	0	0
		Very High	0	0	0	2.4872
		High	3.418	0	0	8.177
		Moderate	15.653	2.3847	0	0
		Normal	82.969	0	0	-17.1854
7	HC	Super	0.166	0	0.0512	0
		Very High	-0.412	0.549	0.0625	0
		High	-10.857	0	0	17.465
		Moderate	26.937	-6.425	0	23.79
		Normal	70.119	0	0	-22.716
	CO	Super	0.199	0	0.02732	0
		Very High	0.06	0	0.12311	0
		High	0.196	1.726	0	0
		Moderate	0.691	0	0	12.545
		Normal	94.651	-8.855	0.23218	0
	NOx	Super	0	0	0	0.7148
		Very High	1.785	0	0	1.371
		High	6.649	1.8667	0	0
		Moderate	26.834	-3.0758	0.32051	0

		Normal	75.761	0	0	-9.467
8	HC	Super	0.085	0	0.05824	0
		Very High	1.926	0	0.10092	0
		High	3.64	4.7051	0	0
		Moderate	24.647	0	0	5.2535
		Normal	85.97	0	0	-28.8098
	CO	Super	-4.77	2.0799	0	0
		Very High	-3.19	0	0	3.4864
		High	-1.115	4.1257	0	0
		Moderate	0.306	0	0	14.9346
		Normal	85.273	-8.1636	0	0
	NOx	Super	-2.8554	0	0	2.6358
		Very High	-4.1839	0	0	4.0035
		High	3.134	0	0	0.6243
		Moderate	26.523	0	0	8.6548
		Normal	78.369	0	0	-16.149
9	HC	Super	-0.137	0	0.06136	0
		Very High	0.608	0	0.11437	0
		High	-15.862	0	-0.10084	18.1976
		Moderate	20.46	0	0	8.5061
		Normal	122.339	5.2094	0	-53.4096
	CO	Super	0.77	-0.7768	0.24325	0
		Very High	0.084	0.8392	0	0
		High	-14.89	0	0	14.97
		Moderate	-17.798	-14.3809	0.24848	52.322
		Normal	110.159	0	0	-31.1218
	NOx	Super	-2.229	0	0	2.4215
		Very High	-4.278	0	0	4.0389
		High	3.988	1.1684	0	0
		Moderate	36.843	0	0	1.1568
		Normal	70.3725	0	0	-12.6413
10	HC	Super	-1.676	0	0	1.8725
		Very High	-0.776	0.5236	0	0
		High	-1.864	2.0374	0	0
		Moderate	-11.979	0	0	14.45
		Normal	128.071	0	0	-27.7418
	CO	Super	-1.213	0	0	2.798

		Very High	-3.123	1.1648	0	0
		High	-17.225	0	0	13.074
		Moderate	16.151	0	0	7.952
		Normal	143.146	7.039	0	-60.409
	NOx	Super	-0.337	0	0	0.355
		Very High	-0.13	0.2783	0	0
		High	0.539	0	0.06592	0
		Moderate	13.45	0	0.15456	0
		Normal	84.897	0	-0.24025	0
11	HC	Super	-1.031	0	0	1.6397
		Very High	0	0	0	2.1878
		High	-3.339	2.8571	0	0
		Moderate	5.927	0	0	14.209
		Normal	107.45	0	0	-29.3827
	CO	Super	0	0	0	0.24169
		Very High	-1.879	0.4656	0	0
		High	4.041	0	0.20882	0
		Moderate	6.753	2.4039	0	0
		Normal	115.792	0	0	-25.034
	NOx	Super	0	0	0	0
		Very High	-2.491	0	0	2.6
		High	-9.744	0	0	10.5918
		Moderate	9.604	0	0	16.3178
		Normal	102.631	0	0	-29.5096
12	HC	Super	-0.092	0	0.05721	0
		Very High	0	0	0	2.3655
		High	-4.204	2.8345	0	0
		Moderate	13.76	3.9987	0	0
		Normal	118.253	0	0	-33.685
	CO	Super	0	0	0	3.1002
		Very High	-2.372	0.5564	0	0
		High	-8.124	3.2019	0	0
		Moderate	-1.688	0	0	10.8518
		Normal	117.826	0	0	-26.498
	NOx	Super	0	0	0	0
		Very High	-1.982	0	0	2.815

		High	-5.572	0	0	9.837
		Moderate	7.117	0	0	16.704
		Normal	100.436	0	0	-29.356
13	HC	Super	-1.06	0	0.0704	0
		Very High	0.03	0	0.0574	0
		High	2.91	0	0.1574	0
		Moderate	7.251	4.3863	0	0
		Normal	153.377	4.3249	0	-52.8213
	CO	Super	-2.338	1.126	0	0
		Very High	0.371	0	0.02884	0
		High	-6.866	3.546	0	0
		Moderate	13.058	2.741	0	0
		Normal	130.796	0	0	-33.573
	NOx	Super	0	0	0	0
		Very High	0	0	0	0
		High	1.525	0	0.03028	0
		Moderate	5.802	0	0.24022	0
		Normal	98.817	-2.871	0	0
14	HC	Super	-1.674	0	0	1.8634
		Very High	-0.778	0.5213	0	0
		High	-1.88	2.0286	0	0
		Moderate	-12.236	0	0	14.7028
		Normal	128.291	0	0	-27.9334
	CO	Super	-1.216	0	0	2.783
		Very High	-8.387	0	0	5.142
		High	-17.18	0	0	13.015
		Moderate	15.349	0	0	8.303
		Normal	111.433	0	0	-29.243
	NOx	Super	-0.337	0	0	0.3532
		Very High	-0.403	0.3686	0	0
		High	0.527	0	0.06572	0
		Moderate	14.066	0	0.14698	0
		Normal	92.553	-3.1457	0	0
15	HC	Super	-1.0301	0	0.06819	0
		Very High	0.0255	0	0.05553	0
		High	3.011	0	0.15284	0
		Moderate	7.736	4.46	0	0

		Normal	134.047	0	0	-34.3017
	CO	Super	-2.2694	1.0888	0	0
		Very High	0.3553	0	0.0279	0
		High	-6.056	3.3971	0	0
		Moderate	11.418	3.0317	0	0
		Normal	131.962	0	0	-33.974
	NOx	Super	-0.3397	0.11786	0	0
		Very High	-0.59	0.2649	0	0
		High	1.471	0	0.02926	0
		Moderate	8.535	0	0.19379	0
		Normal	95.852	-2.7208	0	0
16	HC	Super	-2.296	0	0	2.1296
		Very High	2.252	0	0.02768	0
		High	0.49	4.765	0	0
		Moderate	21.05	0	0	6.28
		Normal	90.06	0	0	-28.54
	CO	Super	-1.179	0	0	2.7532
		Very High	-5.75	0	0	3.9185
		High	0.186	4.5518	0	0
		Moderate	-0.25	0	0	13.134
		Normal	87.02	-8.0337	0	0
	NOx	Super	-0.174	0	0.02143	0
		Very High	-1.611	0	0	1.5451
		High	3.658	0	0	0.852
		Moderate	24.377	0	0	11.0443
		Normal	80.602	0	0	-19.654

4.5.2.2 Additional Changes to the Regime Growth Rates

During beta testing of EMFAC2000, the fleet average FTP based emission rates were compared to data collected during BAR's random roadside tests. These comparisons revealed that the HC and CO rates calculated by EMFAC2000, for 1985 and newer model years were higher than those observed in the random roadside sample. Conversely, the NOx rates were lower than those observed in the random roadside sample for the same years.

Sierra staff was asked to review the basic emission rates, and determine the probable cause of these emission differences. Sierra staff noted that in the development of the regime growth rates, EPA data were classified into the regimes using Federal certification standards instead of the California certification standards. This resulted in potential high emitters being classified as normal emitters. The regime growth rates for technology groups 9, 10, 12 and 13 were revised. Table 4-39 shows the revised regime growth rates.

Table 4-39 Revised Regime Growth Rates

Tech. Group	Species	Regime	Intercept A	Linear B	Quadratic C	Square Root D
9	HC	Normal	101.002	0	0	-30.8359
		Moderate	16.875	7.6004	-0.4684	0
		High	-8.279	0	0	12.8909
		Very High	0.608	0	0.11437	0
		Super	-0.137	0	0.06136	0
	CO	Normal	76.125	-5.3415	0	0
		Moderate	20.266	0	0	4.7454
		High	-10.996	0	0	11.8972
		Very High	0.463	0	0.06282	0
		Super	0.069	0	0.09332	0
	NOx	Normal	74.753	0	0	-16.6521
		Moderate	42.283	0	-0.03903	0
		High	1.953	1.5443	0	0
		Very High	-4.468	0	0	4.7021
		Super	-1.703	1.2579	0	0
10	HC	Normal	103.857	-6.2008	0	0
		Moderate	-17.243	0	0	15.5692
		High	-2.575	1.9662	0	0
		Very High	0.126	0	0.04756	0
		Super	-1.963	0	0	1.8398
	CO	Normal	125.757	0	0	-21.1541
		Moderate	-11.308	0	0	10.1092
		High	-1.877	1.2748	0	0
		Very High	-2.399	0	0	1.8767
		Super	-3.711	0	0	3.1843

	NOx	Normal	88.123	-4.7844	0	0
		Moderate	0.69	0	0	13.3924
		High	2.212	0	0.02082	0
		Very High	-0.91	0	0.09309	0
		Super	0.152	0	0.03301	0
12	HC	Normal	105.898	0	0	-29.2096
		Moderate	5.74	0	0	14.9709
		High	-11.858	0	0	10.942
		Very High	4.966	0	0	0.1715
		Super	-0.628	0	0.06733	0
	CO	Normal	111.264	0	0	-22.6882
		Moderate	3.026	0	0	9.6354
		High	-9.46	0	0	7.0193
		Very High	-0.787	0	0.04424	0
		Super	-1.63	0	0	4.1078
	NOx	Normal	100.568	0	0	-26.8723
		Moderate	13.275	0	0	13.2327
		High	-9.447	0	0	9.8849
		Very High	-0.637	0.8346	0	0
		Super	0	0	0	0
13	HC	Normal	109.046	-6.5884	0	0
		Moderate	-25.539	0	0	20.124
		High	-2.737	1.4625	0	0
		Very High	-0.283	0	0.04918	0
		Super	-0.372	0.1617	0	0
	CO	Normal	105.743	-3.5649	0	0
		Moderate	1.425	0	0.17265	0
		High	-0.925	0.6891	0	0
		Very High	-0.72	0.4792	-0.03283	0
		Super	-1.278	0.5484	0	0
	NOx	Normal	95.246	-4.6266	0	0
		Moderate	9.326	2.8196	0	0
		High	-0.216	0	0.07875	0
		Very High	-0.498	0.3305	0	0
		Super	-0.651	0	0.04112	0

4.6 Emission Rates

The previous sections have described various data analyses that were used for regime growth functions and the I&M analysis. This section presents the basic emission rate data, by technology group and emissions regime.

4.6.1 Introduction

All data from the surveillance data sets and the I&M data sets (including the 1994 pilot program) were used to compute the emission rate by technology group and regime. This full data set was used to get as many vehicles as possible for the emission rates of the individual regimes and technology groups, particularly for the super-emitting regimes, which have a small number of vehicles. This means that the vehicles, which were used to determine the regime boundaries and growth rates, were only a subset of the vehicles, which were eventually used to determine the regime *emission rates*.

For the normal regime only, the emission rate can depend on mileage (which is directly linked to vehicle age in EMFAC2000.) The emissions versus mileage relationship is a linear regression. The EMFAC2000 slope is non-zero only in cases where the regression slope is statistically different from zero at the 95% confidence level, *and* the slope increases emissions by 10% or more of the emission standard over 50,000 miles.[*] For all other regimes the emission rate is not a function of mileage. As in the CALIMFAC model, the emission rate is calculated using the arithmetic mean of all emission rates in the regime.

For some technology-group/regime combinations there were not enough data to get a valid emission rate. In these cases, data from similar technology groups and/or regimes were used. These adjustments to the data are shown in Table 4-40.

Table 4-40
Data Substitutions for Emission Rate Values

Species	Regime	New Technology Group	Data Used
HC	Very High & Super	6 (oxidation catalyst, 1980-and-later model years)	Oxidation catalyst, 1975 and later model years
	Super	13 (1986 and later, TWC, MPFI, 0.7 NOx)	1981 and later, TWC, MPFI, 0.7 NOx
	Super	14 (1981 and later, TWC, TBI/Carb, 0.4 NOx)	1981 and later, TWC, TBI/Carb, 0.7 NOx
	Very High & Super	15 (1981 and later, TWC, MPFI, 0.4 NOx)	1981 and later, TWC, MPFI, 0.4 & 0.7 NOx
CO	Super	1 and 2 (pre-1975 without and with secondary air)	Use very high value for same technology groups
	Very High & Super	6 (oxidation catalyst, 1980 and later model years)	Oxidation catalyst, 1975 and later model years
	Very High & Super	14 (1981 and later, TWC, TBI/Carb, 0.4 NOx)	1981 and later, TWC, TBI/Carb, 0.4 & 0.7 NOx

	Very High & Super	15 (1981 and later, TWC, MPFI, 0.4 NOx)	1981 and later, TWC, MPFI, 0.4 & 0.7 NOx
NOx	Super	8 (1975-1979 TWC with TBI/Carb)	Same as very high for the technology group
	Very High & Super	6 (oxidation catalyst, 1980 and later model years)	Oxidation catalyst, 1975 and later model years

4.6.2 Future Technology Groups

Data on regime growth functions, emission rates and I&M identification and repair rates for new technology groups are required to obtain model results for future calendar years. The available surveillance data set covers technology groups one through sixteen. The data for future technology groups is generally found by using data for existing technology groups with similar control technologies. Appropriate adjustments are made to account for lower emission standards in future technology groups. In the discussion below the new technology groups whose properties are found from other groups are called derived groups. The technology groups providing the data are called reference groups.

4.6.2.1 Technology groups 17 and 18

These groups are 1993 and later, three-way catalyst (TWC), with emission standards of 0.25 g/mi. HC and 0.4 g/mi. NOx. Group 17 uses throttle body injection or carburetors (TBI/Carb) and group 18 uses multipoint fuel injection (MPFI). They were included in CALIMFAC as group numbers 15 and 16. In EMFAC2000, these groups have the same regime growth functions as groups 14 and 15,[*] which have the same emission control technology but different emission standards. The emission rates for new groups 17 and 18 are found from new groups 14 and 15 by the following adjustment process. This is the same process used in the original CALIMFAC analysis.

- The intercept for the normal regime emissions in the derived groups (17 and 18 in this case) is found by multiplying the normal intercept in the reference groups (14 and 15) by ratio of emission standards (0.25/0.39 for HC, 3.4/7.0 for CO, and 1.0 for NOx).

- The slope giving the increase in the normal emissions with odometer reading in the derived group is the same as the slope in the reference group.

- The mean emission rates for the moderate, high, very highs and supers in the derived groups are found by multiplying the corresponding emission rates in the reference groups by ratio of emission standards.

This same adjustment procedure was used for all other derived groups with new emission standards.

The I&M data (identification rate and move matrix) for groups 17 and 18 are the same as those for groups 15 and 16, respectively.

4.6.2.2 Technology groups 19 and 20

These differ from groups 17 and 18, respectively, only in the presence of second-generation onboard diagnostics (OBD II.) The emission rates for technology groups 19 and 20 are the same as the reference groups 17 and 18. The regime growth functions for groups 19 and 20 are a modification of the regime growth functions for groups 17 and 18, which account for the presence of OBD II.

ARB staff believes that OBD II will eliminate high, very high, and super emitters for up to 70,000 miles. This is readily handled because of the existing treatment for the regime growth functions. As noted earlier, the raw regime growth functions, for a given odometer reading, are adjusted so that values below zero are set to zero and values above one are set to one. Thus, if the existing regime growth functions for high, very high or super are zero for all odometer readings below 70,000 miles no adjustment is required. If the regime growth functions gives a positive population fraction in these regimes the regime growth function equation can be adjusted so that its population is zero for all odometer readings below 70,000 miles.

In addition to the adjustment of the regime growth functions, ARB staff believes that vehicles with OBD II will be readily identified and repaired in I&M procedures. Following their direction, two separate modifications were used in EMFAC2000 for OBD II vehicles:

- The mechanic inspection efficiency for visual/functional tests was set to 95% for all checks used in the visual/functional test.

- The move matrix for OBD II vehicles was modified so that, after repair, OBD II vehicles migrate evenly to the moderate and normal emission regimes. This was done by setting the move-matrix components for the high, very high, and super regimes so that 50% of the population in each of these before-repair regimes to the normal regime after repair and 50% to the moderate regime. The move matrix for OBD II vehicles originally in the normal and moderate regimes was not changed.

The procedures discussed here for technology groups 19 and 20 were used to adjust the regime growth functions and the I&M data for all technology groups with OBD II.

4.6.2.3 Technology groups 21 and 22

These are transitional low emission vehicles (TLEVs) which are assumed to use using TWC with MPFI. Group 21 does not have OBD II but group 22 does.

4.6.2.4 Technology groups 23 and 24

These are low-emission vehicles (LEVs) and and ultra-low-emission vehicles (ULEVs). These groups use the same regime growth functions and I&M data as the TLEVs in group 22. The following ratios of emission standards were used in the emission rate adjustment procedure: $HC_{23}/HC_{22} = 0.5$, $HC_{24}/HC_{23} = 40/75$, $CO_{24}/CO_{23} = 0.5$, and $NOx_{23}/NOx_{22} = 0.5$. All other standard ratios are unity.

Recent certification data was used to obtain emissions data for the normal regime for TLEVs, LEVs and ULEVs.

4.6.2.5 Technology group 25

These are zero-emission vehicles (ZEVs) for which the emission rate of all regimes is zero. The population of normals is set to one and the population of all other regimes is set to zero for all odometer readings. The identification rate for I&M is zero.

4.6.2.6 Technology groups 26 and 27

These groups are used for light and medium-duty trucks for 1996 and later model years. These vehicles meet a 0.7 g/mi. NOx standard and are equipped with OBD II. Both groups will use three-way catalysts. Group 26, with TBI/Carb, will use the regime growth functions for group 10; group 27 with MPFI will use the regime growth functions for group 13. Both sets of regime growth functions are adjusted for OBD II as described in the discussion of technology groups 19 and 20. The HC and CO emission rates for these groups will be scaled from the group 10 and 13 emission rates to the 1995 and later standards for LDTs with weights between 3,751 and 5,750 pounds.* This gives standard ratios of 0.32/0.39 for HC and 4.4/7.0 for CO to be used for adjusting the emission rates. The identification rates and the move matrices for these groups 26 and 27 are also taken from similar data for groups 10 and 13, respectively. However, those data are adjusted for OBD II in the same manner described for technology groups 19 and 20.

4.6.2.7 Technology groups 28 to 30

These groups represent vehicles certifying to the LEV II emission standards. Section 4.9 details how these emission rates were calculated for these technology groups.

4.6.2.8 Technology groups 40-43

These groups represents Mexican vehicles which are considered in the emission inventories for San Diego and Imperial Counties (Section 12.0). These groups represent the following emission control technologies:

Group 40 – Non-catalyst vehicles
Group 41 - Oxidation catalyst vehicles
Group 42 - Three-way catalyst vehicles with TBI/Carb
Group 43 - Three-way catalyst vehicles with MPFI

The FTP based emission rates for HC, CO and NOx are shown in Tables 4-41, 4-42 and 4-43, respectively.

Table 4-41 Hydrocarbon Emission Rate (g/mi.)

Technology Group and Regime			Raw Averages					Final data with adjustments for missing data					
Old Tech	New Tech	Regime	Number	Bag One	Bag Two	Bag 3	Comp	Number	Bag One	Bag Two	Bag 3	Comp	Adjustment Method
1	1	Normal	305	4.816	2.963	3.220	3.570	305	4.816	2.963	3.220	3.570	
1	1	Moderate	255	7.995	5.722	5.144	6.404	255	7.995	5.722	5.144	6.404	
1	1	High	37	11.686	12.938	9.169	12.983	37	11.686	12.938	9.169	12.983	
1	1	Very High	14	27.327	25.677	23.038	25.839	14	27.327	25.677	23.038	25.839	
1	1	Super	18	36.403	40.943	32.918	38.457	18	36.403	40.943	32.918	38.457	
2	2	Normal	144	4.572	1.986	2.041	2.402	144	4.572	1.986	2.041	2.402	
2	2	Moderate	78	7.162	4.920	4.828	5.331	78	7.162	4.920	4.828	5.331	
2	2	High	13	16.738	13.010	10.797	12.959	13	16.738	13.010	10.797	12.959	
2	2	Very High	5	18.573	23.807	20.595	20.027	5	18.573	23.807	20.595	20.027	
2	2	Super	12	31.533	31.088	34.209	37.332	12	31.533	31.088	34.209	37.332	
3	3	Normal	70	1.548	0.505	0.767	0.787	70	1.548	0.505	0.767	0.787	
3	3	Moderate	64	2.814	0.882	1.206	1.368	64	2.814	0.882	1.206	1.368	
3	3	High	67	4.684	1.672	1.542	2.248	67	4.684	1.672	1.542	2.248	
3	3	Very High	14	9.697	4.072	3.960	5.218	14	9.697	4.072	3.960	5.218	
3	3	Super	3	12.394	15.449	7.580	12.643	3	12.394	15.449	7.580	12.643	
4	4	Normal	312	1.577	0.271	0.495	0.602	312	1.577	0.271	0.495	0.602	

4	4	Moderate	139	2.777	0.778	1.026	1.258	139	2.777	0.778	1.026	1.258	
4	4	High	172	5.684	2.956	2.646	3.438	172	5.684	2.956	2.646	3.438	
4	4	Very High	23	12.935	8.735	7.388	9.257	23	12.935	8.735	7.388	9.257	
4	4	Super	9	28.230	25.989	21.855	25.470	9	28.230	25.989	21.855	25.470	
5	ELIMINATED	Normal	81	1.365	0.210	0.409	0.503	81	1.365	0.210	0.409	0.503	
5	ELIMINATED	Moderate	102	2.732	0.799	0.799	1.201	102	2.732	0.799	0.799	1.201	
5	ELIMINATED	High	143	4.705	2.474	2.159	2.854	143	4.705	2.474	2.159	2.854	
5	ELIMINATED	Very High	18	7.892	5.381	3.830	5.523	18	7.892	5.381	3.830	5.523	
5	ELIMINATED	Super	22	22.848	15.996	14.704	17.141	22	22.848	15.996	14.704	17.141	
5.1	5	Normal	60	1.568	0.261	0.503	0.597	60	1.568	0.261	0.503	0.597	
5.1	5	Moderate	75	3.078	1.020	0.974	1.433	75	3.078	1.020	0.974	1.433	
5.1	5	High	134	4.832	2.577	2.239	2.956	134	4.832	2.577	2.239	2.956	
5.1	5	Very High	18	7.892	5.381	3.830	5.523	18	7.892	5.381	3.830	5.523	
5.1	5	Super	22	22.848	15.996	14.704	17.141	22	22.848	15.996	14.704	17.141	
5.2	6	Normal	21	0.832	0.078	0.161	0.257	21	0.832	0.078	0.161	0.257	
5.2	6	Moderate	27	1.784	0.193	0.320	0.556	27	1.784	0.193	0.320	0.556	
5.2	6	High	9	2.809	0.939	0.970	1.335	9	2.809	0.939	0.970	1.335	
5.2	6	Very High	0					18	7.892	5.381	3.830	5.523	Old group 5
5.2	6	Super	0					22	22.848	15.996	14.704	17.141	Old group 5
6	7	Normal	361	0.954	0.159	0.273	0.354	361	0.954	0.159	0.273	0.354	

6	7	Moderate	493	1.648	0.306	0.499	0.636	493	1.648	0.306	0.499	0.636
6	7	High	434	3.362	1.179	1.308	1.668	434	3.362	1.179	1.308	1.668
6	7	Very High	96	6.326	3.639	3.394	4.129	96	6.326	3.639	3.394	4.129
6	7	Super	43	18.950	14.072	12.111	14.649	43	18.950	14.072	12.111	14.649
7	8	Normal	4	1.004	0.123	0.189	0.327	4	1.004	0.123	0.189	0.327
7	8	Moderate	14	1.501	0.322	0.474	0.610	14	1.501	0.322	0.474	0.610
7	8	High	10	3.009	1.408	1.370	1.734	10	3.009	1.408	1.370	1.734
7	8	Very High	3	5.812	4.698	2.763	4.398	3	5.812	4.698	2.763	4.398
7	8	Super	6	13.508	12.179	7.893	11.280	6	13.508	12.179	7.893	11.280
7.1	ELIMINATED	Normal	74	0.930	0.093	0.185	0.292	74	0.930	0.093	0.185	0.292
7.1	ELIMINATED	Moderate	86	1.621	0.291	0.430	0.605	86	1.621	0.291	0.430	0.605
7.1	ELIMINATED	High	83	3.035	1.242	1.275	1.622	83	3.035	1.242	1.275	1.622
7.1	ELIMINATED	Very High	43	4.908	3.640	2.873	3.759	43	4.908	3.640	2.873	3.759
7.1	ELIMINATED	Super	15	15.505	11.560	8.508	11.534	15	15.505	11.560	8.508	11.534
8.91	9	Normal	265	0.792	0.133	0.230	0.296	265	0.792	0.133	0.230	0.296
8.91	9	Moderate	408	1.468	0.333	0.507	0.616	408	1.468	0.333	0.507	0.616
8.91	9	High	272	2.778	1.091	1.184	1.466	272	2.778	1.091	1.184	1.466
8.91	9	Very High	78	5.083	3.219	2.682	3.457	78	5.083	3.219	2.682	3.457
8.91	9	Super	25	16.441	12.966	12.093	13.432	25	16.441	12.966	12.093	13.432
8.92	10	Normal	162	0.773	0.116	0.204	0.276	162	0.773	0.116	0.204	0.276

8.92	10 Moderate	138	1.350	0.356	0.470	0.593	138	1.350	0.356	0.470	0.593	
8.92	10 High	74	2.798	1.242	1.340	1.591	74	2.798	1.242	1.340	1.591	
8.92	10 Very High	24	5.268	3.102	3.017	3.521	24	5.268	3.102	3.017	3.521	
8.92	10 Super	3	7.573	10.189	5.433	8.337	3	7.573	10.189	5.433	8.337	
10	11 Normal	26	0.922	0.093	0.178	0.288	26	0.922	0.093	0.178	0.288	
10	11 Moderate	25	1.594	0.312	0.436	0.612	25	1.594	0.312	0.436	0.612	
10	11 High	25	2.588	1.459	1.350	1.662	25	2.588	1.459	1.350	1.662	
10	11 Very High	12	4.290	3.963	2.730	3.691	12	4.290	3.963	2.730	3.691	
10	11 Super	2	10.267	7.923	10.223	8.999	2	10.267	7.923	10.223	8.999	
11.1	12 Normal	59	0.904	0.097	0.183	0.288	59	0.904	0.097	0.183	0.288	
11.1	12 Moderate	124	1.632	0.337	0.426	0.630	124	1.632	0.337	0.426	0.630	
11.1	12 High	78	2.662	1.154	1.078	1.446	78	2.662	1.154	1.078	1.446	
11.1	12 Very High	18	5.597	3.158	2.511	3.484	18	5.597	3.158	2.511	3.484	
11.1	12 Super	5	7.602	7.615	5.040	6.908	5	7.602	7.615	5.040	6.908	
11.2	13 Normal	170	0.921	0.077	0.139	0.269	170	0.921	0.077	0.139	0.269	
11.2	13 Moderate	113	1.438	0.284	0.407	0.557	113	1.438	0.284	0.407	0.557	
11.2	13 High	35	2.749	1.131	1.082	1.453	35	2.749	1.131	1.082	1.453	
11.2	13 Very High	8	3.842	3.833	2.427	3.448	8	3.842	3.833	2.427	3.448	
11.2	13 Super	1	25.370	23.962	20.226	23.226	6	10.563	10.340	7.571	9.628	From old 11.1 and 11.2
12	14 Normal	18	0.607	0.103	0.190	0.231	18	0.607	0.103	0.190	0.231	

12	14 Moderate	18	1.313	0.322	0.527	0.584	18	1.313	0.322	0.527	0.584	
12	14 High	9	2.571	1.293	1.317	1.564	9	2.571	1.293	1.317	1.564	
12	14 Very High	2	6.035	3.072	3.636	3.839	2	6.035	3.072	3.636	3.839	
12	14 Super	0					28	15.491	12.668	11.379	12.886	From old 12, 8.91 and 8.92
13	15 Normal	88	0.872	0.061	0.126	0.247	88	0.872	0.061	0.126	0.247	
13	15 Moderate	30	1.628	0.271	0.406	0.589	30	1.628	0.271	0.406	0.589	
13	15 High	10	2.580	1.455	1.489	1.698	10	2.580	1.455	1.489	1.698	
13	15 Very High	1	2.866	3.397	2.399	3.012	27	4.976	3.367	2.482	3.456	From old 11.1, 11.2, and 13
13	15 Super	0					6	10.563	10.340	7.571	9.628	From old 11.1, 11.2, and 13
14	16 Normal	44	0.928	0.089	0.188	0.291	44	0.928	0.089	0.188	0.291	
14	16 Moderate	47	1.668	0.272	0.415	0.599	47	1.668	0.272	0.415	0.599	
14	16 High	48	3.272	1.095	1.217	1.577	48	3.272	1.095	1.217	1.577	
14	16 Very High	28	5.082	3.389	2.946	3.719	28	5.082	3.389	2.946	3.719	
14	16 Super	7	18.713	12.068	8.545	12.477	7	18.713	12.068	8.545	12.477	
15	17 Normal							0.389	0.066	0.122	0.148	.25/.39 times new 14
15	17 Moderate							0.842	0.206	0.338	0.374	.25/.39 times new 14
15	17 High							1.648	0.829	0.844	1.003	.25/.39 times new 14
15	17 Very High							3.869	1.969	2.331	2.461	.25/.39 times new 14
15	17 Super							9.930	8.121	7.295	8.260	.25/.39 times new 14
16	18 Normal							0.559	0.039	0.081	0.158	.25/.39 times new 15
16	18 Moderate							1.044	0.174	0.260	0.378	.25/.39 times new 15
16	18 High							1.654	0.933	0.954	1.088	.25/.39 times new 15
16	18 Very High							3.190	2.158	1.591	2.215	.25/.39 times new 15
16	18 Super							6.771	6.628	4.853	6.172	.25/.39 times new 15
	19 Normal							0.389	0.066	0.122	0.148	Same as new 17
	19 Moderate							0.842	0.206	0.338	0.374	Same as new 17

19 High	1.648	0.829	0.844	1.003	Same as new 17
19 Very High	3.869	1.969	2.331	2.461	Same as new 17
19 Super	9.930	8.121	7.295	8.260	Same as new 17
20 Normal	0.559	0.039	0.081	0.158	Same as new 18
20 Moderate	1.044	0.174	0.260	0.378	Same as new 18
20 High	1.654	0.933	0.954	1.088	Same as new 18
20 Very High	3.190	2.158	1.591	2.215	Same as new 18
20 Super	6.771	6.628	4.853	6.172	Same as new 18
21 Normal	0.279	0.020	0.040	0.079	Half of new 20
21 Moderate	0.522	0.087	0.130	0.189	Half of new 20
21 High	0.827	0.466	0.477	0.544	Half of new 20
21 Very High	1.595	1.079	0.796	1.108	Half of new 20
21 Super	3.386	3.314	2.427	3.086	Half of new 20
22 Normal	0.279	0.020	0.040	0.079	Half of new 20
22 Moderate	0.522	0.087	0.130	0.189	Half of new 20
22 High	0.827	0.466	0.477	0.544	Half of new 20
22 Very High	1.595	1.079	0.796	1.108	Half of new 20
22 Super	3.386	3.314	2.427	3.086	Half of new 20
23 Normal	0.140	0.010	0.020	0.040	Half of new 22
23 Moderate	0.261	0.043	0.065	0.094	Half of new 22
23 High	0.413	0.233	0.239	0.272	Half of new 22
23 Very High	0.797	0.540	0.398	0.554	Half of new 22
23 Super	1.693	1.657	1.213	1.543	Half of new 22
24 Normal	0.075	0.005	0.011	0.021	New 23 times 0.040/0.075
24 Moderate	0.139	0.023	0.035	0.050	New 23 times 0.040/0.075
24 High	0.221	0.124	0.127	0.145	New 23 times 0.040/0.075
24 Very High	0.425	0.288	0.212	0.295	New 23 times 0.040/0.075
24 Super	0.903	0.884	0.647	0.823	New 23 times 0.040/0.075
25 Normal	0.0	0.0	0.0	0.0	Set ZEVs to zero
25 Moderate	0.0	0.0	0.0	0.0	Set ZEVs to zero
25 High	0.0	0.0	0.0	0.0	Set ZEVs to zero
25 Very High	0.0	0.0	0.0	0.0	Set ZEVs to zero
25 Super	0.0	0.0	0.0	0.0	Set ZEVs to zero
26 Normal	0.634	0.095	0.167	0.226	New 10 times 0.32/0.39
26 Moderate	1.108	0.292	0.386	0.487	New 10 times 0.32/0.39

	26	High							2.296	1.019	1.099	1.305	New 10 times 0.32/0.39
	26	Very High							4.322	2.545	2.475	2.889	New 10 times 0.32/0.39
	26	Super							6.214	8.360	4.458	6.841	New 10 times 0.32/0.39
	27	Normal							0.756	0.063	0.114	0.221	New 13 times 0.32/0.39
	27	Moderate							1.180	0.233	0.334	0.457	New 13 times 0.32/0.39
	27	High							2.256	0.928	0.888	1.192	New 13 times 0.32/0.39
	27	Very High							3.152	3.145	1.991	2.829	New 13 times 0.32/0.39
	27	Super							8.667	8.484	6.212	7.900	New 13 times 0.32/0.39

Table 4-42 Carbon Monoxide Emission Rate (g/mi.)

Technology Group and Regime			Raw Averages					Final data with adjustments for missing data					
Old Tech	New Tech	Regime	Number	Bag One	Bag Two	Bag 3	Comp	Number	Bag One	Bag Two	Bag 3	Comp	Adjustment Method
1	1	Normal	282	52.253	29.714	24.003	34.318	282	52.253	29.714	24.003	34.318	
1	1	Moderate	279	87.918	75.102	54.468	77.413	279	87.918	75.102	54.468	77.413	
1	1	High	57	133.896	141.613	102.801	137.196	57	133.896	141.613	102.801	137.196	
1	1	Very High	10	211.78	240.439	158.306	211.989	10	211.780	240.439	158.306	211.989	
1	1	Super	0						211.780	240.439	158.306	211.989	Same as Very High
2	2	Normal	126	44.366	23.585	21.601	28.366	126	44.366	23.585	21.601	28.366	
2	2	Moderate	103	85.241	65.966	53.086	65.836	103	85.241	65.966	53.086	65.836	
2	2	High	20	131.508	114.44	86.925	118.47	20	131.508	114.440	86.925	118.470	
2	2	Very High	1	244.6	112.64	67.58	127.57	1	244.600	112.640	67.580	127.570	
2	2	Super	2	109.11	86.02	72.29	87.03	2	244.600	112.640	67.580	127.570	Same as Very High

3	3	Normal	100	18.713	5.75	6.213	8.523	100	18.713	5.750	6.213	8.523
3	3	Moderate	79	31.729	16.477	13.401	18.801	79	31.729	16.477	13.401	18.801
3	3	High	29	59.054	36.822	30.81	39.843	29	59.054	36.822	30.810	39.843
3	3	Very High	5	96.35	95.882	73.094	89.724	5	96.350	95.882	73.094	89.724
3	3	Super	5	127.416	114.968	69.894	105.126	5	127.416	114.968	69.894	105.126
4	4	Normal	302	19.814	1.462	3.077	5.665	302	19.814	1.462	3.077	5.665
4	4	Moderate	182	42.707	9.747	11.517	17.047	182	42.707	9.747	11.517	17.047
4	4	High	84	68.124	37.552	27.713	41.036	84	68.124	37.552	27.713	41.036
4	4	Very High	48	93.412	68.903	49.495	68.799	48	93.412	68.903	49.495	68.799
4	4	Super	39	154.177	129.265	96.42	124.643	39	154.177	129.265	96.420	124.643
5	ELIMINATED	Normal	126	16.009	2.094	3.484	5.333	126	16.009	2.094	3.484	5.333
5	ELIMINATED	Moderate	121	36.853	15.697	12.57	19.267	121	36.853	15.697	12.570	19.267
5	ELIMINATED	High	72	71.417	43.638	34.074	46.632	72	71.417	43.638	34.074	46.632
5	ELIMINATED	Very High	28	86.551	78.054	54.123	73.448	28	86.551	78.054	54.123	73.448
5	ELIMINATED	Super	19	148.068	136.952	108.756	131.514	19	148.068	136.952	108.756	131.514
5.1	5	Normal	84	18.878	2.403	3.782	6.149	84	18.878	2.403	3.782	6.149
5.1	5	Moderate	108	38.744	16.768	12.975	20.331	108	38.744	16.768	12.975	20.331
5.1	5	High	70	72.395	44.3	34.313	47.231	70	72.395	44.300	34.313	47.231
5.1	5	Very High	28	86.551	78.054	54.123	73.448	28	86.551	78.054	54.123	73.448
5.1	5	Super	19	148.068	136.952	108.756	131.514	19	148.068	136.952	108.756	131.514

5.2	6	Normal	42	10.612	1.527	2.924	3.796	42	10.612	1.527	2.924	3.796	
5.2	6	Moderate	13	21.142	6.802	9.206	10.435	13	21.142	6.802	9.206	10.435	
5.2	6	High	2	37.665	20.77	25.83	25.665	2	37.665	20.770	25.830	25.665	
5.2	6	Very High	0					28	86.551	78.054	54.123	73.448	Old group 5
5.2	6	Super	0					19	148.068	136.952	108.756	131.514	Old group 5
6	7	Normal	761	17.014	1.339	3.122	5.046	761	17.014	1.339	3.122	5.046	
6	7	Moderate	392	40.962	8.03	11.504	15.806	392	40.962	8.030	11.504	15.806	
6	7	High	153	66.819	32.081	30.417	38.847	153	66.819	32.081	30.417	38.847	
6	7	Very High	81	98.204	64.605	50.55	67.76	81	98.204	64.605	50.550	67.760	
6	7	Super	40	148.15	132.765	111.611	129.85	40	148.150	132.765	111.611	129.850	
7	8	Normal	14	16.611	1.662	2.672	5.003	14	16.611	1.662	2.672	5.003	
7	8	Moderate	11	34.54	9.329	9.928	14.756	11	34.540	9.329	9.928	14.756	
7	8	High	2	58.22	38.68	23.715	38.615	2	58.220	38.680	23.715	38.615	
7	8	Very High	4	108.55	80.04	41.8	75.355	4	108.550	80.040	41.800	75.355	
7	8	Super	6	112.862	145.877	102.44	127.168	6	112.862	145.877	102.440	127.168	
7.1	ELIMINATED	Normal	129	15.57	2.219	3.017	5.185	129	15.570	2.219	3.017	5.185	
7.1	ELIMINATED	Moderate	71	32.325	7.015	9.491	12.936	71	32.325	7.015	9.491	12.936	
7.1	ELIMINATED	High	65	51.182	28.371	27.648	33.483	65	51.182	28.371	27.648	33.483	
7.1	ELIMINATED	Very High	12	96.508	76.031	56.968	74.993	12	96.508	76.031	56.968	74.993	
7.1	ELIMINATED	Super	24	135.663	149.737	95.634	132.107	24	135.663	149.737	95.634	132.107	

8.91	9	Normal	396	11.582	1.685	3.927	4.351	396	11.582	1.685	3.927	4.351
8.91	9	Moderate	356	23.136	5.562	8.647	10.05	356	23.136	5.562	8.647	10.050
8.91	9	High	219	42.166	17.798	20.193	23.499	219	42.166	17.798	20.193	23.499
8.91	9	Very High	35	72.744	53.169	49.303	56.155	35	72.744	53.169	49.303	56.155
8.91	9	Super	42	123.235	133.107	98.188	121.369	42	123.235	133.107	98.188	121.369
8.92	10	Normal	199	10.518	2.189	3.882	4.38	199	10.518	2.189	3.882	4.380
8.92	10	Moderate	111	19.599	6.163	8.98	9.717	111	19.599	6.163	8.980	9.717
8.92	10	High	61	39.858	19.665	18.073	23.408	61	39.858	19.665	18.073	23.408
8.92	10	Very High	17	75.878	47.354	55.234	55.433	17	75.878	47.354	55.234	55.433
8.92	10	Super	13	131.436	111.344	98.862	112.078	13	131.436	111.344	98.862	112.078
10	11	Normal	46	11.768	2.588	3.276	4.652	46	11.768	2.588	3.276	4.652
10	11	Moderate	16	22.536	8.128	10.059	11.651	16	22.536	8.128	10.059	11.651
10	11	High	20	40.309	35.668	26.363	34.032	20	40.309	35.668	26.363	34.032
10	11	Very High	2	123.02	60.035	64.375	74.185	2	123.020	60.035	64.375	74.185
10	11	Super	6	106.668	159.625	96.342	131.26	6	106.668	159.625	96.342	131.260
11.1	12	Normal	125	10.404	2.696	3.003	4.378	125	10.404	2.696	3.003	4.378
11.1	12	Moderate	90	17.406	7.737	7.335	9.631	90	17.406	7.737	7.335	9.631
11.1	12	High	46	33.907	19.227	17.011	21.66	46	33.907	19.227	17.011	21.660
11.1	12	Very High	8	57.728	62.511	49.206	57.864	8	57.728	62.511	49.206	57.864
11.1	12	Super	15	126.505	128.693	95.301	119.075	15	126.505	128.693	95.301	119.075

11.2	13	Normal	236	9.387	2.099	2.744	3.788	236	9.387	2.099	2.744	3.788	
11.2	13	Moderate	64	16.789	7.023	7.391	9.149	64	16.789	7.023	7.391	9.149	
11.2	13	High	21	32.53	22.97	19.602	24.024	21	32.530	22.970	19.602	24.024	
11.2	13	Very High	2	48.165	63.3	51.14	56.82	2	48.165	63.300	51.140	56.820	
11.2	13	Super	4	85.078	112.158	72.538	95.64	4	85.078	112.158	72.538	95.640	
12	14	Normal	17	9.591	3.386	4.202	4.896	17	9.591	3.386	4.202	4.896	
12	14	Moderate	24	19.295	8.013	10.565	11.054	24	19.295	8.013	10.565	11.054	
12	14	High	5	27.816	15.41	14.354	17.686	5	27.816	15.410	14.354	17.686	
12	14	Very High	0					52	73.769	51.268	51.242	55.919	From old 12, 8.91 and 8.92
12	14	Super	1	153.75	149.78	136.9	147.07	56	125.684	128.353	99.036	119.671	From old 12, 8.91 and 8.92
13	15	Normal	104	8.662	1.761	2.439	3.378	104	8.662	1.761	2.439	3.378	
13	15	Moderate	19	16.416	7.941	9.592	10.152	19	16.416	7.941	9.592	10.152	
13	15	High	6	26.283	21.517	17.825	21.498	6	26.283	21.517	17.825	21.498	
13	15	Very High	0					10	55.815	62.669	49.593	57.655	From old 11.1, 11.2, and 13
13	15	Super	0					19	117.784	125.212	90.509	114.141	From old 11.1, 11.2, and 13
14	16	Normal	69	17.943	2.081	2.908	5.583	69	17.943	2.081	2.908	5.583	
14	16	Moderate	44	35.332	6.031	9.175	12.948	44	35.332	6.031	9.175	12.948	
14	16	High	43	56.025	24.497	28.429	32.989	43	56.025	24.497	28.429	32.989	
14	16	Very High	6	79.642	78.69	64.61	75.022	6	79.642	78.690	64.610	75.022	
14	16	Super	12	161.56	146.723	91.878	134.999	12	161.560	146.723	91.878	134.999	

15	17	Normal	4.658	1.645	2.041	2.378	3.4/7 times new 14
15	17	Moderate	9.372	3.892	5.132	5.369	3.4/7 times new 14
15	17	High	13.511	7.485	6.972	8.590	3.4/7 times new 14
15	17	Very High	35.830	24.902	24.889	27.161	3.4/7 times new 14
15	17	Super	61.046	62.343	48.103	58.126	3.4/7 times new 14
16	18	Normal	4.207	0.855	1.185	1.641	3.4/7 times new 15
16	18	Moderate	7.973	3.857	4.659	4.931	3.4/7 times new 15
16	18	High	12.766	10.451	8.658	10.442	3.4/7 times new 15
16	18	Very High	27.110	30.439	24.088	28.004	3.4/7 times new 15
16	18	Super	57.209	60.817	43.961	55.440	3.4/7 times new 15
	19	Normal	4.658	1.645	2.041	2.378	Same as new 17
	19	Moderate	9.372	3.892	5.132	5.369	Same as new 17
	19	High	13.511	7.485	6.972	8.590	Same as new 17
	19	Very High	35.830	24.902	24.889	27.161	Same as new 17
	19	Super	61.046	62.343	48.103	58.126	Same as new 17
	20	Normal	4.207	0.855	1.185	1.641	Same as new 18
	20	Moderate	7.973	3.857	4.659	4.931	Same as new 18
	20	High	12.766	10.451	8.658	10.442	Same as new 18
	20	Very High	27.110	30.439	24.088	28.004	Same as new 18
	20	Super	57.209	60.817	43.961	55.440	Same as new 18
	21	Normal	4.207	0.855	1.185	1.641	Same as new 20
	21	Moderate	7.973	3.857	4.659	4.931	Same as new 20
	21	High	12.766	10.451	8.658	10.442	Same as new 20
	21	Very High	27.110	30.439	24.088	28.004	Same as new 20
	21	Super	57.209	60.817	43.961	55.440	Same as new 20
	22	Normal	4.207	0.855	1.185	1.641	Same as new 21
	22	Moderate	7.973	3.857	4.659	4.931	Same as new 21
	22	High	12.766	10.451	8.658	10.442	Same as new 21
	22	Very High	27.110	30.439	24.088	28.004	Same as new 21
	22	Super	57.209	60.817	43.961	55.440	Same as new 21
	23	Normal	4.207	0.855	1.185	1.641	Same as new 22
	23	Moderate	7.973	3.857	4.659	4.931	Same as new 22
	23	High	12.766	10.451	8.658	10.442	Same as new 22

23 Very High	27.110	30.439	24.088	28.004	Same as new 22
23 Super	57.209	60.817	43.961	55.440	Same as new 22
24 Normal	2.104	0.428	0.592	0.820	Half of new 23
24 Moderate	3.987	1.929	2.329	2.465	Half of new 23
24 High	6.383	5.226	4.329	5.221	Half of new 23
24 Very High	13.555	15.220	12.044	14.002	Half of new 23
24 Super	28.605	30.409	21.981	27.720	Half of new 23
25 Normal	0.0	0.0	0.0	0.0	Set ZEVs to zero
25 Moderate	0.0	0.0	0.0	0.0	Set ZEVs to zero
25 High	0.0	0.0	0.0	0.0	Set ZEVs to zero
25 Very High	0.0	0.0	0.0	0.0	Set ZEVs to zero
25 Super	0.0	0.0	0.0	0.0	Set ZEVs to zero
26 Normal	6.611	1.376	2.440	2.753	New 10 times 4.4/7
26 Moderate	12.319	3.874	5.645	6.108	New 10 times 4.4/7
26 High	25.054	12.361	11.360	14.714	New 10 times 4.4/7
26 Very High	47.695	29.765	34.719	34.844	New 10 times 4.4/7
26 Super	82.617	69.988	62.142	70.449	New 10 times 4.4/7
27 Normal	5.900	1.319	1.725	2.381	New 13 times 4.4/7
27 Moderate	10.553	4.414	4.646	5.751	New 13 times 4.4/7
27 High	20.447	14.438	12.321	15.101	New 13 times 4.4/7
27 Very High	30.275	39.789	32.145	35.715	New 13 times 4.4/7
27 Super	53.478	70.499	45.595	60.117	New 13 times 4.4/7

Table 4-43 Oxides of Nitrogen Emission Rates (g/mi.)

Technology Group and Regime			Raw Averages					Final data with adjustments for missing data					
Old Tech	New Tech	Regime	Number	Bag One	Bag Two	Bag 3	Comp	Number	Bag One	Bag Two	Bag 3	Comp	Adjustment Method
	1	1 Normal	409	2.778	1.678	3.005	2.421	409	2.778	1.678	3.005	2.421	
	1	1 Moderate	157	4.457	2.741	4.876	3.857	157	4.457	2.741	4.876	3.857	
	1	1 High	46	5.537	3.913	6.359	5.079	46	5.537	3.913	6.359	5.079	
	1	1 Very High	9	5.708	4.096	6.579	4.993	9	5.708	4.096	6.579	4.993	
	1	1 Super	8	8.541	5.592	9.881	6.825	8	8.541	5.592	9.881	6.825	
	2	2 Normal	133	2.508	1.388	2.466	2.015	133	2.508	1.388	2.466	2.015	
	2	2 Moderate	62	4.134	2.502	4.491	3.455	62	4.134	2.502	4.491	3.455	
	2	2 High	29	5.064	3.215	5.087	4.266	29	5.064	3.215	5.087	4.266	
	2	2 Very High	16	5.85	3.1	6.003	4.534	16	5.850	3.100	6.003	4.534	
	2	2 Super	12	7.273	4.887	7.188	6.164	12	7.273	4.887	7.188	6.164	
	3	3 Normal	97	1.79	1.003	1.681	1.352	97	1.790	1.003	1.681	1.352	
	3	3 Moderate	65	2.628	1.593	2.611	2.085	65	2.628	1.593	2.611	2.085	
	3	3 High	51	3.739	2.407	3.903	3.091	51	3.739	2.407	3.903	3.091	
	3	3 Very High	5	5.516	4.356	6.598	5.212	5	5.516	4.356	6.598	5.212	
	3	3 Super	0						5.516	4.356	6.598	5.212	Same as Very High

4	4	Normal	305	1.955	1.131	1.83	1.49	305	1.955	1.131	1.830	1.490	
4	4	Moderate	168	3.124	1.922	2.931	2.451	168	3.124	1.922	2.931	2.451	
4	4	High	146	4.552	2.99	4.754	3.797	146	4.552	2.990	4.754	3.797	
4	4	Very High	32	6.305	4.699	6.83	5.627	32	6.305	4.699	6.830	5.627	
4	4	Super	4	7.894	6.92	10.59	8.12	4	7.894	6.920	10.590	8.120	
5	ELIMINATED	Normal	167	1.796	0.919	1.465	1.251	167	1.796	0.919	1.465	1.251	
5	ELIMINATED	Moderate	89	2.634	1.609	2.454	2.056	89	2.634	1.609	2.454	2.056	
5	ELIMINATED	High	84	3.727	2.612	3.827	3.181	84	3.727	2.612	3.827	3.181	
5	ELIMINATED	Very High	22	5.313	4.06	5.997	4.849	22	5.313	4.060	5.997	4.849	
5	ELIMINATED	Super	4	5.077	4.98	5.926	5.259	4	5.077	4.980	5.926	5.259	
5.1	5	Normal	144	1.928	0.988	1.593	1.349	144	1.928	0.988	1.593	1.349	
5.1	5	Moderate	73	2.884	1.798	2.75	2.287	73	2.884	1.798	2.750	2.287	
5.1	5	High	69	4.142	2.915	4.254	3.542	69	4.142	2.915	4.254	3.542	
5.1	5	Very High	21	5.465	4.177	6.169	4.988	21	5.465	4.177	6.169	4.988	
5.1	5	Super	2	6.706	7.199	9.637	7.763	2	6.706	7.199	9.637	7.763	
5.2	6	Normal	23	1	0.502	0.702	0.663	23	1.000	0.502	0.702	0.663	
5.2	6	Moderate	16	1.493	0.748	1.102	1	16	1.493	0.748	1.102	1.000	
5.2	6	High	15	1.818	1.22	1.861	1.52	15	1.818	1.220	1.861	1.520	
5.2	6	Very High	1	2.103	1.605	2.388	1.924	22	5.313	4.060	5.997	4.849	Old group 5
5.2	6	Super	2	3.448	2.761	2.215	2.755	4	5.077	4.980	5.926	5.259	Old group 5

6	7	Normal	734	1.484	0.791	1.2	1.048	734	1.484	0.791	1.200	1.048
6	7	Moderate	308	2.274	1.326	1.972	1.699	308	2.274	1.326	1.972	1.699
6	7	High	272	3.231	2.085	3.13	2.61	272	3.231	2.085	3.130	2.610
6	7	Very High	71	4.265	2.963	4.415	3.63	71	4.265	2.963	4.415	3.630
6	7	Super	42	4.892	4.17	5.723	4.772	42	4.892	4.170	5.723	4.772
7	8	Normal	20	1.711	0.725	1.134	1.042	20	1.711	0.725	1.134	1.042
7	8	Moderate	14	2.73	1.291	2.115	1.816	14	2.730	1.291	2.115	1.816
7	8	High	2	2.689	2.008	2.914	2.395	2	2.689	2.008	2.914	2.395
7	8	Very High	1	7.022	2.673	7.048	4.795	1	7.022	2.673	7.048	4.795
7	8	Super	0						7.022	2.673	7.048	4.795
7.1	ELIMINATED	Normal	127	1.275	0.495	0.84	0.749	127	1.275	0.495	0.840	0.749
7.1	ELIMINATED	Moderate	114	2.226	1.105	1.694	1.504	114	2.226	1.105	1.694	1.504
7.1	ELIMINATED	High	31	3.254	1.965	3.04	2.528	31	3.254	1.965	3.040	2.528
7.1	ELIMINATED	Very High	22	4.26	3.016	4.318	3.633	22	4.260	3.016	4.318	3.633
7.1	ELIMINATED	Super	7	5.692	4.58	5.993	5.197	7	5.692	4.580	5.993	5.197
8.91	9	Normal	376	0.857	0.334	0.483	0.483	376	0.857	0.334	0.483	0.483
8.91	9	Moderate	425	1.496	0.724	1.014	0.964	425	1.496	0.724	1.014	0.964
8.91	9	High	128	2.283	1.404	1.832	1.704	128	2.283	1.404	1.832	1.704
8.91	9	Very High	77	3.325	2.194	2.757	2.583	77	3.325	2.194	2.757	2.583
8.91	9	Super	42	5.375	3.882	4.853	4.458	42	5.375	3.882	4.853	4.458

8.92	10 Normal	206	0.814	0.325	0.47	0.466	206	0.814	0.325	0.470	0.466
8.92	10 Moderate	143	1.37	0.732	0.976	0.931	143	1.370	0.732	0.976	0.931
8.92	10 High	30	2.051	1.464	1.745	1.662	30	2.051	1.464	1.745	1.662
8.92	10 Very High	15	2.98	2.297	2.821	2.583	15	2.980	2.297	2.821	2.583
8.92	10 Super	7	4.075	4.076	4.662	4.237	7	4.075	4.076	4.662	4.237
10	11 Normal	34	1.344	0.428	0.929	0.755	34	1.344	0.428	0.929	0.755
10	11 Moderate	36	2.337	1.14	1.881	1.597	36	2.337	1.140	1.881	1.597
10	11 High	11	3.654	2.192	3.48	2.85	11	3.654	2.192	3.480	2.850
10	11 Very High	7	4.637	2.905	4.386	3.671	7	4.637	2.905	4.386	3.671
10	11 Super	2	5.815	3.74	5.584	4.677	2	5.815	3.740	5.584	4.677
11.1	12 Normal	59	0.895	0.294	0.556	0.491	59	0.895	0.294	0.556	0.491
11.1	12 Moderate	134	1.595	0.776	1.114	1.039	134	1.595	0.776	1.114	1.039
11.1	12 High	62	2.39	1.367	1.886	1.721	62	2.390	1.367	1.886	1.721
11.1	12 Very High	21	3.307	2.028	2.746	2.49	21	3.307	2.028	2.746	2.490
11.1	12 Super	8	4.515	4.122	4.58	4.329	8	4.515	4.122	4.580	4.329
11.2	13 Normal	184	0.926	0.254	0.421	0.438	184	0.926	0.254	0.421	0.438
11.2	13 Moderate	113	1.513	0.748	1.021	0.982	113	1.513	0.748	1.021	0.982
11.2	13 High	20	2.329	1.368	1.828	1.694	20	2.329	1.368	1.828	1.694
11.2	13 Very High	8	3.038	1.968	2.527	2.343	8	3.038	1.968	2.527	2.343
11.2	13 Super	2	5.804	4.987	6.382	5.54	2	5.804	4.987	6.382	5.540

12	14 Normal	11	0.646	0.181	0.252	0.297	11	0.646	0.181	0.252	0.297	
12	14 Moderate	17	0.995	0.369	0.5	0.535	17	0.995	0.369	0.500	0.535	
12	14 High	8	1.246	0.752	0.983	0.919	8	1.246	0.752	0.983	0.919	
12	14 Very High	6	2.202	1.075	1.548	1.439	6	2.202	1.075	1.548	1.439	
12	14 Super	5	2.84	2.124	2.575	2.395	5	2.840	2.124	2.575	2.395	
13	15 Normal	72	0.641	0.123	0.219	0.257	72	0.641	0.123	0.219	0.257	
13	15 Moderate	34	1.116	0.341	0.613	0.577	34	1.116	0.341	0.613	0.577	
13	15 High	9	1.481	0.727	1.125	0.993	9	1.481	0.727	1.125	0.993	
13	15 Very High	7	2.338	1.208	1.768	1.597	7	2.338	1.208	1.768	1.597	
13	15 Super	7	3.318	2.195	3.173	2.697	7	3.318	2.195	3.173	2.697	
14	16 Normal	73	1.116	0.462	0.715	0.663	73	1.116	0.462	0.715	0.663	
14	16 Moderate	64	2.061	1.047	1.503	1.383	64	2.061	1.047	1.503	1.383	
14	16 High	18	3.073	1.822	2.786	2.346	18	3.073	1.822	2.786	2.346	
14	16 Very High	14	3.874	3.096	4.089	3.53	14	3.874	3.096	4.089	3.530	
14	16 Super	5	5.643	4.916	6.156	5.406	5	5.643	4.916	6.156	5.406	
15	17 Normal							0.646	0.181	0.252	0.297	Same as new 14
15	17 Moderate							0.995	0.369	0.500	0.535	Same as new 14
15	17 High							1.246	0.752	0.983	0.919	Same as new 14
15	17 Very High							2.202	1.075	1.548	1.439	Same as new 14
15	17 Super							2.840	2.124	2.575	2.395	Same as new 14
16	18 Normal							0.641	0.123	0.219	0.257	Same as new 15
16	18 Moderate							1.116	0.341	0.613	0.577	Same as new 15
16	18 High							1.481	0.727	1.125	0.993	Same as new 15
16	18 Very High							2.338	1.208	1.768	1.597	Same as new 15
16	18 Super							3.318	2.195	3.173	2.697	Same as new 15

19 Normal	0.646	0.181	0.252	0.297	Same as new 17
19 Moderate	0.995	0.369	0.500	0.535	Same as new 17
19 High	1.246	0.752	0.983	0.919	Same as new 17
19 Very High	2.202	1.075	1.548	1.439	Same as new 17
19 Super	2.840	2.124	2.575	2.395	Same as new 17
20 Normal	0.641	0.123	0.219	0.257	Same as new 18
20 Moderate	1.116	0.341	0.613	0.577	Same as new 18
20 High	1.481	0.727	1.125	0.993	Same as new 18
20 Very High	2.338	1.208	1.768	1.597	Same as new 18
20 Super	3.318	2.195	3.173	2.697	Same as new 18
21 Normal	0.641	0.123	0.219	0.257	Same as new 20
21 Moderate	1.116	0.341	0.613	0.577	Same as new 20
21 High	1.481	0.727	1.125	0.993	Same as new 20
21 Very High	2.338	1.208	1.768	1.597	Same as new 20
21 Super	3.318	2.195	3.173	2.697	Same as new 20
22 Normal	0.641	0.123	0.219	0.257	Same as new 21
22 Moderate	1.116	0.341	0.613	0.577	Same as new 21
22 High	1.481	0.727	1.125	0.993	Same as new 21
22 Very High	2.338	1.208	1.768	1.597	Same as new 21
22 Super	3.318	2.195	3.173	2.697	Same as new 21
23 Normal	0.321	0.062	0.110	0.129	Half of new 22
23 Moderate	0.558	0.171	0.307	0.289	Half of new 22
23 High	0.741	0.364	0.563	0.497	Half of new 22
23 Very High	1.169	0.604	0.884	0.799	Half of new 22
23 Super	1.659	1.098	1.587	1.349	Half of new 22
24 Normal	0.321	0.062	0.110	0.129	Same as new 23
24 Moderate	0.558	0.171	0.307	0.289	Same as new 23
24 High	0.741	0.364	0.563	0.497	Same as new 23
24 Very High	1.169	0.604	0.884	0.799	Same as new 23
24 Super	1.659	1.098	1.587	1.349	Same as new 23
25 Normal	0.0	0.0	0.0	0.0	Set ZEVs to zero
25 Moderate	0.0	0.0	0.0	0.0	Set ZEVs to zero
25 High	0.0	0.0	0.0	0.0	Set ZEVs to zero
25 Very High	0.0	0.0	0.0	0.0	Set ZEVs to zero
25 Super	0.0	0.0	0.0	0.0	Set ZEVs to zero
26 Normal	0.814	0.325	0.470	0.466	Same as new 10
26 Moderate	1.370	0.732	0.976	0.931	Same as new 10
26 High	2.051	1.464	1.745	1.662	Same as new 10
26 Very High	2.980	2.297	2.821	2.583	Same as new 10
26 Super	4.075	4.076	4.662	4.237	Same as new 10

27 Normal	0.926	0.254	0.421	0.438	Same as new 13
27 Moderate	1.513	0.748	1.021	0.982	Same as new 13
27 High	2.329	1.368	1.828	1.694	Same as new 13
27 Very High	3.038	1.968	2.527	2.343	Same as new 13
27 Super	5.804	4.987	6.382	5.540	Same as new 13

4.7 U.C. Based Emission Rates

The basic without I&M rates are based on the FTP driving cycle. In MVEI7G, to better represent more contemporary driving, these rates FTP based rates were multiplied by cycle-correction factors and corrected using speed correction factors. However, since then more data had been collected from vehicles that were tested on both the FTP and the UC test. Ideally one could develop regression relationship describing the variation in the UC based emissions from the FTP tests. This relationship could then be used in converting the basic FTP rates to a UC basis.

CARB's database on vehicles tested over both the UC and FTP tests exceeds 1300. This data was analyzed to develop the following relationship.

$UC = e^{b} * (FTP)^{m}$ [4-7]

Where b and m are the regression coefficients.

Table 4-44 and 4-45 shows these coefficients for Bag 1 and 2, respectively.

Table 4-44 Regression Coefficients for Bag 1

Tech. & MY		HC			CO			NOx		
Groups	**n**	**m**	**b**	**R^2**	**m**	**b**	**R^2**	**m**	**b**	**R^2**
Fuel Injected										
81 to 85	73	0.74	1.08	0.68	0.70	1.69	0.63	0.70	0.66	0.73
86 to 92	368	0.86	1.01	0.60	0.74	1.60	0.56	0.76	0.79	0.65
GE to 93	128	0.90	1.04	0.76	0.85	1.36	0.67	0.97	0.89	0.67
LE to 80	31	0.90	1.04	0.84	0.84	1.46	0.82	0.56	0.67	0.41
Throttle Body										
81 to 84	37	0.80	1.04	0.85	0.82	1.53	0.84	0.80	0.52	0.79
GE to 85	155	0.69	1.06	0.61	0.64	1.95	0.62	0.78	0.64	0.73
Carburetor										
75 to 80	185	0.84	1.14	0.70	0.82	1.48	0.80	0.86	0.37	0.76
81 to 85	175	0.84	1.00	0.78	0.80	1.41	0.75	0.80	0.50	0.70
GE to 86	101	0.74	1.08	0.74	0.77	1.56	0.73	0.69	0.58	0.60
Non-Cat										
LE to 79	95	0.72	1.30	0.64	0.78	1.66	0.81	0.86	0.23	0.78

Table 4-45 Regression Coefficients for Bag 2

Tech. & MY Groups	**n**	**HC**			**CO**			**NOx**		
		m	**b**	**R^2**	**m**	**b**	**R^2**	**m**	**b**	**R^2**
Fuel Injected										
81 to 85	73	0.74	-0.24	0.84	0.59	1.12	0.63	0.76	0.46	0.74
86 to 92	368	0.62	-0.44	0.63	0.54	0.99	0.38	0.69	0.25	0.64
GE to 93	128	0.52	-1.17	0.44	0.60	0.57	0.37	0.56	-0.30	0.42
LE to 80	31	0.77	-0.10	0.77	0.65	0.87	0.61	0.64	0.81	0.59
Throttle Body										
81 to 84	37	0.71	-0.10	0.81	0.44	1.96	0.49	0.63	0.45	0.80
GE to 85	155	0.67	0.24	0.72	0.43	1.43	0.37	0.64	0.34	0.76
Carburetor										
75 to 80	185	0.74	0.11	0.75	0.54	1.82	0.61	0.92	0.47	0.65
81 to 85	175	0.74	0.08	0.78	0.48	1.87	0.53	0.74	0.37	0.58
GE to 86	101	0.72	0.11	0.81	0.49	1.79	0.55	0.67	0.29	0.70
Non-Cat										
LE to 79	95	0.59	0.48	0.59	0.59	1.62	0.58	0.81	0.73	0.58

Section 4.13 FACTORS FOR CONVERTING THC EMISSION RATES TOG/ROG

This section describes the factors used in determining the fraction of total hydrocarbons (THC) that are comprised of total organic gases (TOG), reactive organic gases (ROG) and methane (CH4). These factors are based on a memorandum entitled "Organic Gas Speciation Profiles" from Don McNerny, Chief of the Modeling and Meteorology Branch to Mark Carlock, Chief of the Motor Vehicle Analysis Branch.

4.13.1 Introduction

During exhaust or evaporative emissions testing conducted during the Federal Test Procedure (FTP), the hydrocarbon emissions are measured using a flame ionization detector (FID). The FID measures total hydrocarbons or compounds with hydrogen and carbon atoms only; carbonyls are not included in THC. This is reflected in the exhaust and evaporative emission rates, which are measurements of THC. TOG includes all organic gases emitted to the atmosphere. ROG is the fraction of TOG that is reactive and does not include compounds that are exempt from regulations, i.e., methane, ethane, and acetone. The fraction of TOG that is either THC or ROG is determined by examination of the speciation profiles.

4.13.2 Methodology

In EMFAC2000, there are 13 vehicle classes (Table 4.13-1) with each vehicle class having up to six emission processes: starting, running exhaust, hot soak, diurnal, resting loss and running loss emissions. Ideally, given sufficient speciation data, one could derive conversion factors that are vehicle class, emissions process and fuel (pre and post cleaner burning gas or clean diesel) dependent. However, because of insufficient data the conversion factors (Table 4.13-2) cover several vehicle classes and technology groups. For example, the THC to TOG equation for running exhaust emissions is assumed to be the same for both catalyst and non-catalyst equipped vehicles, and across all vehicle classes. This assumption results from the fact that speciation tests have not been performed on non-catalyst equipped vehicles, other than passenger cars or light-duty trucks. EMFAC2000, however, should be coded to allow for future changes in the conversion factors that may be specific to the vehicle class, emissions regime, emission process and fuel type. Further, the conversion factors should be coded at the regime level. In the future the model may be required to output of TOG/ROG/CH4 emissions as a function of the emissions regime.

Additionally, the conversion factors shown in Table 4.13-2 are valid to 0.1[*] g/mi. THC. Below this value, the conversion factors can be unstable. The model is coded to generate the same conversion factors assuming 0.1 g/mi. for THC for emission rates below this level.

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[*] This value was chosen after consulting with Paul Allen of the Planning and Technical Support Division

Table 4.13-1 Vehicle Classes in EMFAC2000

Vehicle Class	Fuel	Code	Description	Weight Class
1	ALL	PC	PASSENGER CARS	ALL
2	ALL	T1	LIGHT-DUTY TRUCKS	0- 3750
3	ALL	T2	LIGHT-DUTY TRUCKS	3751- 5750
4	ALL	T3	MEDIUM-DUTY TRUCKS	5751- 8500
5	ALL	T4	LIGHT-HEAVY DUTY TRUCKS	8501-10000
6	ALL	T5	LIGHT-HEAVY DUTY TRUCKS	10001-14000
7	ALL	T6	MEDIUM-HEAVY DUTY TRUCKS	14001-33000
8	ALL	T7	HEAVY-HEAVY DUTY TRUCKS	33001-60000
9	ALL	T8	LINE-HAUL VEHICLES	60001+
10	DSL	UB	URBAN BUSES	ALL
11	ALL	MC	MOTORCYCLES	ALL
12	ALL	SB	SCHOOL BUSES	ALL
13	ALL	MH	MOTOR HOMES	ALL

Table 4.13-2 TOG/ROG/CH4 Conversion Factors

Vehicle Class	Fuel Code	Fuel Type	Technology Group	Emissions Process	Equation
1,2,3,4,5,6,7,8, 9,11,12,13	Gasoline	Pre-Cleaner Burning Gas	Catalyst	Running Exhaust	$TOG = 0.00721572 + 1.04581*THC + 0.000596997/(THC) - 0.000107319/(THC^2)$ $ROG = TOG\{0.915753 - 0.0570135/(THC) - 0.00469847/(THC^2) + 0.0008465052/(THC^3)\}$ $CH4 = TOG\{0.0627696 + 0.0584035/(THC) + 0.00476385/(THC^2) - 0.000860145/(THC^3)\}$
“ “	“ “	“ “	“ “	Starting	TOG = 1.0324 * THC ROG = 0.9230 * TOG = 0.95291 * THC CH4 = 0.0624 * TOG = 0.06442 * THC
“ “	“ “	“ “	“ “	Hot Soak	TOG = 1.0026 * THC ROG = 1.0000 * TOG = 1.0026 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
“ “	“ “	“ “	“ “	Running Loss	TOG = 1.0026 * THC ROG = 1.0000 * TOG = 1.0026 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
“ “	“ “	“ “	“ “	Diurnal	TOG = 1.0380 * THC ROG = 1.0000 * TOG = 1.0380 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
“ “	“ “	“ “	“ “	Resting Loss	TOG = 1.0380 * THC ROG = 1.0000 * TOG = 1.0380 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
1,2,3,4,5,6,7,8, 9,11,12,13	Gasoline	Pre-Cleaner Burning Gas	Non - Catalyst	Running Exhaust	$TOG = 0.00721572 + 1.04581*THC + 0.000596997/(THC) - 0.000107319/(THC^2)$ $ROG = TOG\{0.915753 - 0.0570135/(THC) - 0.00469847/(THC^2) + 0.0008465052/(THC^3)\}$ $CH4 = TOG\{0.0627696 + 0.0584035/(THC) + 0.00476385/(THC^2) - 0.000860145/(THC^3)\}$
“ “	“ “	“ “	“ “	Starting	TOG = 1.0361 * THC ROG = 0.8957 * TOG = 0.92803 * THC CH4 = 0.0935 * TOG = 0.09687 * THC
“ “	“ “	“ “	“ “	Hot Soak	TOG = 1.0026 * THC ROG = 1.0000 * TOG = 1.0026 * THC

					CH4 = 0.0000 * TOG = 0.0000 * THC
“ “	“ “	“ “	“ “	Running Loss	TOG = 1.0026 * THC ROG = 1.0000 * TOG = 1.0026 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
“ “	“ “	“ “	“ “	Diurnal	TOG = 1.0380 * THC ROG = 1.0000 * TOG = 1.0380 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
“ “	“ “	“ “	“ “	Resting Loss	TOG = 1.0380 * THC ROG = 1.0000 * TOG = 1.0380 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
1,2,3,4,5,6,7,8, 9,11,12,13	Gasoline	Cleaner Burning Gas	Catalyst	Running Exhaust	TOG = 0.0115168 + 1.05894*THC - 0.00129204/(THC) + 5.66768E-05/(THC^{2}) ROG = TOG{0.95015 – 0.105111/(THC) + 0.012543/(THC^{2}) - 0.000616031/(THC^{3})} CH4 = TOG{0.0356821 + 0.106396/(THC) - 0.0125986/(THC^{2}) – 0.000613197/(THC^{3})}
“ “	“ “	“ “	“ “	Starting	TOG = 1.0641 * THC ROG = 0.9366 * TOG = 0.99664 * THC CH4 = 0.0528 * TOG = 0.05618 * THC
“ “	“ “	“ “	“ “	Hot Soak	TOG = 1.0644 * THC ROG = 1.0000 * TOG = 1.0644 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
“ “	“ “	“ “	“ “	Running Loss	TOG = 1.0644 * THC ROG = 1.0000 * TOG = 1.0644 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
“ “	“ “	“ “	“ “	Diurnal	TOG = 1.1248 * THC ROG = 1.0000 * TOG = 1.1248 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
“ “	“ “	“ “	“ “	Resting Loss	TOG = 1.1248 * THC ROG = 1.0000 * TOG = 1.1248 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
1,2,3,4,5,6,7,8, 9,11,12,13	Gasoline	Cleaner Burning Gas	Non - Catalyst	Running Exhaust	TOG = 0.0115168 + 1.05894*THC - 0.00129204/(THC) + 5.66768E-05/(THC^{2}) ROG = TOG{0.95015 – 0.105111/(THC) + 0.012543/(THC^{2}) - 0.000616031/(THC^{3})}

					CH4 = TOG{0.0356821 + 0.106396/(THC) - 0.0125986/(THC^{2}) – 0.000613197/(THC^{3})}
“ “	“ “	“ “	“ “	Starting	TOG = 1.0657 * THC ROG = 0.9248 * TOG = 0.98556 * THC CH4 = 0.0649 * TOG = 0.06916 * THC
“ “	“ “	“ “	“ “	Hot Soak	TOG = 1.0644 * THC ROG = 1.0000 * TOG = 1.0644 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
“ “	“ “	“ “	“ “	Running Loss	TOG = 1.0644 * THC ROG = 1.0000 * TOG = 1.0644 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
“ “	“ “	“ “	“ “	Diurnal	TOG = 1.1248 * THC ROG = 1.0000 * TOG = 1.1248 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
“ “	“ “	“ “	“ “	Resting Loss	TOG = 1.1248 * THC ROG = 1.0000 * TOG = 1.1248 * THC CH4 = 0.0000 * TOG = 0.0000 * THC
1,2,3,4,5,6,7,8,9,10,11,12,13	Diesel	Pre – Clean Diesel	All	Running Exhaust	TOG = 1.4417 * THC ROG = 0.8784 * TOG = 1.26639 * THC CH4 = 0.0408 * TOG = 0.058821 * THC
“ “	“ “	Clean Diesel	“ “	“ “	TOG = 1.4417 * THC ROG = 0.8784 * TOG = 1.26639 * THC CH4 = 0.0408 * TOG = 0.058821 * THC

SECTION 10.0 HEAVY-DUTY TRUCKS EMISSION FACTORS DEVELOPMENT

10.1 Heavy-Duty Diesel Trucks (HDDT) Emission Factors

Introduction

This section outlines the development of chassis dynamometer test based emission factors for heavy-duty diesel trucks (HDDT). In the MVEI7G model, heavy-duty truck emissions were based on testing various engines on an engine dynamometer rather than testing the entire vehicle on a chassis dynamometer. Basic emission rates were derived from emissions test data collected during HDDT engine certification using the USEPA’s heavy-duty engine transient cycle. Emissions from engine testing are expressed as grams per brake horsepower-hour, and must be converted to grams per mile units for use in the emissions inventory models.

The conversion factors used were a function of the fuel density, the brake-specific-fuel consumption (BSFC) of the engine and the fuel economy (miles per gallon) of the vehicle. Because of the wide variation in fuel economy, gross vehicle weight, horsepower ratings, and transmission types, the gram per mile emissions derived from engine dynamometer test data using conversion factors may not be representative of the actual emissions of HDDTs. Further, engine testing is a cost prohibitive method of measuring in-use emissions from vehicles. Unlike light-duty surveillance testing, the testing of HDDTs requires taking a revenue generating truck out of service, pulling the engine, testing and reinstalling it. Emissions estimates based on chassis dynamometer test data are more representative, there is no need for conversion factors and vehicles can be readily tested on the dynamometer. Modeling HDDT emissions based on chassis tests instead of engine tests represents a significant change in EMFAC2000. Therefore, staff organized and consulted several times with members of the “Heavy-Duty Vehicle Emissions Modeling”, (HDVEM) advisory committee. Members of this committee represented various HDDT engine manufacturers and its association, university professors with expertise in HDDT chassis testing and emissions modeling, the California Trucking Association and consultants involved either in HDDT chassis testing or emissions modeling.

In EMFAC2000, diesel-powered truckss with a gross vehicle weight of 8,501 pounds or greater are classified in the following manner:

Table 10.1-1 Heavy-Duty Trucks Weight Class

GVW in lbs	Vehicle Class
8,501 to 14,000	Light-Heavy Duty Trucks (LHDT)
14,001 to 33,000	Medium-Heavy Duty Trucks (MHDT)
> 33,000	Hevay-Heavy Duty Trucks (HHDT)

Since 1995, emissions standards for LHDTs have been aligned with medium-duty trucks. Therefore in EMFAC2000, LHDTs are included with medium-duty trucks which are defined as trucks with gross vehicle weight between 8,500 and 14,000 pounds.

10.2 Data Sources

For heavy-heavy and medium-heavy trucks, data from three sources were used to derive the chassis dynamometer based emission rates in EMFAC2000. The first data set, made available by U.S. EPA, was obtained from the New York State Department of Environmental Conservation and Energy (NYSDEC). Under sub-contract to Energy and Environmental Analysis, Inc. (EEA), U.S. EPA and NYSDEC, the West Virginia University (WVU) Department of Mechanical and Aerospace Engineering conducted chassis dynamometer based emissions tests on 35 heavy-heavy and medium-heavy diesel trucks on various chassis test cycles. With the agreement of HDVEM advisory committee, the ARB used emissions test results performed over the EPA Urban Dynamometer Driving Schedule for Heavy-Duty Vehicles (referred to as UDDS or Test-D). The UDDS test cycle (shown in Figure 10.2-A1 of the Appendix) is a chassis dynamometer based test cycle derived from in-use vehicle activity data - the same data used to develop the current heavy-duty engine certification test procedure presented in the Code of Federal Regulations, Title 40, Part 86, Subpart N. It was developed to represent heavy-duty driving in all U.S. Urban areas (40 CFR Part 86 Subpart M). In this study, repeat tests were performed using the UDDS cycle. A substantial decrease in PM emissions was observed between some first and subsequent repeat tests. Staff consulted with WVU personnel who suggested that the differences were due to the fact that sometimes the PM sampling filters were not replaced before the first test. Although WVU personnel agreed to check the database for this discrepancy staff has not received the revised data. In the absence of any other information, staff removed from the analysis, entire emissions test results (HC, CO, NOx, PM and CO2) of the first test where the difference between the first and second test for PM emissions was greater than 35%.

The second data set was obtained from a report entitled “Heavy-Duty Diesel Vehicle Testing for the Northern Front Range Air Quality Study (NFRAQS)” prepared by the Colorado Institute for Fuels and High Altitude Engine Research (CIFER) at the Colorado School of Mines (CSM). CIFER conducted the study by testing 21 trucks and buses on various test procedures under hot and cold start conditions. Test data from a total of 11 heavy-heavy and medium-heavy diesel trucks tested on the UDDS cycle under hot start conditions were obtained from the database. The tests were conducted at high altitude, therefore, altitude correction factors were applied before emissions test results were merged with other data for this analysis. The altitude correction factors were taken from EPA’s report entitled “Update of Heavy-Duty Emission Levels (Model Years 1988-2004+) for Use in MOBILE6”, page 23. Table 10.2-1 shows the altitude correction used from the EPA document.

The third data set was obtained from WVU and included tests performed on 4 heavy-heavy diesel trucks on the UDDS cycle. Table 10.2-A1 to A3 in the appendix show the raw data used to derive the emission rates for heavy-heavy and medium-heavy duty trucks.

Table 10.2-1 Heavy-duty Diesel Vehicle High Altitude Adjustment Factors for HC, CO, NOx, and PM

HC	CO	NOX	PM
2.05	2.46	1.02	1.47

Two data sources were used to derive the emissions rates for light-heavy diesel trucks. The first data set was obtained from the U.S. EPA. The tests were conducted by College of Engineering, Center for Environmental Research and Technology (CE-CERT) in Riverside under contract to the U.S. EPA with the objective to investigate the effect of payload on exhaust emissions. It included bag specific results from 5 trucks tested over the Federal Test Procedure (shown in Figure 10.2-A2 of the Appendix) and three different payloads. Staff used data obtained from testing the trucks at the equivalent test weight (ETW). The ETW is the test weight equal to the empty weight of the vehicle plus 40% fuel fill in the tank. Vehicles in this data set were tested with California reformulated diesel fuel in the tank at the time the vehicle was received. The second data set was obtained from a repot entitled “Characterizing Particulate Emissions from Medium- and Light-Heavy Duty Diesel Fueled Vehicles” prepared by CE-CERT for the South Coast Air Quality Management District (SCAQMD). This data set included bag specific FTP test results from 15 trucks tested at the equivalent test weight. Vehicles in this data set were tested with the Federal certification diesel fuel, Type 2-D. Fuel correction factors from Table 10.9-2 were applied to the first data set before they were merged with the second data set.

Table 10.2-A4 in the appendix shows the raw data used to derive emission rates for light-heavy diesel trucks. Table 10.2-A5 in the appendix shows the federal and California standards for heavy-duty trucks. Table 10.1-2 shows the number of trucks from each data set by model year

10.3 Heavy-Heavy Diesel Trucks Emission Rates

The emissions data used in this analysis represented diesel powered heavy-heavy diesel trucks built between 1981 and 1998. In developing the emission factors for EMFAC2000, replicate tests were first averaged for each vehicle. A scatter plot of the resulting emissions as a function of model year, shown in Figures 10.3-1a to 10.3-1d, were then plotted for each pollutant and curve fit to determine the best equation.

Table 10.1-2 Number of Trucks by Weight Class and Model Year

Model Year	HHDT			**Total HHDT**	MHDT		**Total MHDT**	LHDT		**Total LHDT**
	NYSDEC	CIFER	WVU		NYSDEC	CIFER		SCAQMD-CE-CERT	EPA-CE-CERT	
1966	1	---	---	**1**	---	---	**---**	---	---	**---**
1981	---	1	---	**1**	---	---	**---**	---	---	**---**
1982	---	---	1	**1**	---	---	**---**	1	---	**1**
1983	---	1	---	**1**	---	---	**---**	---	---	**---**
1984	1	---	---	**1**	---	---	**---**	1	---	**1**
1985	1	---	1	**2**	1	---	**1**	2	---	**2**
1986	---	---	---	**---**	---	---	**---**	1	---	**1**
1987	---	---	---	**---**	1	1	**2**	2	---	**2**
1988	2	---	---	**2**	1	---	**1**	---	1	**1**
1989	1	---	---	**1**	1	2	**3**	1	---	**1**
1990	---	1	---	**1**	2	1	**3**	---	---	**---**
1991	1	---	---	**1**	---	---	**---**	---	1	**1**
1992	---	---	---	**---**	2	---	**2**	1	---	**1**
1993	1	1	---	**2**	2	2	**4**	---	1	**1**
1994	1	---	---	**1**	2	---	**2**	3	1	**4**
1995	---	1	1	**2**	2	---	**2**	1	1	**2**
1996	1	---	---	**1**	4	---	**4**	2	---	**2**
1997	1	---	---	**1**	1	---	**1**	---	---	**---**
1998	3	---	1	**4**	1	---	**1**	---	---	**---**
1999	---	---	---	**---**	1	---	**1**	---	---	**---**
Total	14	5	4	**23**	21	6	**27**	15	5	**20**

Regression equations were used to calculate the average emission rates for model years that were within the data points, i.e. model years 1981 to 1998. Model years prior to 1981 were assumed to have the same average emission rate as the 1981 model year. For model years 1999 and later, an average emission rate was calculated by multiplying the average emission rate of the 1991-93 model year group by the ratio of the standards of the 1999+ model year to the 1991-93 model year groups. The 1991-93 model year group was considered as a basis for calculating the 1999+ model year average emissions because this group had the lowest NOx emissions and therefore was considered to be free of off-cycle NOx. For CO2 emissions an average of all model year emissions was calculated and applied to all model year groups. The resulting average emission rates by technology groups are shown in Table 10.3-1.

The scatter plot for NOx emissions, Figure 10.3-1, shows an increase in emissions between model years 1993 and 1998 although the NOx standard decreases from 5 g/bhp-hr in 1993 to 4 g/bhp-hr in 1998. A possible explanation is “off-cycle NOx”. Off-cycle NOx emissions are excess emissions produced by heavy-duty diesel engines as a result of defeat devices programmed to default to a fuel economy mode during periods of sustained cruise. This mode of operation is outside of the limits of the engine certification test and therefore, the excess emissions are not captured during certification testing. The majority of heavy-duty diesel engines produced between 1988 to 1998 display off-cycle NOx emissions. In EMFAC2000, it is assumed that off-cycle NOx would be eliminated by the 1999 model year. As a part of the settlement, an agreement (Consent Decree) was reached between the EPA and heavy-duty diesel engine manufactures involved with defeat devices to meet a 2 g/bhp-hr NOx emissions standard originally scheduled for 2004, in October of 2002. Based on projected engine production estimates submitted by engine manufacturers during certification, for calendar year 1998, the market share of heavy-heavy diesel engines manufactures involved in the consent decree was 99.9% of the total market of heavy-heavy diesel engines. Therefore, in EMFAC2000, it is assumed that 99.9% of the 2003 model year heavy-duty engines will be subject to the 2 g/bhp-hr NOx emissions standard and the remaining 0.1% will meet a 4 g/bhp-hr. In 2004, 100% of the heavy-duty engines will meet the 2 g/bhp-hr NOx emissions standard.

For CO2 emissions, the scatter plot of the data points did not produce a well correlated regression equation. Therefore, an average of all model year emissions was calculated and applied for all model years.

10.4 Medium-Heavy Diesel Truck Emission Rates

The same procedure used for heavy-heavy duty trucks was followed in calculating the average emission rates of medium-heavy diesel trucks. First, averages of replicate tests were calculated for each truck and the resulting emissions were then plotted as a function of the model years (Figures 10.4-1a to 10.4-1d). For each pollutant, a regression equation was obtained by passing a best fit curve through the data points. Using the equations, average emission rates were calculated for each model year within the data points (1985 to 1999). Model years prior to 1985 were assumed to have the same average emission rates as the 1985 model year. For model years 2000 and later, average emission rates were calculated by taking the ratio of standards with respect to the 1998-99 model year and multiplying by the 1998-99 model year group average emission rate.

Based on projected engine production estimates submitted by engine manufacturers during certification, for calendar year 1998, the market share of medium-heavy diesel engines manufactures involved in the consent decree was 94.1% of the total market of medium-heavy diesel engines. Therefore, in EMFAC2000, it is assumed that 94.1% of the 2003 model year medium-heavy diesel engines will be subject to the 2 g/bhp-hr NOx emissions standard and the remaining 5.9% will meet a 4 g/bhp-hr standard. In 2004, 100% of the heavy-duty engines will meet the 2 g/bhp-hr NOx emissions standard. Tables 10.4-1 show the average emission rates for each technology group of medium-heavy diesel trucks.

CO2 emissions were calculated in a similar way as in heavy-heavy duty engines.

10.5 Light-Heavy Diesel Truck Emission Rates

A scatter plot of the emissions results by model year for each pollutant showed two distinct groups of data points. The first group, corresponding to model years prior to 1990, had lower NOx and higher PM emissions while the second group, corresponding to model years 1991 and later had higher NOx and lower PM emissions. This change in emissions is the transition from indirect to direct injection technology. For each pollutant, two average emission rates were calculated, one for model years before 1990 and a second for model years after 1990. These averages were applied for model years that are within the data set, i.e. 1982 to 1996. Model years prior to 1982 were assumed to have the same average emission rate as the 1982 model year. For model years after 1996, the average emission rates were calculated using the ratio of standards and the average emission rate of the 1991-93 model year group. Table 10.5-1 and Table 10.5-2 show the average emission rates and figure 10.5-1a to 10.5-1h show a plot of the average emission rates.

10.6 Federal Heavy-Heavy Diesel Truck Emission Rates

The same procedure used for California certified heavy-heavy diesel trucks was followed to calculate the average emission rates for federally certified heavy-heavy diesel trucks. Except for the difference in the technology groups, the two methods are identical. The calculated average emission rates are shown in Table 10.6-1.

Figure 10.3-1a HHDT NOx Emissions

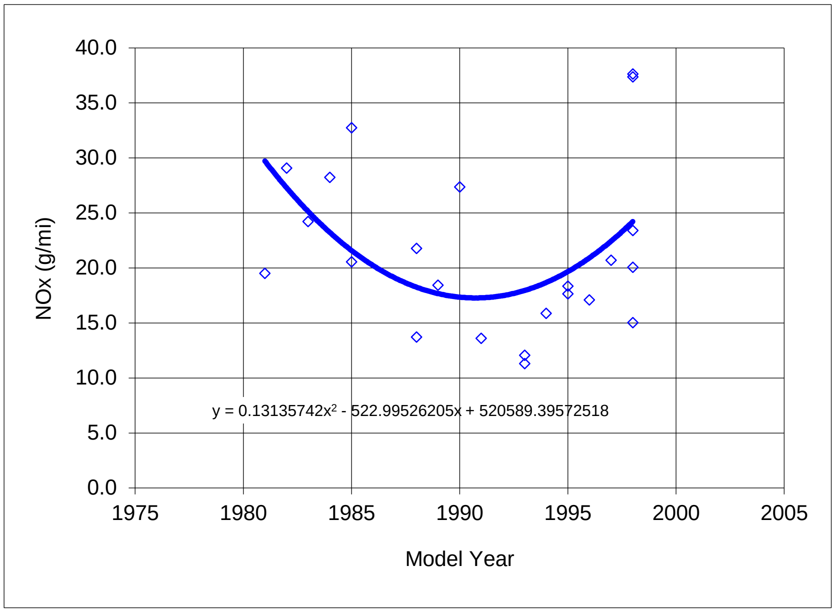


Figure 10.3-1b HHDT PM Emissions

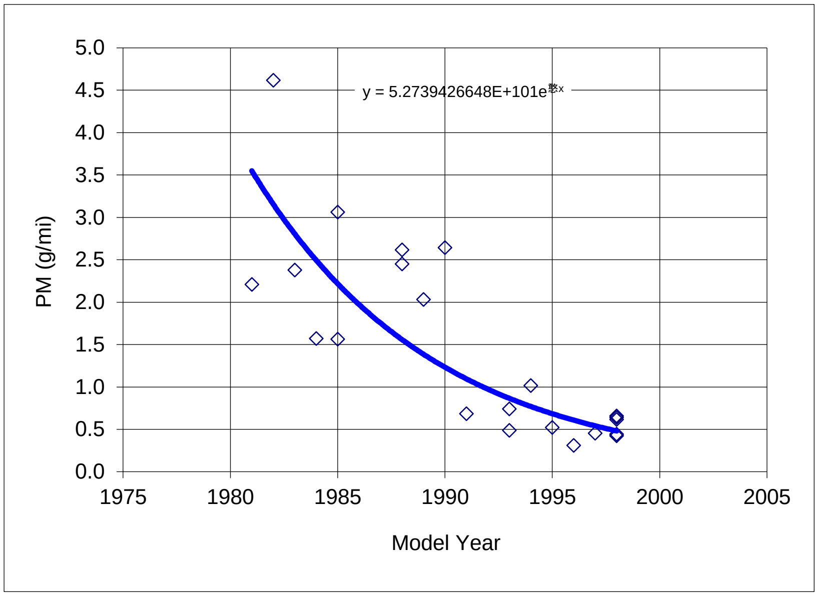


Figure 10.3-1c HHDT HC Emissions

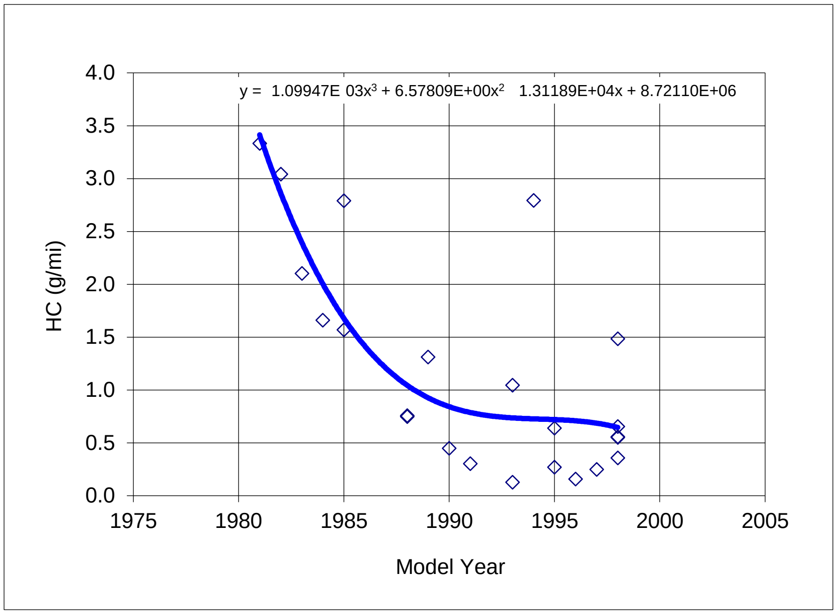


Figure 10.3-1d HHDT CO Emissions

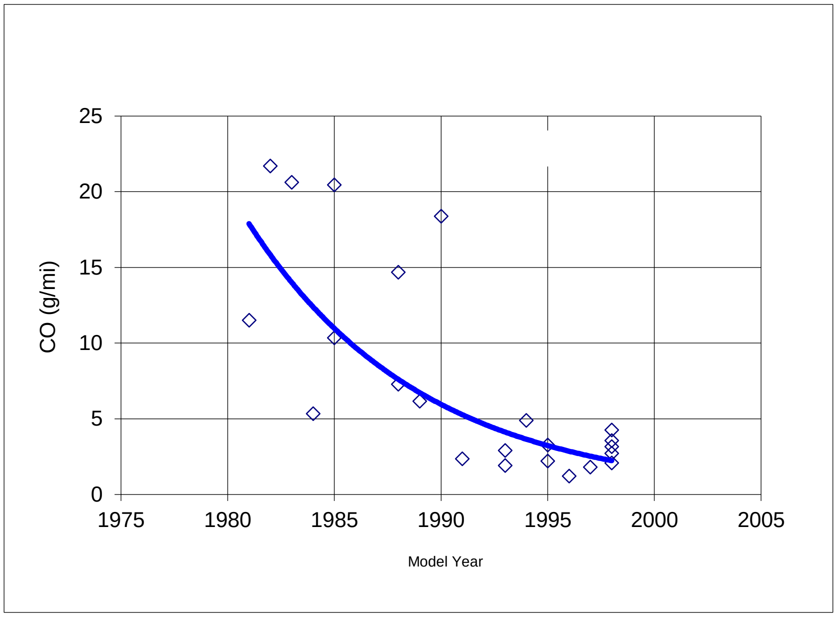


Table 10.3-1 Heavy-Heavy Diesel - Average Emission Rates (g/mi)

California – Heavy-Heavy Diesel Trucks					
MY Group	HC	CO	NOX	PM	CO_2
Pre 1975	3.41	17.89	29.72	3.55	2179
1975-76	3.10	16.70	28.32	3.32	2179
1977-79	3.10	16.70	28.32	3.32	2179
1980-83	3.10	16.70	28.32	3.32	2179
1984-86	1.57	10.42	21.04	2.11	2179
1987-90	0.94	6.76	17.76	1.39	2179
1991-93	0.76	4.69	17.57	0.98	2179
1994-97	0.71	3.07	20.42	0.65	2179
1998	0.65	2.24	24.21	0.48	2179
1999-02	0.65	2.24	14.06	0.39	2179
2003	0.32	2.24	7.03	0.39	2179
2004	0.32	2.24	7.03	0.39	2179

Figure 10.4-1a Medium-Heavy Diesel NOx Emissions

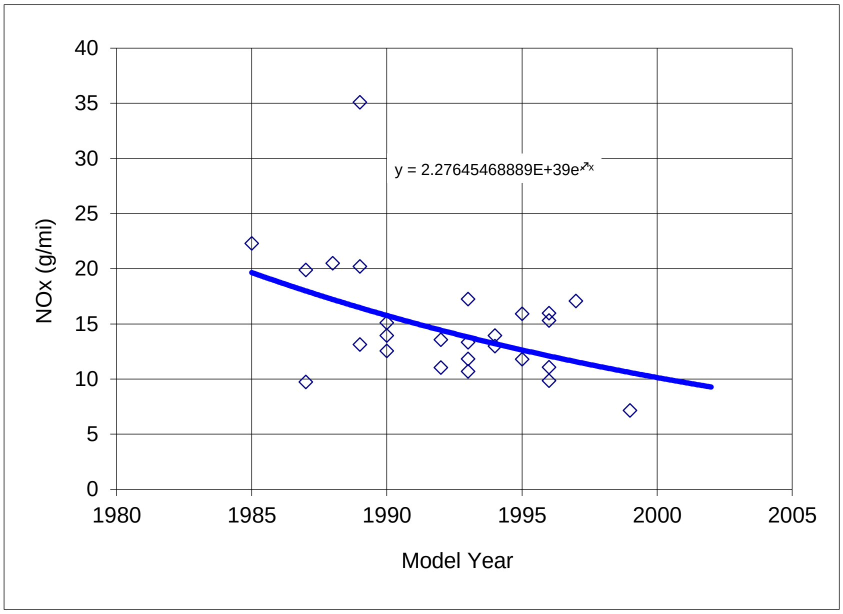


Figure 10.4-1b Medium-Heavy Diesel PM Emissions

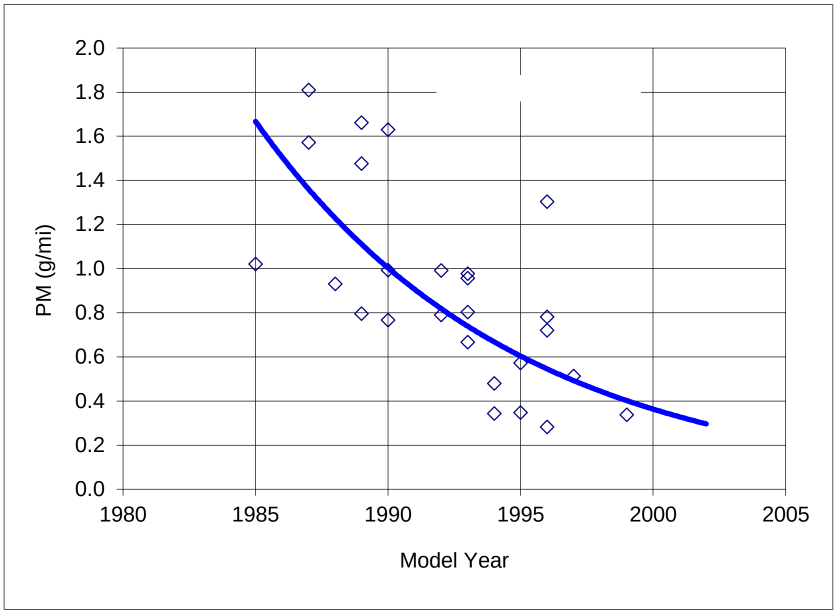


Figure 10.4-1c Medium-Heavy Diesel HC Emissions

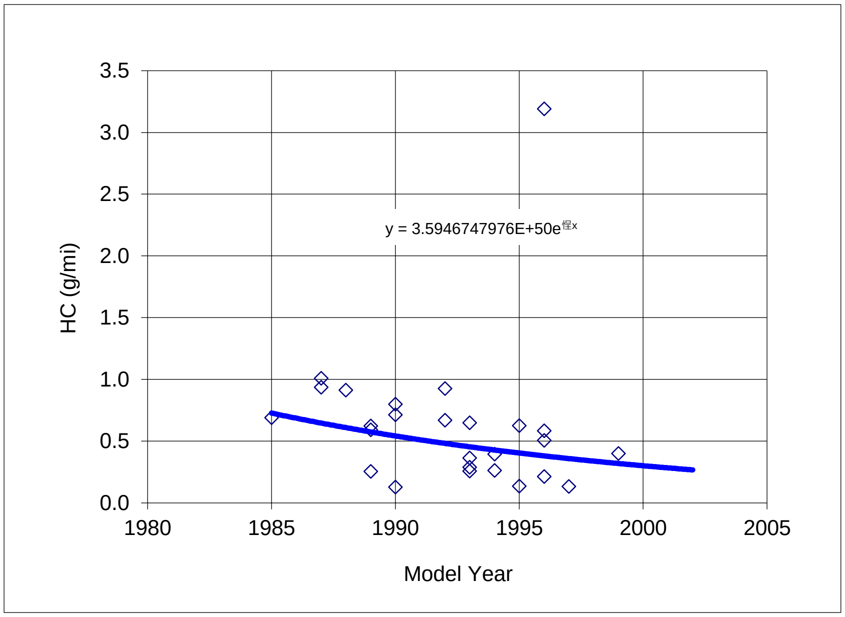


Figure 10.4-1d Medium-Heavy Diesel CO Emissions

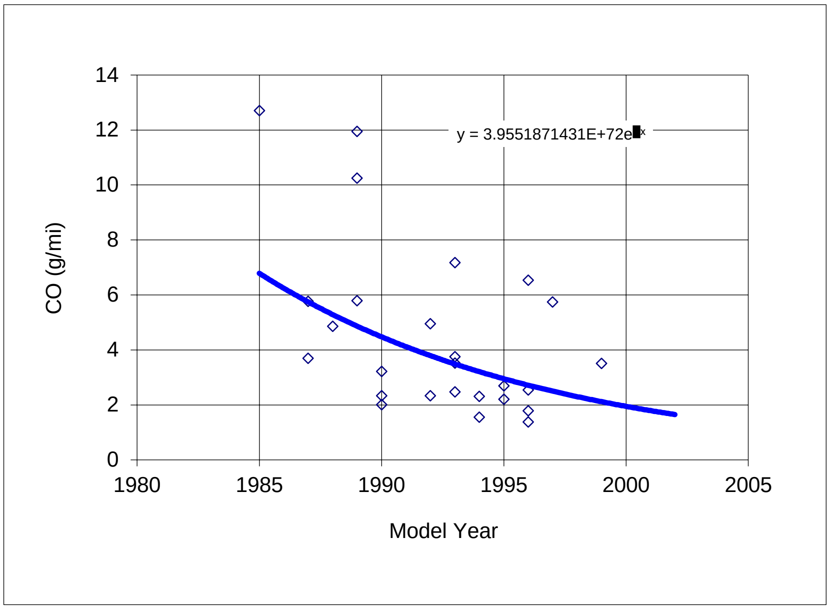


Table 10.4-1 Medium-Heavy Diesel - Average Emission Rates (g/mi)

California – Medium-Heavy Diesel Trucks					
MY Group	HC	CO	NOX	PM	CO_2
Pre 1975	0.73	6.79	19.65	1.67	1505
1975-76	0.73	6.79	19.65	1.67	1505
1977-79	0.73	6.79	19.65	1.67	1505
1980-83	0.73	6.79	19.65	1.67	1505
1984-86	0.70	6.39	19.03	1.55	1505
1987-90	0.58	4.88	16.48	1.11	1505
1991-93	0.48	3.80	14.44	0.82	1505
1994-97	0.39	2.84	12.38	0.58	1505
1998	0.34	2.30	11.07	0.44	1505
1999-02	0.34	2.30	11.07	0.44	1505
2003	0.21	2.30	6.09	0.44	1505
2004+	0.20	2.30	5.78	0.44	1505

Figure 10.5-1a Light-Heavy Diesel - BAG1 NOx Emissions

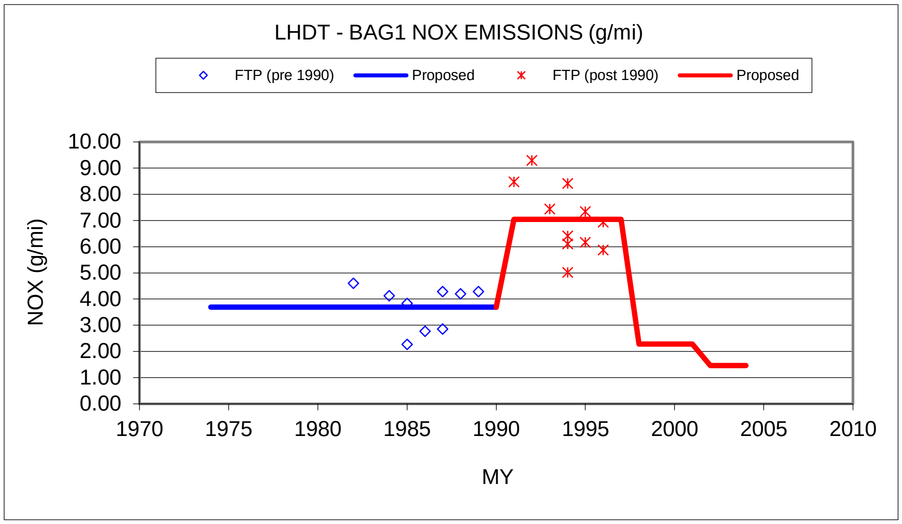


Figure 10.5-1b Light-Heavy Diesel – BAG1 PM Emissions

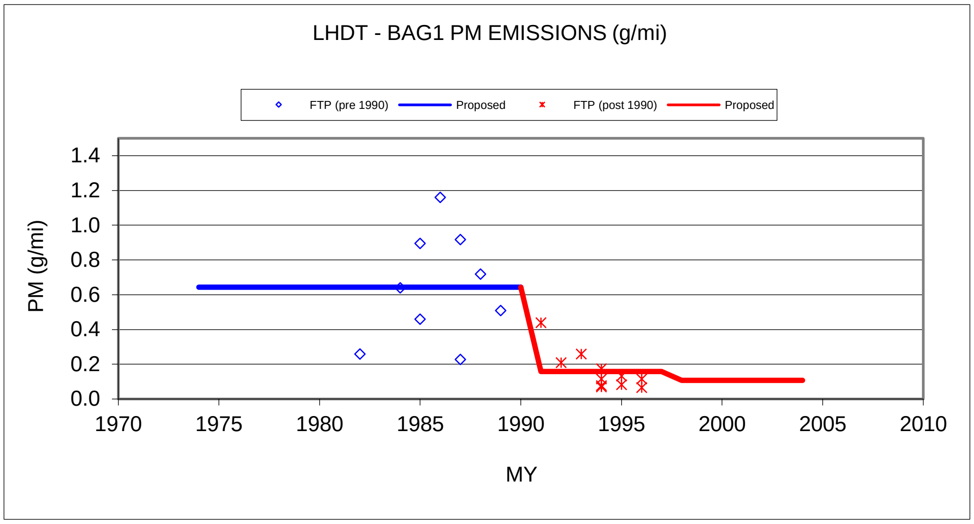


Figure 10.5-1c Light-Heavy Diesel - BAG1 HC Emissions

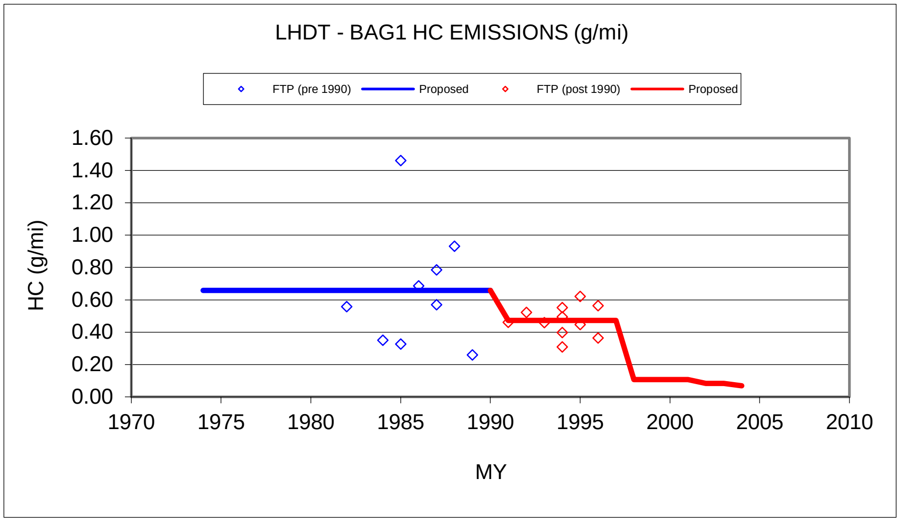


Figure 10.5-1d Light-Heavy Diesel - BAG1 CO Emissions

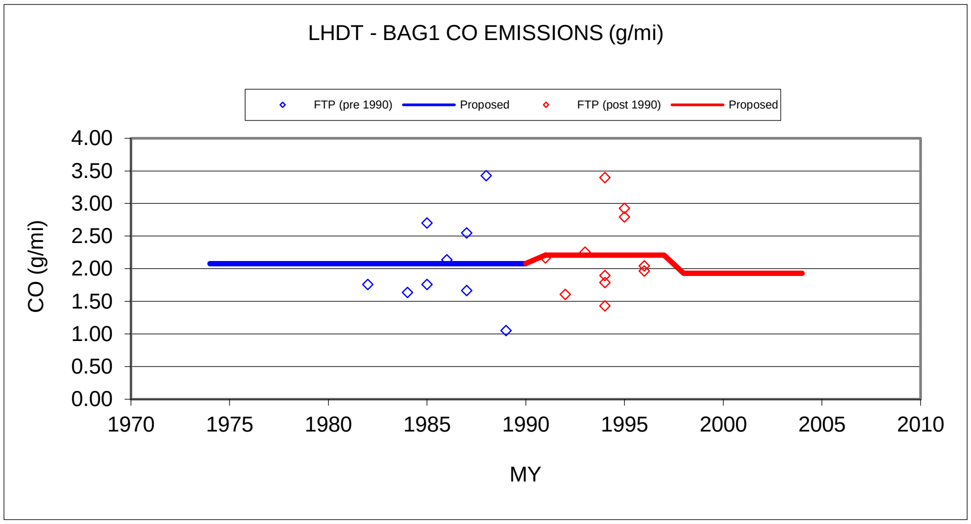


Figure 10.5-1e Light-Heavy Diesel – BAG2 NOX Emissions

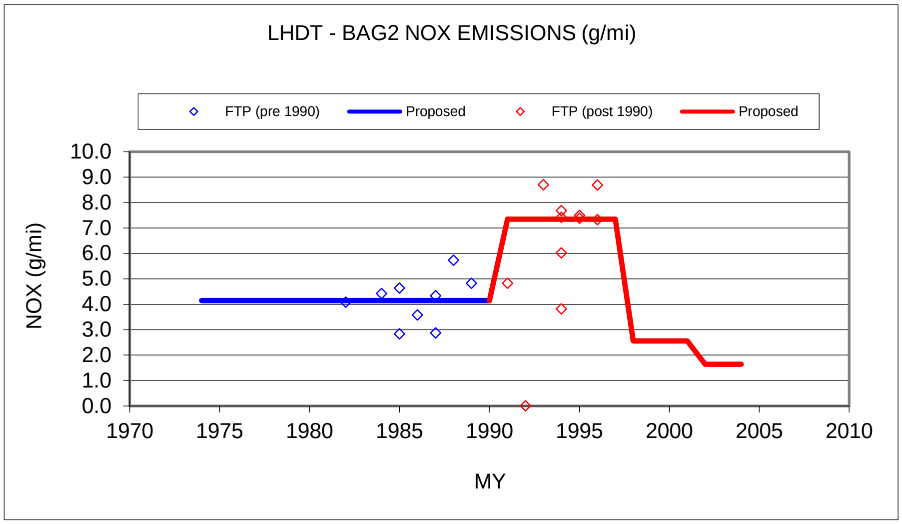


Figure 10.5-1f Light-Heavy Diesel – BAG2 PM Emissions

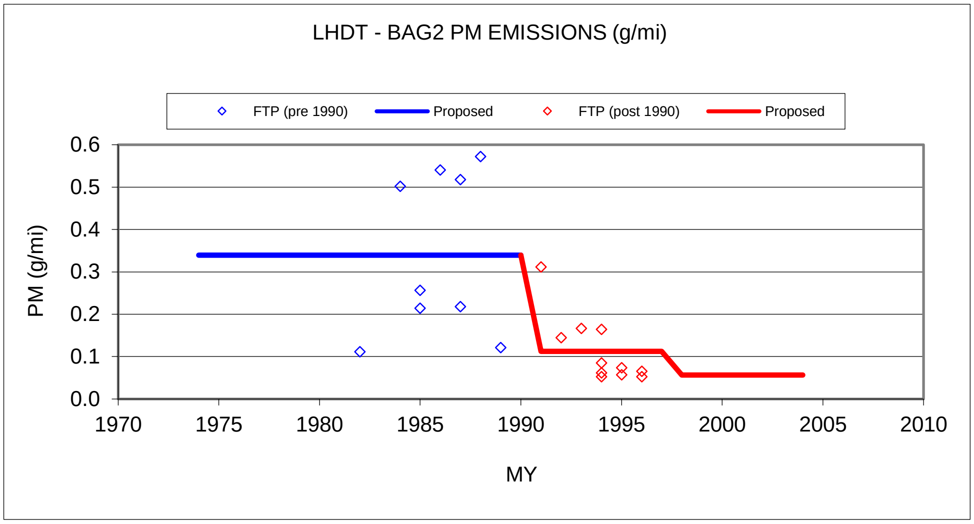


Figure 10.5-1g Light-Heavy Diesel – BAG2 HC Emissions

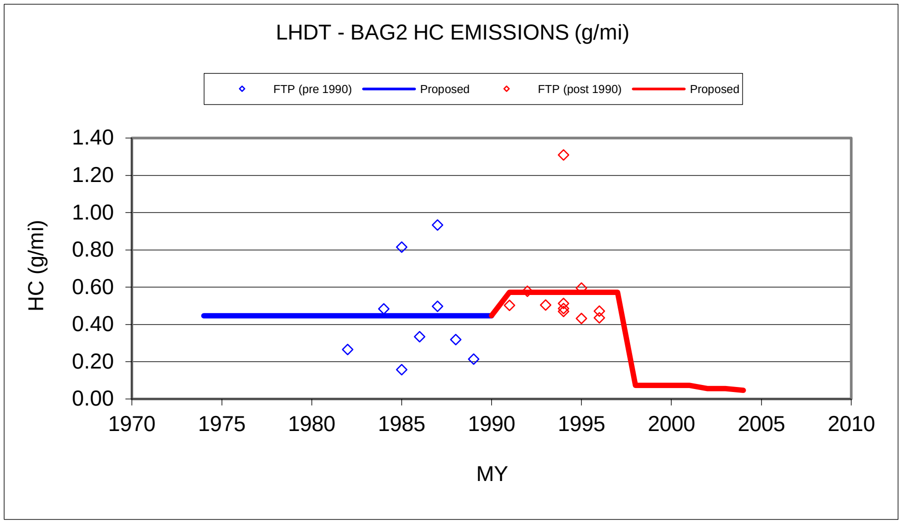


Figure 10.5-1h Light-Heavy Diesel – BAG2 CO Emissions

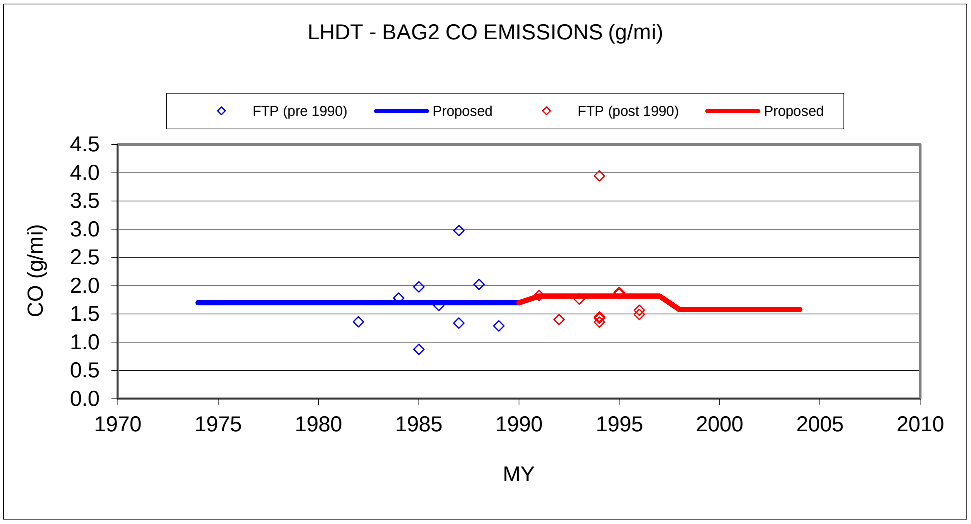


Table 10.5-1 Light-Heavy Diesel - Average Emission Rates (g/mi)

California – Light-Heavy Diesel Trucks										
MY Group	BAG1					BAG2				
	THC	CO	NOX	PM	CO2	THC	CO	NOX	PM	CO2
Pre 1975	0.66	2.08	3.86	0.77	745	0.45	1.70	4.32	0.40	642
1975-76	0.66	2.08	3.86	0.77	745	0.45	1.70	4.32	0.40	642
1977-79	0.66	2.08	3.86	0.77	745	0.45	1.70	4.32	0.40	642
1980-83	0.66	2.08	3.86	0.77	745	0.45	1.70	4.32	0.40	642
1984-86	0.66	2.08	3.86	0.77	745	0.45	1.70	4.32	0.40	642
1987-90	0.66	2.08	3.86	0.77	745	0.45	1.70	4.32	0.40	642
1991-93	0.47	2.21	7.28	0.15	678	0.57	1.82	7.64	0.11	601
1994	0.47	2.21	7.28	0.15	577	0.57	1.82	7.64	0.11	540
1995	0.47	2.21	7.28	0.15	544	0.57	1.82	7.64	0.11	519
1996-97	0.47	2.21	7.28	0.15	544	0.57	1.82	7.64	0.11	519
1998-99	0.11	1.93	2.38	0.13	544	0.07	1.58	2.67	0.07	519
2000-01	0.11	1.93	2.38	0.13	544	0.07	1.58	2.67	0.07	519
2002-03	0.08	1.93	1.53	0.13	544	0.06	1.58	1.71	0.07	519
2004+	0.07	1.93	1.53	0.13	544	0.05	1.58	1.71	0.07	519

Table 10.6-1 Federal Heavy-Heavy Diesel - Average Emission Rates (g/mi)

Federal – Heavy-Heavy Diesel Trucks					
MY Group	HC	CO	NOX	PM	CO_2
pre 1974	3.41	17.89	29.72	3.55	2179
1974-78	3.41	17.89	29.72	3.55	2179
1979-83	3.10	16.70	28.32	3.32	2179
1984-87	1.57	10.42	21.04	2.11	2179
1988-90	0.94	6.76	17.76	1.39	2179
1991-93	0.76	4.69	17.57	0.98	2179
1994-97	0.71	3.07	20.42	0.65	2179
1998	0.65	2.24	24.21	0.48	2179
1999-02	0.65	2.24	14.06	0.39	2179
2003	0.32	2.24	7.03	0.39	2179
2004+	0.32	2.24	7.03	0.39	2179

10.7 Effect of Tampering and Malfunctions on Heavy-Duty Diesel Truck Emissions - Deterioration Rates

It is assumed that the emissions from diesel powered trucks will remain stable in the absence of tampering, malfunction and malmaintenance. The deterioration factors to be used in EMFAC2000 are based upon the assumption of the frequency of occurrence and consequence of nineteen specific instances of tampering and malmaintenance which are the same as those used in MVEI7G and outlined in the Radian Corporation (Radian) report entitled "Heavy-Duty Diesel Vehicle Inspection and Maintenance Study - Volume II - Quantifying the Problem".

Basic Equation

As stated above, the Radian model estimates the effects of nineteen specific instances of tampering and malmaintenance using the following equation:

1.	Injection Timing Advanced	
2.	Injection Timing Retarded	
15.	Electronics Failed	$[(1.0+\Delta EF_{1} +\Delta EF_{2} +\Delta EF_{15} +\Delta EF_{16}+\Delta EF_{19})$ X
16.	Electronics Tampered	
19.	EGR Disabled	
3.	Minor Injection Problems	$(1.0+\Delta EF_{3} +\Delta EF_{4})$ X
4.	Moderate Injection Problems	
6.	Puff Limiter Mis-Set	$(1.0+\Delta EF_{6}+\Delta EF_{7})$ X
7.	Puff Limiter Disabled	
8.	Maximum Fuel High	$(1.0+\Delta EF_{8})$ X
9.	Clogged Air Filter	$(1.0+\Delta EF_{9})$ X
10.	Wrong/Worn Turbo	$(1.0+\Delta EF_{10})$ X
11.	Intercooler Clogged	$(1.0+\Delta EF_{11})$ X
12.	Other Air Problems	$(1.0+\Delta EF_{12})$ X
17.	Catalytic Converter Removed	$(1.0+\Delta EF_{17}+ \Delta EF_{18})] - 1.0 +$
18.	Trap Removed/Disabled	
5.	Severe Injection Problems	$+\Delta EF_{5}$
13.	Mechanical Failure	$+\Delta EF_{13}$
14.	Excess Oil Consumption	$+\Delta EF_{14} = \Delta EF_{total}$

The equation accounts for the fact that some failures and/or engine modifications are mutually exclusive. For example, injection timing can not be retarded and advanced on the same vehicle at the same time. The resulting factor, ΔEF_{total}, is the change in the overall fleet average emission factor and is pollutant and weight class (light-heavy, medium-heavy or heavy-heavy) specific. Because the report was prepared for the Air Resources Board in 1987, in EMFAC2000, the methodology was updated to reflect current and projected heavy-duty fleet characteristics. These updates involved revisions to the frequency of occurrence of acts of tampering and malmaintenance of emission control devices, revisions to the projections of the use of emission control devices based on latest engine certification data which also required a change in the assumed future tampering and malmaintenance rate and a change in emissions rates due to emissions control component tampering and malfunction. These changes are described in detail in the following paragraphs.

10.7.1 Estimates of Frequency of Occurrence

1960-1990

Radian estimated the frequency of occurrence of acts of tampering and malmaintenance based upon survey and observation. These estimates were revised by Engine, Fuel and Emissions Engineering, Inc., (EFEE), in a report prepared for the U.S. Environmental Protection Agency entitled "Modeling Deterioration In Heavy-Duty Diesel Particulate Emissions", which was finalized in 1998. The estimates shown in Table 10.7-1 were used for engines built between 1960 through 1987, and 1988 to 1990 in the absence of an enforcement program.

In general, these estimates represent a lower occurrence of tampering and malmaintenance than those originally reported by Radian and used by the Air Resources Board in previous versions of the inventory estimation model. Although the supporting survey information was not made available, little additional information exist and these revised estimates will be used in EMAFC2000.

1991-1997

Because the original report by Radian was completed in 1987, the estimates of the frequency of occurrence of tampering and malmaintenance for 1991 and newer vehicles relied on projections of the use of certain emission control devices to meet more stringent standards. EFEE revisited these assumptions in the report mentioned above based on U.S. EPA certification information. A similar analysis of certification data for model years 1992 to 1998 was performed by the ARB and the alternative estimates are displayed in Table 10.7-2.

Modification to the projections of the use of emission control devices also requires a change in the assumed future tampering rate. Although the tampering and malmaintenance rates originally suggested by Radian were reflective of the fleet as a whole, some suggested occurrences of component malfunction were greater than the percentage of the fleet so equipped. Table 10.7-3 contrasts the Radian, EFEE and ARB suggested tampering and malmaintenance rates for 1991 to 1993 engines, and for those engines manufactured after 1993.

Table 10.7-1 Frequency of Occurrence of Acts of Tampering and Malmaintenance (Pre 1991)

Frequency of occurrence of acts of tampering and malmaintenance						
	HHDT		MHDT		LHDT	
DEFECT	**Pre 88**	**88-90**	**Pre 88**	**88-90**	**Pre 80**	**88-90**
Timing Advanced	8%	13%	10%	10%	10%	10%
Timing Retarded	15%	12%	6%	6%	10%	10%
Minor Injector Problem	20%	20%	20%	20%	20%	20%
Mod. Injector Problem	10%	10%	10%	10%	10%	10%
Severe Injector Problem	3%	3%	3%	3%	5%	5%
Puff Limiter Misset	29%	23%	18%	18%	2%	5%
Puff Limiter Disabled	30%	23%	15%	15%	1%	3%
Max Fuel High	24%	18%	14%	14%	15%	15%
Clogged Air Filter	22%	20%	23%	19%	21%	19%
Wrong/Worn Turbo	12%	10%	10%	9%	5%	5%
Intercooler Clogged	3%	7%	1%	4%	0%	4%
Other Air Problem	15%	15%	14%	12%	9%	12%
Engine Mech. Failure	2%	2%	2%	2%	3%	3%
Excess Oil Cons.	2%	2%	3%	3%	5%	5%
Electronics Failed	0%	2%	0%	0%	0%	0%
Electronics Tampered	0%	0%	0%	0%	0%	0%
Cat Removed	0%	0%	0%	0%	0%	0%
EGR Stuck Open	0%	0%	0%	0%	0%	0%
EGR Disabled	0%	0%	0%	0%	0%	0%

Table 10.7-2 Percent of Fleet Equipped with Emission Control Devices

Percent of Fleet Equipped with Emission Control Device							
	Radian	EFEE	ARB		Radian	EFEE	ARB
Weight Class	1991-93	1991-93	1991-93		1994-97	1994-97	1994-97
	Turbocharging						
Heavy-Heavy	100%	100%	67%		100%	100%	100%
Medium-Heavy	100%	100%	67%		100%	100%	100%
Light-Heavy	100%	10%	67%		100%	100%	100%
	Catalytic Converter						
Heavy-Heavy	40%	0.3%	0%		0%	0%	0%
Medium-Heavy	50%	0.2%	0%		0%	60%	68%
Light-Heavy	50%	0%	0%		0%	80%	70%
	Exhaust Gas Recirculation						
Heavy-Heavy	0%	0%	0%		0%	0%	0%
Medium-Heavy	10%	0%	0%		20%	0%	0%
Light-Heavy	20%	0%	0%		30%	0%	19%
	Particulate Trap						
Heavy-Heavy	10%	0%	0%		100%	0%	0%
Medium-Heavy	30%	0%	0%		100%	0%	0%
Light-Heavy	50%	0%	0%		100%	0%	0%

Table 10.7-3 Frequency of Occurrence of Acts of Tampering and Malmaintenance (1991-93)

Frequency of Occurrence 1991-1993									
	HHDT			MHDT			LHDT		
DEFECT	Radian	EFEE	ARB	Radian	EFEE	ARB	Radian	EFEE	ARB
Timing Advanced	5%	11%	**11%**	5%	10%	**10%**	5%	10%	**10%**
Timing Retarded	3%	9%	**9%**	4%	6%	**6%**	4%	10%	**6%**
Minor Injector Problem	15%	20%	**15%**	15%	20%	**15%**	15%	20%	**15%**
Mod. Injector Problem	10%	10%	**10%**	10%	10%	**10%**	10%	10%	**10%**
Severe Injector Problem	4%	3%	**3%**	5%	3%	**3%**	5%	5%	**3%**
Puff Limiter Misset	2%	16%	**16%**	2%	17%	**17%**	2%	2%	**5%**
Puff Limiter Disabled	5%	16%	**16%**	4%	14%	**14%**	4%	4%	**3%**
Max Fuel High	3%	13%	**13%**	2%	14%	**14%**	5%	14%	**14%**
Clogged Air Filter	8%	18%	**15%**	10%	19%	**15%**	10%	19%	**15%**
Wrong/Worn Turbo	5%	9%	**5%**	5%	5%	**5%**	7%	10%	**5%**
Intercooler Clogged	5%	6%	**5%**	3%	5%	**5%**	3%	5%	**5%**
Other Air Problem	8%	8%	**8%**	8%	8%	**8%**	8%	8%	**8%**
Engine Mech. Failure	2%	2%	**2%**	2%	2%	**2%**	2%	3%	**2%**
Excess Oil Cons.	5%	2%	**5%**	8%	3%	**5%**	10%	5%	**5%**
Electronics Failed	5%	3%	**3%**	8%	0%	**3%**	8%	0%	**3%**
Electronics Tampered	15%	5%	**5%**	10%	0%	**5%**	7%	0%	**5%**
Cat Removed	8%	6%	**0%**	8%	0%	**0%**	8%	0%	**0%**
EGR Stuck Open	4%	0%	**0%**	9%	0%	**0%**	15%	0%	**0%**
EGR Disabled	0%	0%	**0%**	3%	0%	**0%**	6%	0%	**0%**

Table 10.7-3 Frequency of Occurrence of Acts of Tampering and Malmaintenance (1994-97)

Frequency of Occurrence 1994-97									
	HHDT			MHDT			LHDT		
DEFECT	Radian	EFEE	ARB	Radian	EFEE	ARB	Radian	EFEE	ARB
Timing Advanced	5%	3%	**5%**	5%	10%	**5%**	5%	6%	**5%**
Timing Retarded	3%	3%	**3%**	4%	5%	**3%**	4%	6%	**3%**
Minor Injector Problem	15%	20%	**15%**	15%	20%	**15%**	15%	20%	**15%**
Mod. Injector Problem	10%	10%	**10%**	10%	10%	**10%**	10%	10%	**10%**
Severe Injector Problem	4%	3%	**3%**	5%	3%	**3%**	5%	5%	**3%**
Puff Limiter Misset	0%	4%	**4%**	0%	15%	**4%**	2%	1%	**4%**
Puff Limiter Disabled	0%	4%	**4%**	0%	13%	**4%**	4%	2%	**4%**
Max Fuel High	3%	3%	**3%**	2%	12%	**3%**	5%	7%	**3%**
Clogged Air Filter	8%	16%	**15%**	10%	18%	**15%**	10%	15%	**15%**
Wrong/Worn Turbo	5%	8%	**5%**	5%	5%	**5%**	7%	9%	**5%**
Intercooler Clogged	5%	5%	**5%**	3%	5%	**5%**	3%	5%	**5%**
Other Air Problem	8%	8%	**8%**	8%	8%	**8%**	8%	8%	**8%**
Engine Mech. Failure	2%	2%	**2%**	2%	2%	**2%**	2%	3%	**2%**
Excess Oil Cons.	5%	2%	**5%**	8%	3%	**5%**	10%	5%	**5%**
Electronics Failed	5%	5%	**3%**	8%	2%	**3%**	8%	4%	**3%**
Electronics Tampered	15%	10%	**5%**	10%	1%	**5%**	7%	3%	**5%**
Cat Removed	0%	0%	**0%**	0%	6%	**6%**	0%	8%	**6%**
EGR Stuck Open	40%	0%	**0%**	30%	0%	**0%**	30%	0%	**0%**
EGR Disabled	0%	0%	**0%**	6%	0%	**0%**	9%	0%	**0%**

1998+

Based on experience gained through malfunctioning and tampering rates of emissions related components of light duty vehicles, staff assumed a lower rate of occurrence for most of the 1998 plus defects as shown in Table 10.7-4.

Table 10.7-4 Frequency of Occurrence of Acts of Tampering and Malmaintenance (1998-2002 and 2002+)

Frequency of occurrence of acts of tampering and malmaintenance						
	HHDT		**MHDT**		**LHDT**	
DEFECT	**1998-02**	**2002+**	**1998-02**	**2002+**	**1998-02**	**2002+**
Timing Advanced	2%	2%	2%	2%	2%	2%
Timing Retarded	2%	2%	2%	2%	2%	2%
Minor Injector Problem	15%	8%	15%	8%	15%	8%
Mod. Injector Problem	10%	5%	10%	5%	10%	5%
Severe Injector Problem	3%	0%	3%	0%	3%	0%
Puff Limiter Misset	0%	0%	0%	0%	0%	0%
Puff Limiter Disabled	0%	0%	0%	0%	0%	0%
Max Fuel High	0%	0%	0%	0%	0%	0%
Clogged Air Filter	15%	15%	15%	15%	15%	15%
Wrong/Worn Turbo	5%	5%	5%	5%	5%	5%
Intercooler Clogged	5%	5%	5%	5%	5%	5%
Other Air Problem	8%	8%	8%	8%	8%	8%
Engine Mech. Failure	2%	2%	2%	2%	2%	2%
Excess Oil Cons.	3%	3%	3%	3%	3%	3%
Electronics Failed	3%	3%	3%	3%	3%	3%
Electronics Tampered	5%	5%	5%	5%	5%	5%
Cat Removed	0%	0%	1%	1%	1%	1%
EGR Stuck Open	0%	0%	0%	0%	0%	0%
EGR Disabled	0%	10%	0%	10%	0%	10%

10.7.2 Emission Increases Due to Tampering

For each incidence of tampering and malmaintenance, Radian estimated a change in the basic emission rate. These estimates were based on engine dynamometer data where tests were performed with and with out the malfunction present. Tables 10.7-6, 10.7-7 and 10.7-8 list the Radian estimates of emissions impact, suggested modification to the particulate emissions impacts by EFEE and those to be used in EMFAC2000.

Table 10.7-6 Percent Change in Individual Vehicle Emission Factor

Percent Change in Individual Vehicle Emission Factor												
Radian Report												
DEFECT	Oxides of Nitrogen				Hydrocarbons				Particulate			
	60-87	88-90	91-93	94+	60-87	88-90	91-93	94+	60-87	88-90	91-93	94+
Timing Advanced	70	50	60	60	0	0	30	30	-25	-20	0	0
Timing Retarded	-20	-20	-20	-20	50	50	50	50	50	25	100	100
Minor Injector Problem	0	0	0	0	10	10	20	20	35	35	70	70
Mod. Injector Problem	-5	-5	-5	-5	150	150	300	300	200	200	400	400
Severe Injector Problem	-10	-10	-10	-10	500	500	1100	1100	700	700	1500	4200
Puff Limiter Misset	0	0	0	0	0	0	0	0	20	20	50	50
Puff Limiter Disabled	0	0	0	0	-20	-20	0	0	50	50	100	100
Max Fuel High	10	10	10	10	0	0	0	0	20	30	30	30
Clogged Air Filter	0	0	0	0	0	0	0	0	40	40	50	50
Wrong/Worn Turbo	0	0	0	0	0	0	0	0	40	40	50	50
Intercooler Clogged	20	20	20	20	-20	-20	-20	-20	40	40	50	50
Other Air Problem	0	0	0	0	0	0	0	0	40	40	40	40
Engine Mech. Failure	-10	-10	-10	-10	200	200	300	500	150	150	300	500
Excess Oil Cons.	0	0	0	0	300	300	300	300	120	150	300	600
Electronics Failed	0	0	0	0	0	30	50	50	0	30	60	60
Electronics Tampered	0	50	80	80	0	0	0	0	0	0	50	50
Cat Removed	0	0	0	0	0	0	100	0	0	0	40	0
EGR Stuck Open	0	0	0	0	0	0	40	100	0	0	200	300

Table 10.7-7 Percent Change in Individual Vehicle Emission Factor

Percent Change in Individual Vehicle Emission Factor																		
EMFAC2000 DEFECT	**Oxides of Nitrogen**						**Hydrocarbons**						**Particulate**					
	Pre 88	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**	**Pre 88**	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**	**Pre 88**	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**
Timing Advanced	70	50	60	60	60	60	0	0	30	30	30	30	-25	-20	0	0	0	0
Timing Retarded	-20	-20	-20	-20	-20	-20	50	50	50	50	50	50	50	25	100	100	100	100
Minor Injector Problem	-6	-5	-5	-1	-1	-1	686	1008	1008	1723	1723	1723	75	104	104	347	347	347
Mod. Injector Problem	-6	-5	-5	-1	-1	-1	686	1008	1008	1723	1723	1723	75	104	104	347	347	347
Severe Injector Problem	-7	-5	-5	-1	-1	-1	324	1008	1008	1723	1723	1723	654	104	104	347	347	347
Puff Limiter Misset	0	0	0	0	0	0	0	0	0	0	0	0	20	20	50	50	50	50
Puff Limiter Disabled	0	0	0	0	0	0	-20	-20	0	0	0	0	50	50	100	100	100	100
Max Fuel High	10	10	10	10	10	10	0	0	0	0	0	0	20	30	30	30	30	30
Clogged Air Filter	0	0	0	0	0	0	0	0	0	0	0	0	40	40	50	50	50	50
Wrong/Worn Turbo	0	0	0	0	0	0	0	0	0	0	0	0	40	40	50	50	50	50
Intercooler Clogged	20	20	25	25	25	25	-20	-20	-20	-20	-20	-20	40	40	50	50	50	50
Other Air Problem	0	0	0	0	0	0	0	0	0	0	0	0	40	40	40	40	40	40
Engine Mech. Failure	-10	-10	-10	-10	-10	-10	200	200	300	500	500	500	150	150	300	500	500	500
Excess Oil Cons.	0	0	0	0	0	0	300	300	300	300	300	300	120	150	300	600	600	600
Electronics Failed	0	0	0	0	0	0	0	30	50	50	50	50	0	30	60	60	60	60
Electronics Tampered	0	50	80	80	80	80	0	0	0	0	0	0	0	0	50	50	50	50
Cat Removed	0	0	0	0	0	0	0	0	100	0	0	0	0	0	40	40	40	40
EGR Stuck Open	0	0	0	0	0	0	0	0	40	100	100	100	0	0	200	300	300	300
EGR Disabled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-30

Table 10.7-8 Percent Change in Individual Vehicle PM Emission Factor

Percent Change in Individual Vehicle PM Emission Factor										
DEFECT	**EFEE**				**EMFAC2000**					
	60-87	**88-90**	**91-93**	**94+**	**Pre 88**	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**
Timing Advanced	-25	-20	0	0	-25	-20	0	0	0	0
Timing Retarded	50	25	100	100	50	25	100	100	100	100
Minor Injector Problem	35	35	70	70	75	104	104	347	347	347
Mod. Injector	200	200	400	600	75	104	104	347	347	347
Severe Injector Problem	500	700	3200	3200	654	104	104	347	347	347
Puff Limiter Misset	20	20	50	50	20	20	50	50	50	50
Puff Limiter Disabled	50	50	100	100	50	50	100	100	100	100
Max Fuel High	20	30	30	30	20	30	30	30	30	30
Clogged Air Filter	40	40	50	50	40	40	50	50	50	50
Wrong/Worn Turbo	40	40	50	50	40	40	50	50	50	50
Intercooler Clogged	40	40	50	50	40	40	50	50	50	50
Other Air Problem	40	40	40	40	40	40	40	40	40	40
Engine Mech. Failure	150	150	300	500	150	150	300	500	500	500
Excess Oil Cons.	120	150	300	600	120	150	300	600	600	600
Electronics Failed	0	30	60	60	0	30	60	60	60	60
Electronics Tampered	0	0	50	100	0	0	50	50	50	50
Cat Removed	0	0	40	40	0	0	40	40	40	40
EGR Stuck Open	N/A	N/A	N/A	N/A	0	0	200	300	300	300
EGR Disabled	0	0	0	0	0	0	0	0	0	-30

The most significant difference between the impacts suggested by EFEE and those to be used in EMFAC2000 are in the area of the effects of injector problems. To derive the estimates to be used in EMFAC2000, staff analyzed the raw test data used by Radian in the original report and emissions test performed during the CIFER project. As shown in Table 10.7-9, six heavy-duty engines ranging from 1966 to 1975 were tested with either one or two leaking injectors. ARB staff utilized the average emissions increase for five of the six engines (no particulate matter results were reported for one engine) to represent the effect of severe injector problems on pre-1980 engines. Data as shown in Table 10.7-10 from the CIFER project was used to represent the effect of moderate and minor injector problems on pre-1980 engines. Similarly, the CIFER data was used for post 1980 engines. The ratio of the standards was used to adjust this estimate for 1991-1993 and 1994 and newer engines. Similar adjustments were made to the assumed effect on other pollutants.

Table 10.7-9 Emissions Data (g/mile) from Radian Report

MY	Comment	HC	CO	NOx	PM	Fuel
1971	Tuneup	8.31	87.56	35.14	6.7	3.19
	Leaking Inj	35.19	175.5	32.23	32.22	2.91
		26.88	87.94	-2.91	25.52	-0.28
		323%	100%	-8%	381%	-9%
1966	Tuneup	8.96	16.19	62.89	3.02	3.45
	Leaking Inj	41.00	129.70	61.41	34.43	3.14
		32.04	113.51	-1.48	31.41	-0.31
		358%	701%	-2%	1040%	-9%
1969	Baseline	7.89	31.07	38.43	4.31	3.83
	3 Bad Inj	45.57	118.00	33.40	28.94	3.50
		37.68	86.93	-5.03	24.63	-0.33
		478%	280%	-13%	571%	-9%
1969	Tune Up Orig Air	12.78	42.19	50.26	4.91	3.80
	2 leaking 1 Plugged	43.44	147.60	50.74	34.20	3.30
	2 leaking 1 Plugged	38.26	152.10	47.48	36.70	3.30
		28.07	107.66	-1.15	30.54	-0.50
		220%	255%	-2%	622%	-13%
1966	After Tuneup New Air	11.70	40.81	54.46	4.12	3.48
	1 leaking Inj	39.75	138.40	49.52	31.04	3.35
		28.05	97.59	-4.94	26.92	-0.13
		240%	239%	-9%	653%	-4%
	Minimum	220%	100%	-13%	381%	-13%
	Average	324%	315%	-7%	654%	-9%
	Maximum	478%	701%	-2%	1040%	-4%
	Minimum	26.88	86.93	-5.03	24.63	-0.50
	Average	30.54	98.73	-3.10	27.80	-0.31
	Maximum	37.68	113.51	-1.15	31.41	-0.13

Source: Table 6-3 from the report entitled "Heavy-Duty Diesel Vehicle Inspection and Maintenance Study – Volume II – Quantifying the Problem"; prepared by Radian Corporation in 1987.

Table 10.7-10 Emissions Data (g/mi) from U.S. EPA - CIFER

ID	Mileage (miles)	GVW (lb)	Test Weight (lb)	Model Year	Engine Model	Test Cycle	Comment	**HC**	**NOx, IV**	**NOx, Bag**	**CO**	**CO2**	**PM**
1	86671	25000	20000	1995	Navistar X4L	HDTT	As is	43.608	15.338	14.962	28.871	1958.04	5.290
							new injector	2.392	15.380	15.040	12.314	1707.59	1.184
								1723%	**0%**	**-1%**	**134%**	**15%**	**347%**
5	160817	80000	39000	1989	Cum NTC315	HDTT	As is	2.654	20.383	19.508	58.817	2373.88	6.989
							6 new injectors	2.222	21.509	21.074	44.473	2297.75	5.842
								19%	**-5%**	**-7%**	**32%**	**3%**	**20%**
10	191525	80000	52000	1989	Cum NTC315	HDTT	New fuel pump	58.891	26.237	25.187	79.180	2624.57	15.472
14a							New #3 injector	2.809	25.374	24.812	20.225	2578.88	5.385
								1997%	**3%**	**2%**	**291%**	**2%**	**187%**
12	119280	54000	43000	1987	DT466	HDTT	As is	1.841	26.627	25.922	41.220	2327.11	4.688
							Rebuilt injectors	1.287	29.699	29.153	38.869	2064.97	3.975
								43%	**-10%**	**-11%**	**6%**	**13%**	**18%**
								686%	**-4%**	**-6%**	**110%**	**6%**	**75%**
				1989	**Average**			**1008%**	**-1%**	**-2.96%**	**162%**	**2.5%**	**103.5%**

Source: U.S. EPA – Test program entitled "105 Grant to Quantify Emission Benefits of Opacity Testing and Repair for HDDV – FY98" conducted by Colorado Institute for Fuels and Engine Research (CIFER), in collaboration with the Denver Regional Air Quality Council (RAQC) and the Colorado Department of Public Health and Environment (CDPHE).

10.8 Application of Deterioration Factors

Most of the emissions deterioration suggested by the Radian model can be attributed to wear as opposed to deliberate acts of tampering. Given this fact and under the assumption that most maintenance related problems would be corrected upon engine rebuild, ARB staff modified its previous deterioration methodology. Essentially it is assumed that the fleet average emissions would peak just before and engine rebuild and achieve its lowest level just afterward.

Because the ARB is utilizing chassis dynamometer data from randomly selected in-use vehicles as the basis for the revisions to the heavy-duty emission factors to be included in EMFAC2000, it was assumed that these engines were nominally half way between engine rebuilds. Given this assumption, the chassis dynamometer data used to revise the basic emission rates are most representative the half way point between the Radian model's prediction of tampering and malmaintenance and tampering alone.

In other words, it is assumed that the Radian model predicts emissions at their highest levels, prior to rebuild. To establish the lower boundary, the model was rerun zeroing out the effects of engine malfunction. In the alternative scenario, the following ten parameters were mitigated:

1) Minor Injector Problems
2) Moderate Injector Problems
3) Severe Injector Problems
4) Clogged Air Filter
5) Wrong/Worn Turbo
6) Intercooler Clogged
7) Other Air Problems
8) Engine Mechanical Failure
9) Excess Oil Consumption
10) Electronics Failed

The resulting change in emissions are shown in Table 10.8-1.

Using the proposed methodology, the zero mile emission rate would be calculated as:

$$ZM = ER/(1+(EI_{1+}EI_2)/2)$$

The deterioration rate (grams per mile per 10,000 miles) would be calculated as

$$DR = (ER - ZM)/(Odometer/10000)$$

Where ZM is the emission rate at zero miles.

ER is the average emission rate of the chassis dynamometer data.

EI_1 is the emissions impact prediction of the Radian model assuming both tampering and malmaintenance.

EI_2 is the emissions impact prediction of the Radian model assuming the effects of tampering "only".

Odometer is the average odometer reading assumed for vehicles by model year.

Tables 10.8-2, 10.8-3, 10.8-4 and 10.8-5 show the zero-mile emission and deterioration rates respectively for California HHDTs, California MHDTs, California LHDTs and federal HHDTs.

Table 10.8-1 Percent Change in Fleet Average Emission Factor

Heavy-Heavy Diesel Trucks																		
	Oxides Of Nitrogen						**Hydrocarbon**						**Particulate Matter**					
	Pre88	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**	**Pre88**	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**	**Pre88**	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**
Tampering and Malmaintenance	3.4	5.5	9.8	7.6	5.6	5.8	226.9	343.7	332.1	525.8	512.4	240.9	125.1	107.3	138.3	200.2	169.8	100.6
Tamper Only	5.1	6.0	10.2	6.7	4.8	4.8	1.1	1.1	7.8	3.0	1.6	1.6	33.6	22.9	43.7	12.8	4.9	1.9
Average	**4.2**	**5.7**	**10.0**	**7.1**	**5.2**	**5.3**	**114.0**	**172.4**	**170.0**	**264.4**	**257.0**	**121.3**	**79.4**	**65.1**	**91.0**	**106.5**	**87.4**	**51.3**

Medium-Heavy Diesel Trucks																		
	Oxides Of Nitrogen						**Hydrocarbon**						**Particulate Matter**					
	Pre88	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**	**Pre88**	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**	**Pre88**	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**
Tampering and Malmaintenance	5.2	4.2	10.0	7.6	5.6	5.8	227.6	342.1	325.9	525.8	512.4	240.9	95.5	89.8	130.7	206.5	170.7	101.3
Tamper Only	7.3	5.3	10.3	6.7	4.8	4.8	-0.1	-0.1	6.0	3.0	1.6	1.6	14.8	15.2	38.5	15.7	4.9	1.9
Average	**6.2**	**4.7**	**10.1**	**7.1**	**5.2**	**5.3**	**113.8**	**171.0**	**165.9**	**264.4**	**257.0**	**121.3**	**55.2**	**52.5**	**84.6**	**111.1**	**87.8**	**51.6**

Light-Heavy Diesel Trucks																		
	Oxides Of Nitrogen						**Hydrocarbon**						**Particulate Matter**					
	Pre88	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**	**Pre88**	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**	**Pre88**	**88-90**	**91-93**	**94-97**	**98-02**	**2002+**
Tampering and Malmaintenance	4.0	3.3	10.0	7.6	5.6	5.8	257.6	388.0	325.9	525.8	512.4	240.9	92.7	82.0	102.0	206.5	170.7	101.3
Tamper Only	6.6	4.5	10.3	6.7	4.8	4.8	4.8	4.4	6.0	3.0	1.6	1.6	6.5	7.6	19.3	15.7	4.9	1.9
Average	**5.3**	**3.9**	**10.1**	**7.1**	**5.2**	**5.3**	**131.2**	**196.2**	**165.9**	**264.4**	**257.0**	**121.3**	**49.6**	**44.8**	**60.6**	**111.1**	**87.8**	**51.6**

Table 10.8-2 Zero-Mile Emission (ZM) and Deterioration (DR) Rates – HHDT

Zero-Mile Emission (g/mi) and Deterioration Rates (g/mi per 10000 mi)								
California - Heavy-Heavy-Diesel Trucks								
MY GROUP	HC		CO		NOX		PM	
	ZM	DR	ZM	DR	ZM	DR	ZM	DR
Pre 1975	1.60	0.018	8.36	0.095	28.52	0.012	1.98	0.016
1975-76	1.45	0.018	7.81	0.098	27.17	0.013	1.85	0.016
1977-79	1.45	0.019	7.81	0.101	27.17	0.013	1.85	0.017
1980-83	1.45	0.020	7.81	0.108	27.17	0.014	1.85	0.018
1984-86	0.74	0.011	4.87	0.074	20.18	0.011	1.18	0.012
1987-90	0.34	0.009	2.48	0.065	16.79	0.015	0.84	0.008
1991-93	0.28	0.009	1.74	0.056	15.97	0.030	0.51	0.009
1994-97	0.19	0.016	0.84	0.068	19.06	0.042	0.32	0.010
1998	0.18	0.014	0.63	0.049	23.01	0.037	0.26	0.007
1999-02	0.18	0.009	0.63	0.031	13.36	0.013	0.21	0.003
2003	0.14	0.003	1.01	0.023	6.68	0.007	0.26	0.003
2004	0.14	0.003	1.01	0.023	6.68	0.007	0.26	0.003

Table 10.8-3 Zero-Mile Emission (ZM) and Deterioration (DR) Rates – MHDT

Zero-Mile Emission (g/mi) and Deterioration Rates (g/mi per 10000 mi)								
California – Medium-Heavy-Diesel Trucks								
MY GROUP	HC		CO		NOX		PM	
	ZM	DR	ZM	DR	ZM	DR	ZM	DR
Pre 1975	0.34	0.011	3.17	0.100	18.50	0.032	1.07	0.016
1975-76	0.34	0.011	3.17	0.100	18.50	0.032	1.07	0.016
1977-79	0.34	0.011	3.17	0.100	18.50	0.032	1.07	0.016
1980-83	0.34	0.011	3.17	0.100	18.50	0.032	1.07	0.016
1984-86	0.33	0.014	2.99	0.131	17.91	0.043	1.00	0.021
1987-90	0.21	0.016	1.80	0.140	15.74	0.034	0.73	0.017
1991-93	0.18	0.018	1.43	0.139	13.11	0.078	0.45	0.022
1994-97	0.11	0.017	0.78	0.121	11.55	0.048	0.27	0.018
1998	0.09	0.014	0.64	0.097	10.52	0.032	0.24	0.012
1999-02	0.09	0.014	0.64	0.097	10.52	0.032	0.24	0.012
2003	0.09	0.007	1.04	0.074	5.79	0.018	0.29	0.009
2004+	0.09	0.006	1.04	0.074	5.48	0.017	0.29	0.009

Table 10.8-4 Zero-Mile Emission (ZM) and Deterioration (DR) Rates – LHDT

Zero-Mile Emission (g/mi) and Deterioration Rates (g/mi per 10000 mi)

California - Light-Heavy-Diesel Trucks

	BAG 1 Rates								**BAG 2 Rates**							
MY GROUP	**HC**		**CO**		**NOX**		**PM**		**HC**		**CO**		**NOX**		**PM**	
	ZM	**DR**	**ZM**	**DR**	**ZM**	**DR**	**ZM**	**DR**	**ZM**	**DR**	**ZM**	**DR**	**ZM**	**DR**	**ZM**	**DR**
Pre 1975	0.28	0.010	0.90	0.031	3.51	0.005	0.43	0.006	0.19	0.007	0.74	0.025	3.94	0.005	0.23	0.003
1975-76	0.28	0.011	0.90	0.035	3.51	0.005	0.43	0.006	0.19	0.007	0.74	0.028	3.94	0.006	0.23	0.003
1977-79	0.28	0.012	0.90	0.036	3.51	0.006	0.43	0.007	0.19	0.008	0.74	0.030	3.94	0.006	0.23	0.003
1980-83	0.28	0.013	0.90	0.040	3.51	0.006	0.43	0.007	0.19	0.009	0.74	0.033	3.94	0.007	0.23	0.004
1984-86	0.28	0.014	0.90	0.046	3.51	0.007	0.43	0.008	0.19	0.010	0.74	0.037	3.94	0.008	0.23	0.004
1987-90	0.22	0.020	0.70	0.063	3.55	0.006	0.44	0.009	0.15	0.013	0.57	0.051	3.99	0.007	0.23	0.005
1991-93	0.18	0.013	0.83	0.063	6.40	0.029	0.10	0.003	0.22	0.016	0.68	0.052	6.67	0.031	0.07	0.002
1994	0.13	0.016	0.61	0.073	6.58	0.021	0.08	0.004	0.16	0.019	0.50	0.060	6.86	0.022	0.05	0.003
1995	0.13	0.016	0.61	0.073	6.58	0.021	0.08	0.004	0.16	0.019	0.50	0.060	6.86	0.022	0.05	0.003
1996-97	0.13	0.016	0.61	0.073	6.58	0.021	0.08	0.004	0.16	0.019	0.50	0.060	6.86	0.022	0.05	0.003
1998-99	0.03	0.003	0.54	0.063	2.17	0.005	0.06	0.002	0.02	0.002	0.44	0.052	2.43	0.006	0.03	0.001
2000-01	0.03	0.003	0.54	0.063	2.17	0.005	0.06	0.002	0.02	0.002	0.44	0.052	2.43	0.006	0.03	0.001
2002-03	0.04	0.002	0.87	0.048	1.39	0.003	0.07	0.002	0.03	0.001	0.71	0.039	1.56	0.004	0.04	0.001
2004+	0.03	0.002	0.87	0.048	1.39	0.003	0.07	0.002	0.02	0.001	0.71	0.039	1.56	0.004	0.04	0.001

Table 10.8-5 Zero-Mile Emission (ZM) and Deterioration (DR) Rates – MHDT

Zero-Mile Emission (g/mi) and Deterioration Rates (g/mi per 10000 mi)								
Federal - Heavy-Heavy-Diesel Trucks								
MY GROUP	HC		CO		NOX		PM	
	ZM	DR	ZM	DR	ZM	DR	ZM	DR
Pre 1974	1.60	0.018	8.37	0.094	27.98	0.017	2.29	0.012
1974-78	1.60	0.020	8.37	0.105	27.98	0.019	2.29	0.014
1979-83	1.45	0.020	7.81	0.107	26.66	0.020	2.14	0.014
1984-87	0.74	0.011	4.87	0.075	19.81	0.017	1.36	0.010
1988-90	0.35	0.009	2.50	0.066	16.96	0.012	0.91	0.007
1991-93	0.29	0.009	1.76	0.055	15.95	0.031	0.53	0.008
1994-97	0.19	0.016	0.84	0.068	19.06	0.042	0.31	0.010
1998	0.18	0.014	0.63	0.049	23.01	0.037	0.26	0.007
1999-02	0.18	0.009	0.63	0.031	13.36	0.013	0.21	0.003
2003	0.14	0.003	1.01	0.023	6.68	0.007	0.26	0.003
2004+	0.14	0.003	1.01	0.023	6.68	0.007	0.26	0.003

Tables 10.8-6 to 10.8-9 show a comparison of emission factors at a cumulative mileage of 100,000 miles between EMFAC2000 and MVEI7G. For heavy-heavy and medium-heavy diesel trucks, the HC and CO emissions are in general lower in EMFAC2000 than in MVEI7G while NOx emissions are higher. PM emissions for newer model years are higher in EMFAC2000. For light-heavy diesel trucks, the Bag1 and Bag2 HC, CO, NOx and PM emissions factors are in general lower in EMFAC2000.

Table 10.8-6 HHD Gram per Mile Emissions at 100,000 Miles MVEI7G v EMFAC2000

Heavy-Heavy Diesel Trucks								
Model Year	EMFAC2000				MVEI7G			
	HC	CO	NOX	PM	HC	CO	NOX	PM
Pre 1975	1.776	9.307	28.635	2.135	3.866	14.710	23.351	2.171
1975-76	1.630	8.781	27.295	2.013	3.866	14.710	23.351	2.171
1977	1.637	8.818	27.300	2.019	3.734	14.710	23.208	2.171
1978	1.637	8.818	27.300	2.019	3.605	14.203	22.408	2.096
1979	1.637	8.818	27.300	2.019	3.551	14.203	22.349	2.096
1980-83	1.650	8.888	27.309	2.031	3.551	14.203	22.349	2.096
1984	0.848	5.607	20.298	1.300	2.666	13.695	13.941	2.021
1985-86	0.848	5.607	20.298	1.300	2.341	13.695	13.941	2.021
1987	0.434	3.131	16.939	0.926	2.341	13.695	13.941	1.564
1988-89	0.434	3.131	16.939	0.926	2.288	13.383	13.881	1.296
1990	0.434	3.131	16.939	0.926	2.288	13.383	11.291	1.296
1991-93	0.372	2.295	16.274	0.600	1.615	9.838	10.132	0.808
1994-95	0.353	1.525	19.479	0.418	0.983	11.304	10.119	0.259
1996-97	0.353	1.525	19.479	0.418	0.946	10.885	9.744	0.250
1998	0.324	1.122	23.379	0.325	0.946	10.885	7.795	0.250
1999-02	0.269	0.933	13.494	0.243	0.946	10.885	7.795	0.250
2003	0.176	1.245	6.743	0.284	0.946	10.885	7.795	0.250
2004	0.176	1.245	6.743	0.284	0.946	10.885	7.795	0.250

Table 10.8-7 MHDT Gram per Mile Emissions at 100,000 Miles MVEI7G v EMFAC2000

Medium-Heavy Diesel Trucks								
Model Year	EMFAC2000				MVEI7G			
	HC	CO	NOX	PM	HC	CO	NOX	PM
Pre 1975	0.448	4.178	18.823	1.239	3.760	13.024	19.318	2.302
1975-76	0.448	4.178	18.823	1.239	3.760	13.024	19.318	2.302
1977-79	0.448	4.178	18.823	1.239	3.577	13.024	19.149	2.302
1980-83	0.448	4.178	18.823	1.239	3.577	13.024	19.149	2.302
1984-86	0.469	4.303	18.343	1.212	2.446	13.024	9.490	2.302
1987	0.377	3.197	16.078	0.905	2.446	13.024	9.490	1.587
1988-90	0.377	3.197	16.078	0.905	2.065	11.604	9.099	1.305
1991-93	0.359	2.821	13.890	0.666	1.583	9.012	8.805	0.726
1994-97	0.276	1.993	12.037	0.452	0.962	10.199	8.707	0.266
1998	0.238	1.617	10.844	0.359	0.962	10.199	6.966	0.266
1999-02	0.238	1.617	10.844	0.359	0.962	10.199	6.966	0.266
2003	0.162	1.780	5.967	0.383	0.962	10.199	6.966	0.266
2004+	0.156	1.780	5.655	0.383	0.962	10.199	6.966	0.266

Table 10.8-8 LHDT – BAG1 Gram per Mile Emissions at 100,000 Miles MVEI7G v EMFAC2000

Light-Heavy Diesel Trucks								
Model Year	EMFAC2000 - BAG 1				MVEI7G			
	HC	CO	NOX	PM	HC	CO	NOX	PM
Pre 1975	0.383	1.209	3.715	0.584	2.846	10.830	13.611	1.275
1975-76	0.394	1.245	3.721	0.592	2.846	10.830	13.611	1.275
1977-79	0.400	1.263	3.724	0.596	2.708	10.830	13.492	1.275
1980-81	0.412	1.299	3.730	0.604	2.708	10.830	13.492	1.275
1982-83	0.412	1.299	3.730	0.604	2.548	10.193	12.699	1.200
1984-86	0.429	1.354	3.739	0.616	1.742	10.193	6.293	1.200
1987	0.420	1.327	3.779	0.642	1.742	10.193	6.293	1.197
1988-90	0.420	1.327	3.779	0.642	1.489	8.708	6.325	1.051
1991-93	0.311	1.457	6.911	0.120	1.010	6.153	5.967	0.563
1994	0.285	1.334	7.012	0.108	0.652	7.445	5.949	0.222
1995	0.285	1.334	7.012	0.108	0.380	7.445	5.179	0.222
1996-97	0.285	1.334	7.012	0.108	0.110	7.445	4.412	0.222
1998-99	0.065	1.172	2.318	0.096	0.110	7.445	4.412	0.222
2000-01	0.065	1.172	2.318	0.096	0.110	7.445	4.412	0.222
2002-03	0.058	1.353	1.485	0.105	0.080	7.445	3.393	0.222
2004+	0.048	1.353	1.485	0.105	0.072	7.445	2.824	0.222

Table 10.8-8 LHDT – BAG2 Gram per Mile Emissions at 100,000 Miles MVEI7G v EMFAC2000

Light-Heavy Diesel Trucks								
Model Year	EMFAC2000 - BAG 2				MVEI7G			
	HC	CO	NOX	PM	HC	CO	NOX	PM
Pre 1975	0.260	0.989	4.158	0.301	2.846	10.830	13.611	1.275
1975-76	0.268	1.019	4.165	0.305	2.846	10.830	13.611	1.275
1977-79	0.271	1.034	4.168	0.307	2.708	10.830	13.492	1.275
1980-81	0.279	1.064	4.175	0.311	2.708	10.830	13.492	1.275
1982-83	0.279	1.064	4.175	0.311	2.548	10.193	12.699	1.200
1984-86	0.291	1.109	4.185	0.317	1.742	10.193	6.293	1.200
1987	0.285	1.086	4.230	0.331	1.742	10.193	6.293	1.197
1988-90	0.285	1.086	4.230	0.331	1.489	8.708	6.325	1.051
1991-93	0.377	1.199	7.259	0.086	1.010	6.153	5.967	0.563
1994	0.346	1.098	7.365	0.077	0.652	7.445	5.949	0.222
1995	0.346	1.098	7.365	0.077	0.380	7.445	5.179	0.222
1996-97	0.346	1.098	7.365	0.077	0.110	7.445	4.412	0.222
1998-99	0.044	0.959	2.595	0.049	0.110	7.445	4.412	0.222
2000-01	0.044	0.959	2.595	0.049	0.110	7.445	4.412	0.222
2002-03	0.039	1.108	1.662	0.054	0.080	7.445	3.393	0.222
2004+	0.033	1.108	1.662	0.054	0.072	7.445	2.824	0.222

10.9 Clean Diesel Effects

In October of 1993, the state of California's clean diesel regulation which reduced the aromatic content of the fuel to 10 percent by volume, and the sulfur content to 0.05 percent by weight, was implemented. The effect of reducing the sulfur and the aromatic content is to reduce particulates (PM) and NO_x emissions. Federal clean diesel fuel, which was also implemented in 1993, has the same sulfur content as California clean diesel (0.05 % by weight) but did not mandate a reduction in aromatic content. The estimated emission reductions for clean diesel fuels to be used in EMFAC2000 were provided by the Stationary Source Division (SSD) of the ARB. SSD staff estimated fuel correction factors based on emissions testing performed on two heavy-duty engines using fuels with different sulfur and aromatic content. Table 10.9-1 and 10.9-2 include the estimated NOx and PM reductions. Post-1993 heavy-duty diesel trucks are certified using federal fuel because federal and California emissions standards are aligned starting 1991. Since federal fuel has only lower sulfur but no mandate for aromatic content, a fuel correction factor due to lower aromatics for NO_x and PM emissions was applied to post-1993 engines certified for sale in California. The South Coast Air Basin (SCAB) and Ventura County previously mandated low sulfur diesel fuel (0.05 % by weight) which has been in use since 1985. Also included in table 10.9-3 are fuel correction factors for SCAB and Ventura county for calendar years 1985 to 1993. For October 1993 and beyond, clean diesel fuel regulations were implemented statewide.

TABLE 10.9-1 Emissions Reduction due to Lower Sulfur and Aromatic Content

Model Year	Reduction Due to Low Sulfur (0.28 to 0.05 % by weight)	Reduction Due to Low Aromatic (30 to 10 % by volume)	Reduction Due to Low Aromatic (30 to 10 % by volume)	Combined Effect of Lower Sulfur and Aromatic Contents
	PM	PM	NOx	PM
Pre 1991	3.86%	16.73%	5.57%	20.59%
1991+	22.70%	10.07%	12.4%	32.77%

Table 10.9-2 Statewide Clean Diesel Fuel Correction Factors for Calendar Years 1993+

MODEL YEAR	NOX	PM
PRE-91	0.944	0.794
1991-93	0.876	0.672
1994+	0.876	0.899

Table 10.9-3 Low sulfur Diesel Fuel Correction Factors for SCAB and Ventura County only

Model Year	CALENDAR YEAR	PM
All	Pre-1985	1.000
Pre-1991	1985-1993	0.961
1991-1993	1985-1993	0.773
All	1994+	Same as statewide

10.10 Idle Emissions from HDDT

For the first time, emissions associated with idle trips are calculated in EMFAC2000. Operators of heavy-duty trucks may run the engine to power accessories or move in queue to pick up or drop off cargo. These engine on, to engine off events with no appreciable distance traveled, are defined as “idle trips”. In EMFAC2000, the idle emissions rates are obtained from emissions testing of light heavy-duty trucks by the U.S. EPA. Table 10.10-1 displays the percent of total HDDT trips that are idle, and the associated idle emission rates. Based on the HDDT activity data collected by the Air Resources Board, about five percent of all HDDT trips are assumed to be idle trips with the exception of heavy-heavy diesels, where twenty six percent of all trips are assumed to be idle trips.

Table 10.10-1 Idle Emission Factors (grams per hour)

Weight Class	Idle Trips (Percent)	Idle Emission Rates (grams per hour)			
		HC	CO	NOx	CO2
LHD	5%	44	247	396	29687
MHD	5%	44	247	396	29687
HHD	26%	44	247	396	29687
LHG	4%	27	155	2	4777
MHG	6%	27	155	2	4777

10.11 Emissions Comparison

Figures 10.11-1 to 10.11-12 show a statewide emissions inventory comparison between MVEI7G and EMFAC2000 (ver. 199f) runs for calendar years 1995, 2000, 2010 and 2020. The effect of revisions to HDDT emissions factors, activity and population distribution are reflected in this charts.

Figure 10.11-1 Statewide NOx Emissions – MVEI7G v EMFAC2000(v199f)
Heavy-Heavy Diesel Trucks

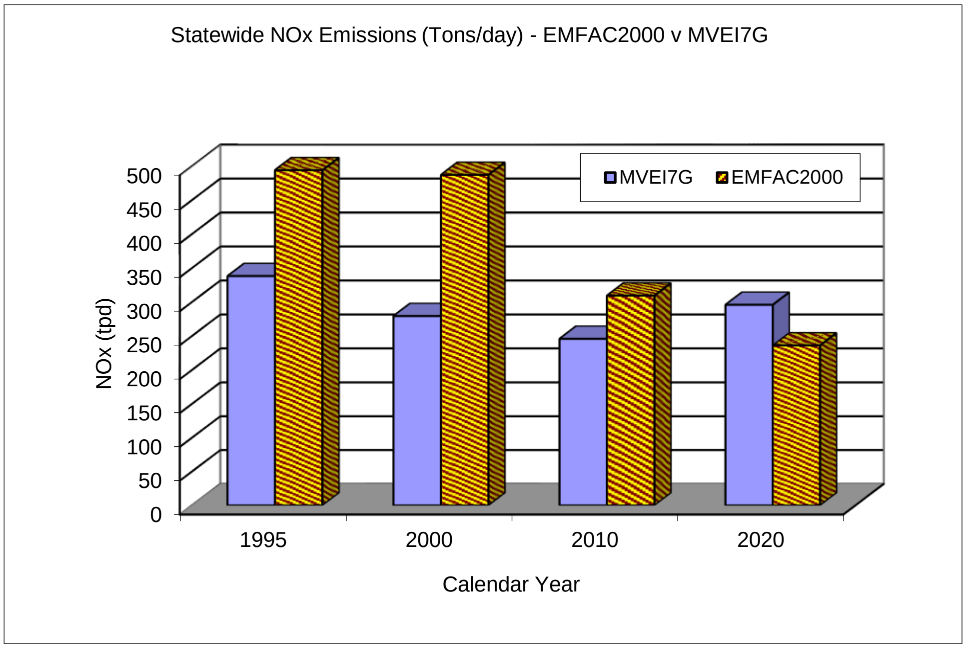


Figure 10.11-2 Statewide PM10 Emissions – MVEI7G v EMFAC2000 (v199f)
Heavy-Heavy Diesel Trucks

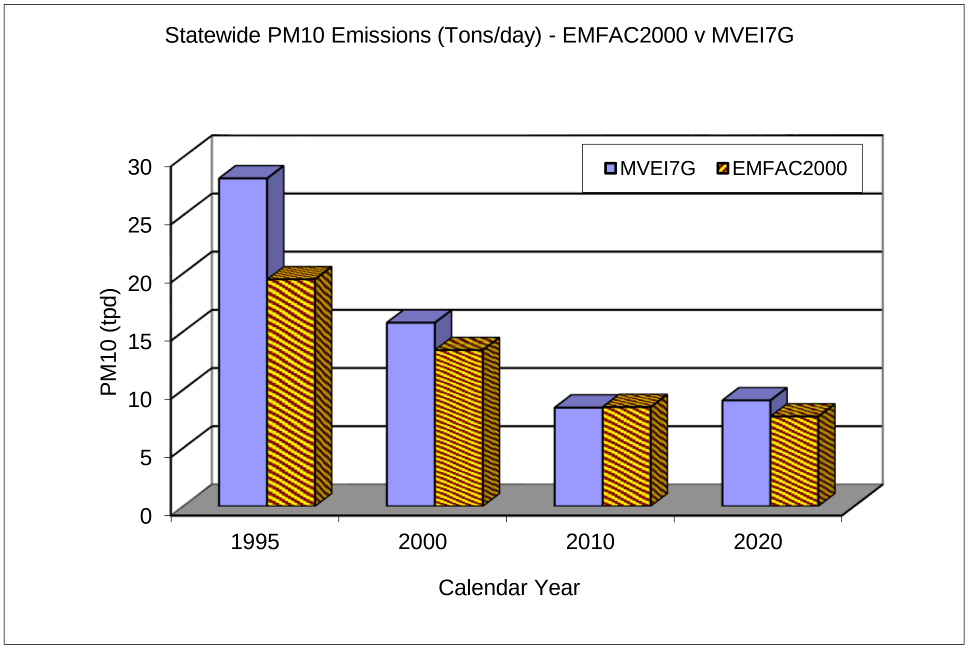


Figure 10.11-3 Statewide TOG Emissions – MVEI7G v EMFAC2000 (v199f)
Heavy-Heavy Diesel Trucks

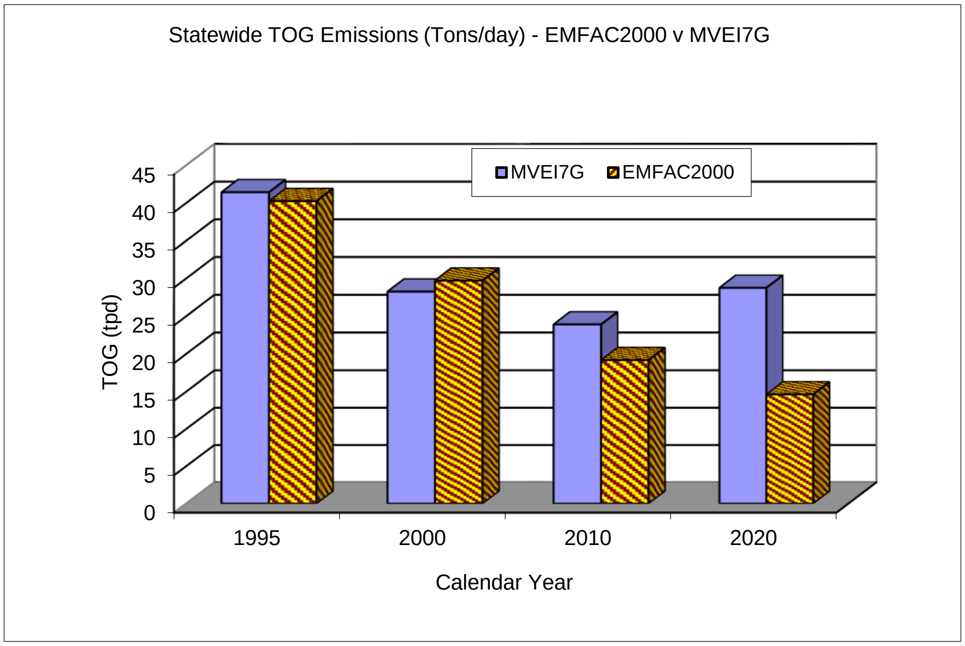


Figure 10.11-4 Statewide CO Emissions – MVEI7G v EMFAC2000 (v199f)
Heavy-Heavy Diesel Trucks

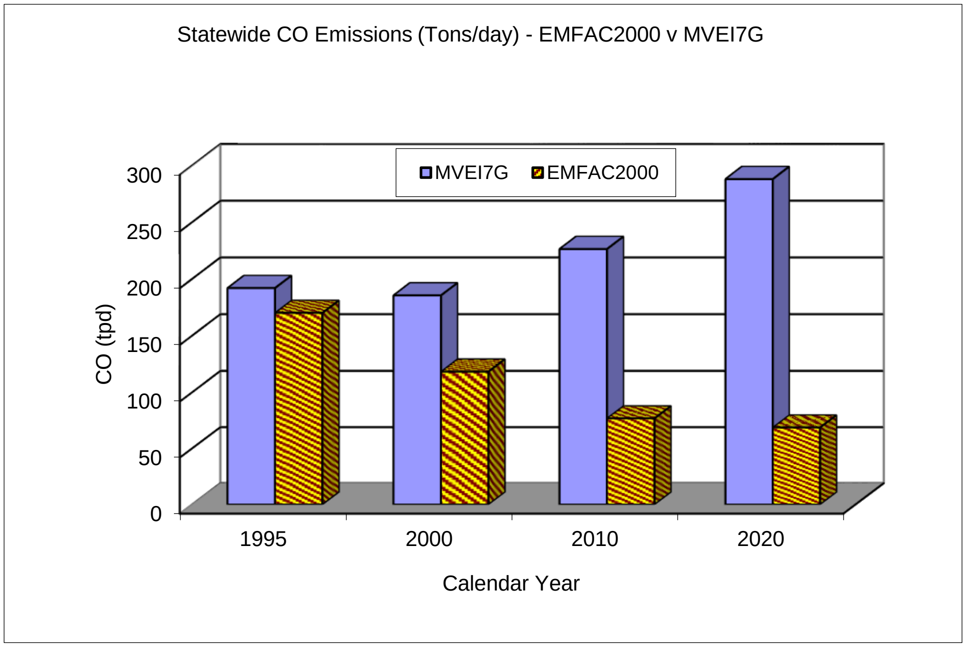


Figure 10.11-5 Statewide NOx Emissions – MVEI7G v EMFAC2000(v199f)
Medium-Heavy Diesel Trucks

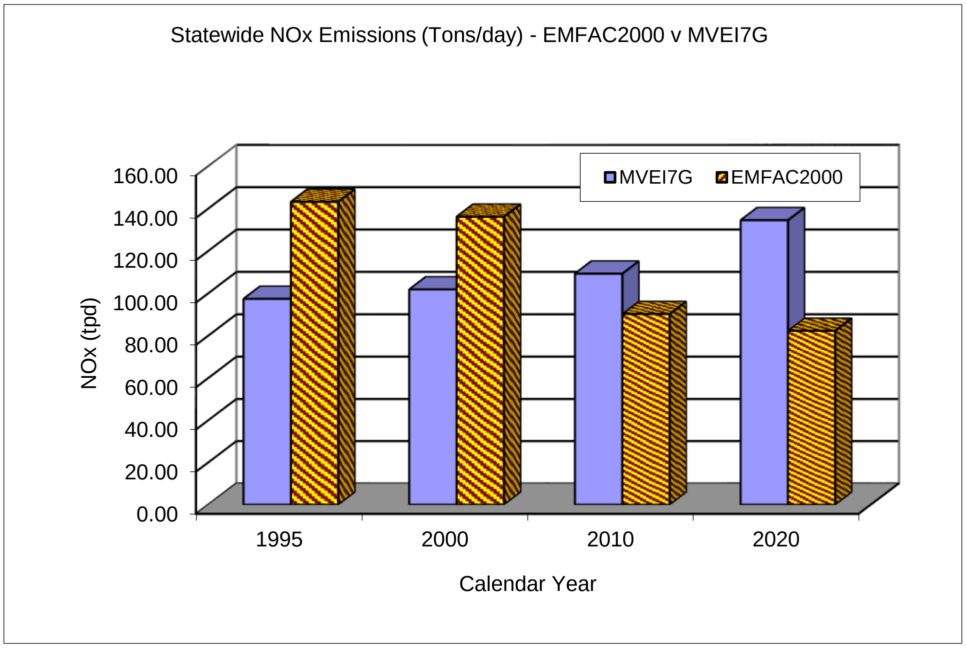


Figure 10.11-6 Statewide PM10 Emissions – MVEI7G v EMFAC2000 (v199f)
Medium-Heavy Diesel Trucks

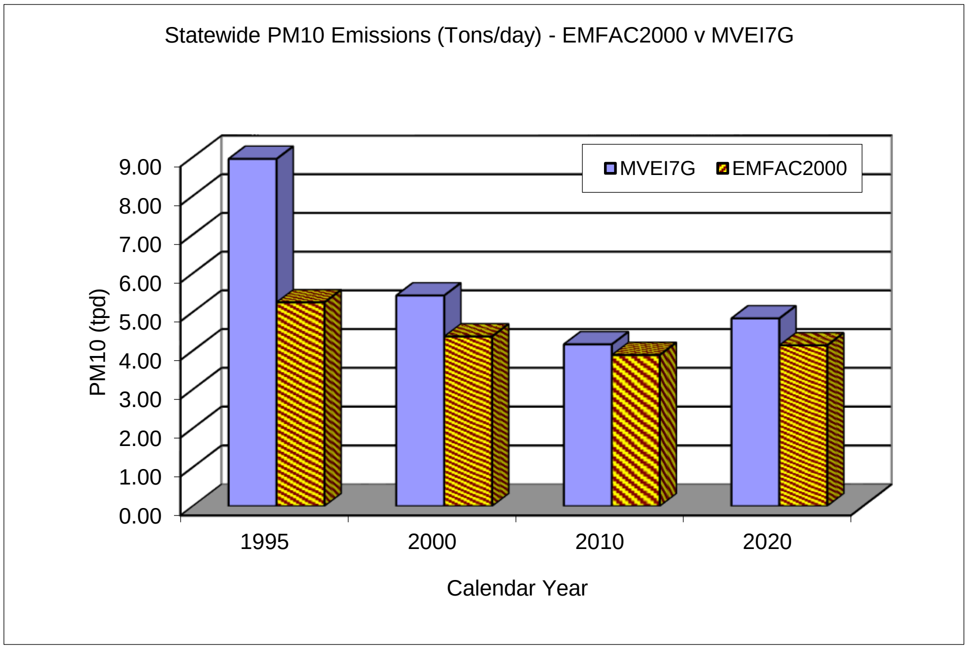


Figure 10.11-7 Statewide TOG Emissions – MVEI7G v EMFAC2000 (v199f)
Medium-Heavy Diesel Trucks

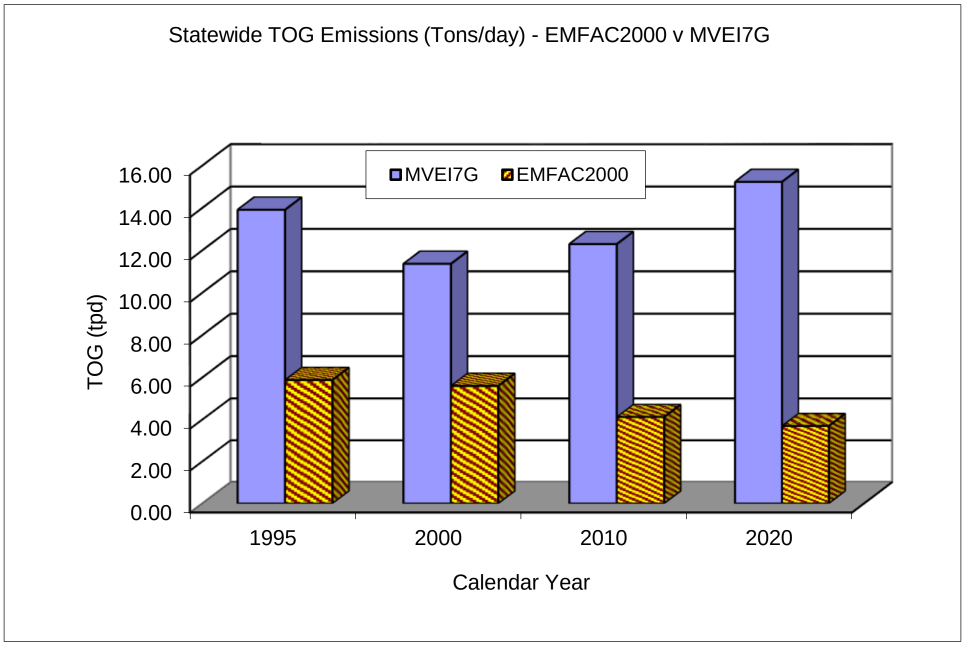


Figure 10.11-8 Statewide CO Emissions – MVEI7G v EMFAC2000 (v199f)
Medium-Heavy Diesel Trucks

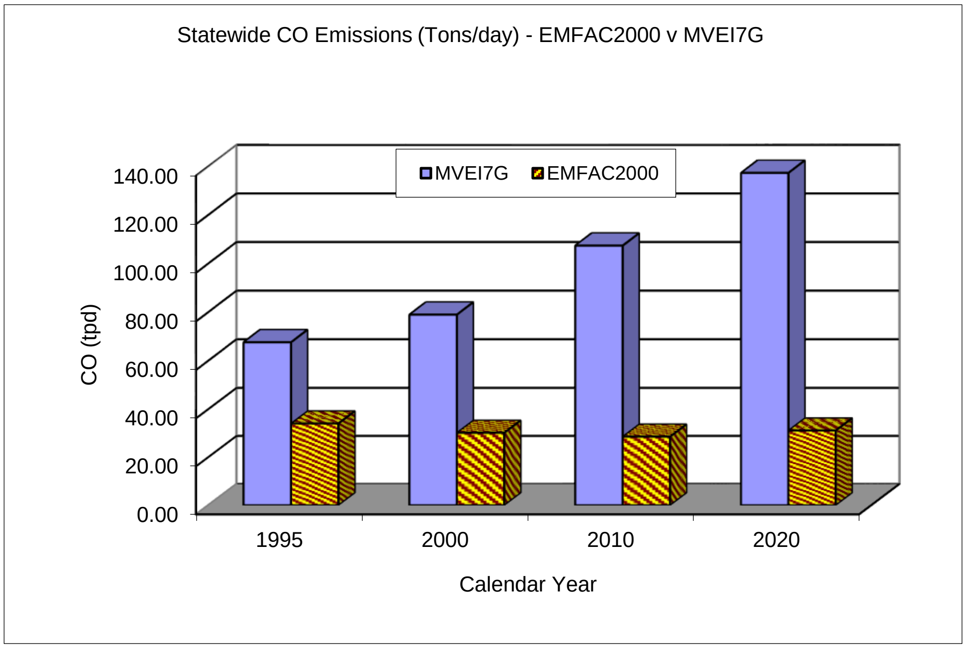


Figure 10.11-9 Statewide NOx Emissions – MVEI7G v EMFAC2000(v199f)
Light-Heavy Diesel Trucks

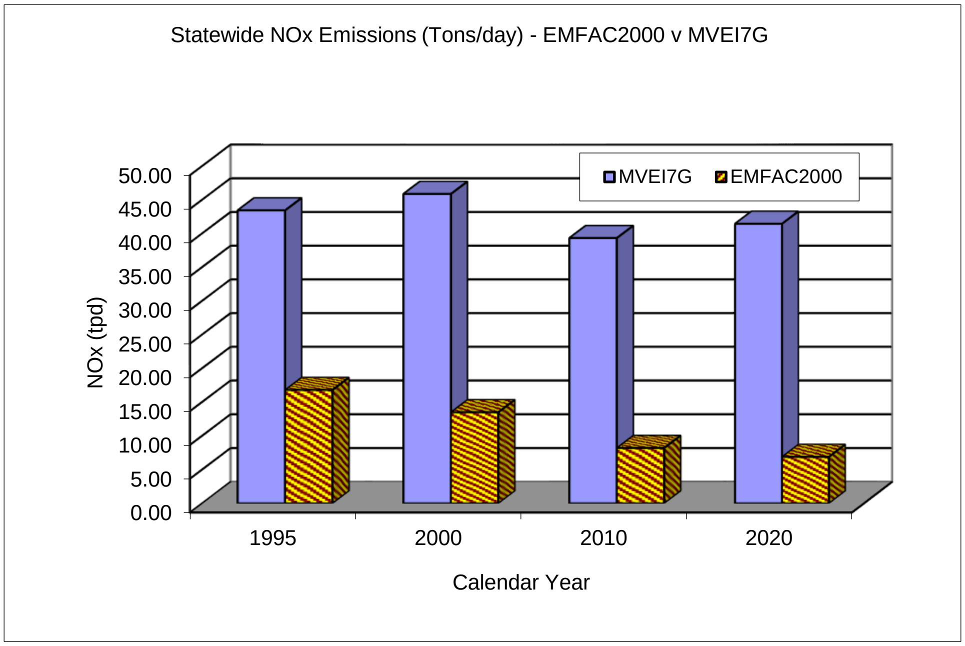


Figure 10.11-10 Statewide PM10 Emissions – MVEI7G v EMFAC2000 (v199f)
Light-Heavy Diesel Trucks

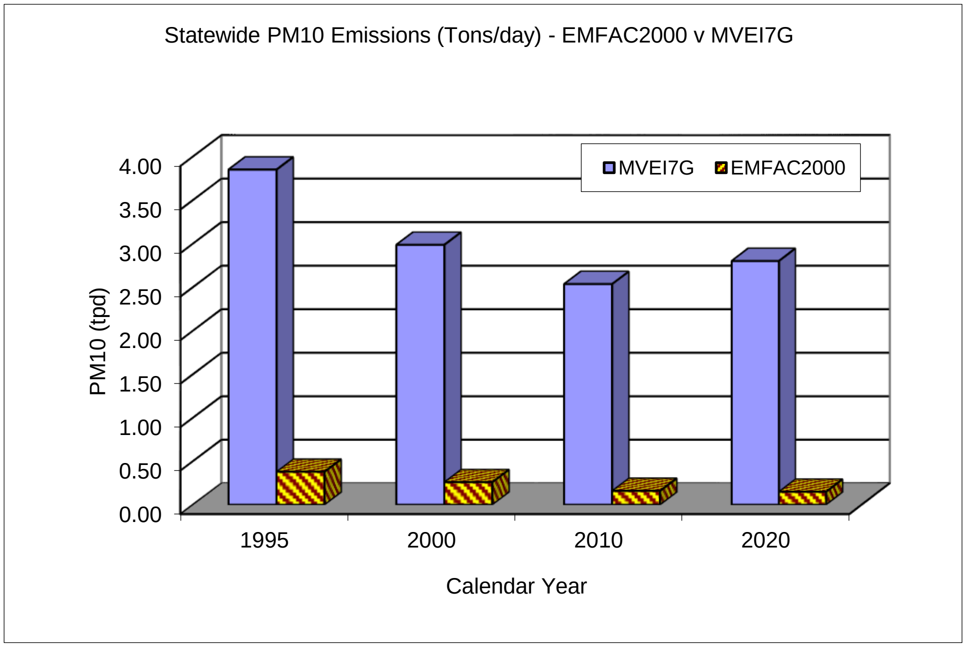


Figure 10.11-11 Statewide TOG Emissions – MVEI7G v EMFAC2000 (v199f)
Light-Heavy Diesel Trucks

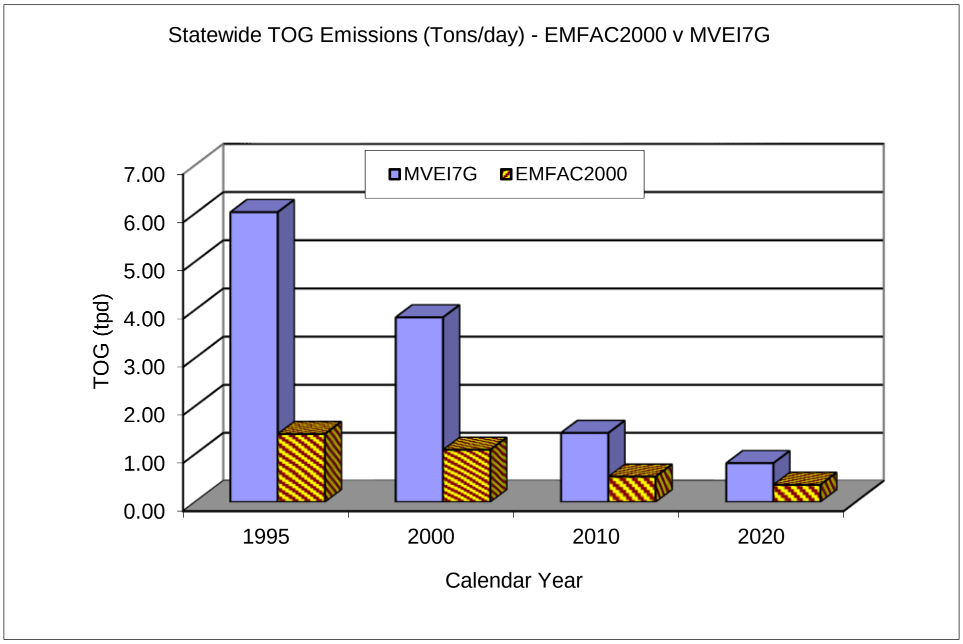
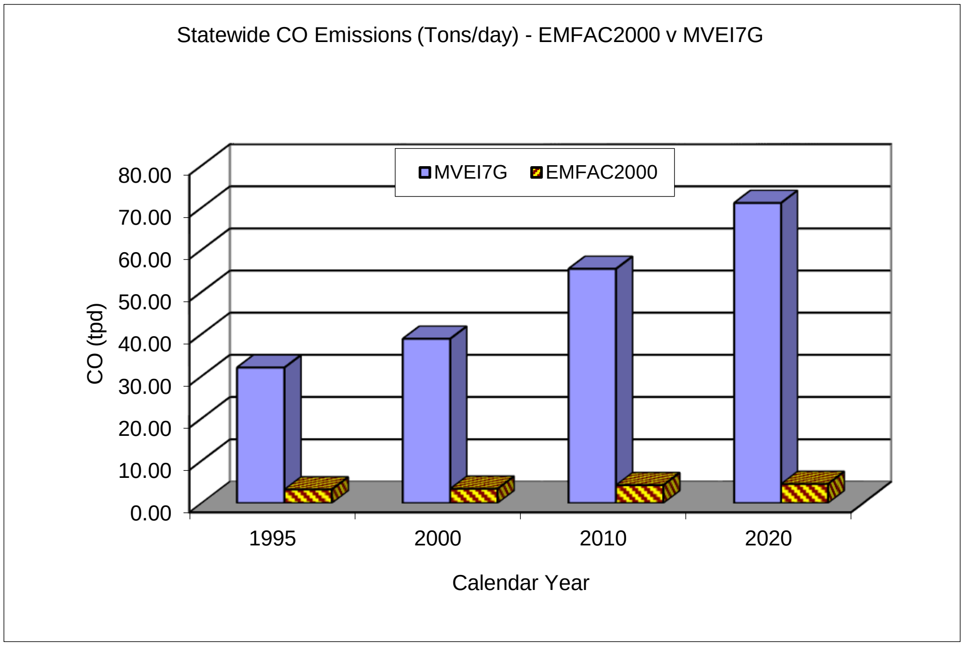


Figure 10.11-12 Statewide CO Emissions – MVEI7G v EMFAC2000 (v199f)
Light-Heavy Diesel Trucks



10.12 Heavy-Duty Gasoline Trucks (HDGT) Emission Factors

Similar to heavy-duty diesel-powered trucks, HDGTs with a gross vehicle weight of 8,501 pounds or greater are classified in the following manner:

Table 10.12-1 Heavy-Duty Gasoline Trucks Weight Class

GVW in lbs	Vehicle Class
8,501 to 14,000	Light-Heavy Duty Trucks (LHGT)
14,001 to 33,000	Medium-Heavy Duty Trucks (MHGT)
> 33,000	Hevay-Heavy Duty Trucks (HHGT)

For heavy-duty gasoline engines, the emissions and deterioration rates are same as those used in EMFAC7G. In EMFAC7G, the heavy-duty gasoline emission factors are based on gram per brake horsepower hour (g/bhp-hr) emission rates derived from engine test data collected from in-use testing and certification test data. The g/bhp-hr emission rates are then converted into grams per mile emission factors using conversion factors defined by the following formula:

$$CF = (\text{Fuel density})/(BSFC*MPG)$$

Where CF = conversion factor in bhr-hr/mile
BSFC = brake specific fuel consumption in lb/bhp-hr
MPG = fuel economy in miles per gallon.

The gram per brake horsepower emission and deterioration rates for pre-1998 models remained unchanged from those in EMFAC7F. In 1998 the 4.0 g/bhp-hr standard took effect and in the year 2004 a 2.5 g/bhp-hr NO_x+NMHC standard will be implemented. The emission rates for the 4.0 g/bhp-hr were derived by taking the ratio of the standards and applying them to the 1997 NOx emission and deterioration rates. For the 2.5 g/bhp-hr NO_x+NMHC standard in 2004, a certification standard of 0.375 g/bhp-hr for NMHC and 2.115 g/bhp-hr for NO_x was assumed. Table 10.12-2 gives the zero mile emission (g/bhp-hr) and deterioration (g/bhp-hr per 10000 miles) rates for heavy-duty gasoline engines.

The weight class specific gram per mile emission rates were calculated by multiplying the g/bhp–hr engine emission rates given in Table 10.12-2 with the weight class specific conversion factors (same as in EMFAC7G) given in Table 10.12-3. The engine deterioration rates are also multiplied by conversion factors to obtain the gram per mile per 10000 miles deterioration rates.

For model years 1995 and beyond, the LHG emission rates take into account the effects of the reclassification of light-heavy-duty gasoline trucks into medium duty trucks (MDV) and the effects of the low emission vehicle regulations. Table 10.12-4 gives the implementation schedule of both the reclassification of light-heavy gasoline trucks into the MDV category and the implementation of the low emission vehicle (LEV) and Ultra

Low Emission Vehicle (ULEV). Table 10.12-5 gives the emission rates associated with these classes of vehicles.

Based on the information provided by various manufacturers, it is believed that 72% of the 1995+ LHGTs are engine certified while the remainder are chassis certified. The base emission rates for chassis certified LHGTs were calculated by taking the ratios of the 1994 medium duty truck standard (trucks with GVW between 6000 to 8500 lbs.) to the 1995 medium duty truck, LEV and ULEV standards applicable to LHGTs and applying them to the 1994 medium duty truck emission rates. The emission rates for engine certified LHG trucks were calculated by taking the ratio of the 1994 engine certification standards to the 1995 medium duty truck, LEV and ULEV engine certification standards and applying them to the 1994 LHGT base emission rates.

Table 10.12-6 shows the combined medium duty, LEV and ULEV zero mile emission and deterioration rates for LHGTs while Table 10.12-7 shows zero mile emission and deterioration rates for MHGTs.

Table 10.12-2 Heavy-Duty Gasoline Engine Emissions Rates

Heavy-Duty Gasoline Engine Emission Rates (g/bhp-hr) and Deterioration Rates (g/bhp-hr per 10000 miles)						
	HC		**CO**		**NOx**	
Model year	**ZM**	**DR**	**ZM**	**DR**	ZM	**DR**
Pre - 1977	5.19	0.18	101.00	4.69	5.00	0.10
1977 - 1984	3.59	0.18	55.95	4.69	4.78	0.10
1985	2.55	0.06	39.90	0.96	3.99	0.10
1986	2.23	0.06	31.39	0.96	3.99	0.10
1987 - 1997	1.00	0.09	13.70	0.60	3.99	0.10
1998+	0.22	0.02	13.70	0.60	1.70	0.04

Table 10.12-3 Heavy-Duty - g/bhp-hr to g/mile - Conversion Factors

Model Year	**LHGT**	**MHGT**
Pre 1973	1.0	1.5
1973 – 1988	1.0	1.5
1989 – 1993	0.9	1.5
1994 – 1997	0.9	1.4
1998+	0.9	1.4

Table 10.12-4 Implementation Schedule of LHGT

Implementation Schedule of Light-Heavy-Duty Trucks Sales Fraction by Model Year			
Model Year	**MED**	**LEV**	**ULEV**
1995	1.00	0.00	0.00
1996-2001	0.50	0.50	0.00
2002-2003	0.00	1.00	0.00
2004	0.00	0.00	1.00

Table 10.12-5 Emission Rates for LEV, ULEV and MDV Standard LHGT

	HC		**CO**		**NOx**	
Category	ZM	DR	ZM	DR	ZM	DR
MDV	0.388	0.036	8.893	0.373	1.955	0.058
LEV	0.279	0.026	8.893	0.373	1.447	0.041
ULEV	0.224	0.020	8.893	0.373	1.227	0.036

Table 10.12-6 Zero mile emission and Deterioration Rates - LHGT

Zero mile emission (g/mi) and Deterioration (g/mi per 10k miles) Rates - LHGT								
MODEL YEAR	HC		CO		**NOx**		PM	
	ZM	DR	ZM	DR	ZM	DR	**ZM**	DR
Pre 1977	5.19	0.180	101.00	4.690	5.00	0.100	1.23	0.036
1977-84	3.59	0.180	55.95	4.690	4.78	0.100	1.23	0.036
1985	2.55	0.060	39.90	0.960	3.99	0.100	1.23	0.036
1986	2.23	0.060	31.39	0.960	3.99	0.100	1.23	0.036
1987-88	1.00	0.090	13.70	0.600	3.99	0.100	1.23	0.036
1989-94	0.90	0.081	12.33	0.540	3.59	0.090	1.23	0.036
1995	0.64	0.058	10.61	0.457	2.77	0.074	1.23	0.036
1996-01	0.39	0.036	8.89	0.373	1.95	0.058	1.23	0.036
2002-03	0.28	0.026	8.89	0.373	1.45	0.041	1.23	0.036
2004+	0.22	0.020	8.89	0.373	1.23	0.036	1.23	0.036

Table 10.12-7 Zero mile emission and Deterioration Rates - MHDG

Zero mile emission (g/mi) and Deterioration (g/mi per 10k miles) Rates - MHDG								
MODEL YEAR	HC		CO		**NOx**		PM	
	ZM	DR	ZM	DR	ZM	DR	**ZM**	DR
Pre 1977	8.87	0.270	151.50	7.035	7.50	0.150	0.054	0.000
1977-84	5.38	0.270	83.93	7.035	7.17	0.150	0.054	0.000
1985	3.83	0.090	59.85	1.440	5.99	0.150	0.054	0.000
1986	3.34	0.090	47.09	1.440	5.99	0.150	0.054	0.000
1987-93	1.50	0.135	20.55	0.900	5.99	0.150	0.054	0.000
1994-97	1.40	0.126	19.18	0.840	5.59	0.140	0.054	0.000
1998-03	1.40	0.126	19.18	0.840	4.47	0.140	0.054	0.000
2004+	0.31	0.023	19.18	0.840	1.90	0.058	0.054	0.000

10.13 Diesel Urban Bus Emission Factors

In MVEI7G emission factors for diesel urban buses were derived from chassis based emissions test data collected from 1962 to 1990 model year buses tested over the New York Bus Composite Cycle (NYBC). The inertia weight used in this test procedure was 19500 lbs, which is less than the average weight of an empty bus (28,000 lbs). In EMFAC2000, emissions factors were derived from chassis dynamometer based emissions test data obtained from the National Renewable Energy Laboratory (NREL). Under contract to NREL, the West Virginia University, Department of Mechanical and Aerospace Engineering tested buses on the standard Central Business District (CBD) test cycle using various test fuels. The CBD test cycle is part of the Transit Coach Design Operating Duty Cycle (SAE J1376, July 1982) designed to simulate driving conditions experienced by buses during a typical route in a downtown business district. Data from 51 buses tested on the CBD using federal diesel fuel (D2) was obtained from NREL. The test weight used was the curb weight plus half passenger load and the weight of the driver. The test data used to derive the emission factors in MVEI7G were not used in the derivation of new emission factors for EMFAC2000 since the two data sets were obtained form two different test cycles with different inertia weights. The raw data used is shown in Tables 10.13-A1 and 10.13-A2 in the appendix.

10.14 Diesel Urban Bus - Emissions Data Analysis

The emissions data used in this analysis represented diesel transit buses built between 1988 to 1996. Repeat tests were first averaged and the results were then plotted as a function of the model year as shown in Figures 10.14-1 to 10.14-4. The scatter plot was then curve-fit to determine the equation.

Pre-1999 Model Years:-

Using the regression equations, emissions are calculated for each model year that are in the data set range, i.e. between 1988 to 1996. Emission factors for model years prior to 1988 were made equal to the calculated emission factor for 1988, while emission factors for model years 1997 to 1998 were made equal to the calculated emissions for 1996 model year buses. Model years were then grouped together based on California transit bus emissions standards (Table 10.14-A3). An average emission factor was then calculated for each model year group. The results are shown in Table 10.14-1.

The curve for NOx emissions, Figure 10.14-1, shows an increasing trend in NOx emissions for model years between 1992 to 1996 although the emissions standard for NOx goes down from 5 g/bhp-hr in 1991-93 to 4 g/bhp-hr in 1996. An explanation for this is that the CBD test procedure is also capturing some off-cycle NOx emissions. In EMFAC2000, it is assumed that off-cycle NOx will be completely eliminated by 1999.

1999-2007 Model Years:-

For the 1999-02 model year group the NOx and PM emissions were calculated by taking the ratio of the standards between the 1999-02 and the 1991-93 model year groups and multiplying the ratio to the 1991-93 model year emission factors. Because of same emissions standards, the 1999-02 model year HC and CO emissions were assumed to be equal to the 1996-98 model year group. Emissions for 2003+ model year groups were calculated using the ratio of standards relative to the 1991-93 model year group. The resulting emissions by model year group are shown on Table 10.14-1.

2008+ Model Years

Since the new bus rule adopted in February 24, 2000 specifies that 15% of the buses in fleets of more than 200 buses will be zero emission buses (ZEBs), a fleet average emission standard was first calculated in order to determine the ratio of standards between the 2008+ and 1991-93 model years. From a survey of transit bus fleet operators in California conducted by the ARB, the fraction of buses in fleets of more than 200 buses was found to be equal to 0.75. Thus the fraction of buses that are ZEBs is 11% (15% of 0.75). The 2008+ model year fleet average emission standard is then equal to = (2007 emission standard)*0.89. The results of this operation were then used to calculate the ratio of standards between the 2008+ and 1991-93 model year groups.

Figures 10.14-A1 to 10.14-A4 in the appendix show comparison of MVEI7G emissions factors versus EMFAC2000 emissions factors.

10.15 Diesel Urban Bus - Deterioration Rates

In MVEI7G, analysis of emission factors as a function of odometer data showed no significant deterioration of emission control systems for buses. This may be due to the regular maintenance performed by transit bus fleet operators. Based on this finding, in MVEI7G, deterioration rates for all model years were assumed to be zero. The same assumption is also applied in EMFAC2000. Therefore, zero mile emission rates for buses were made equal to the average emission rates calculated above.

Table 10.14-1 Diesel Urban Bus - NOx Emissions in g/mi

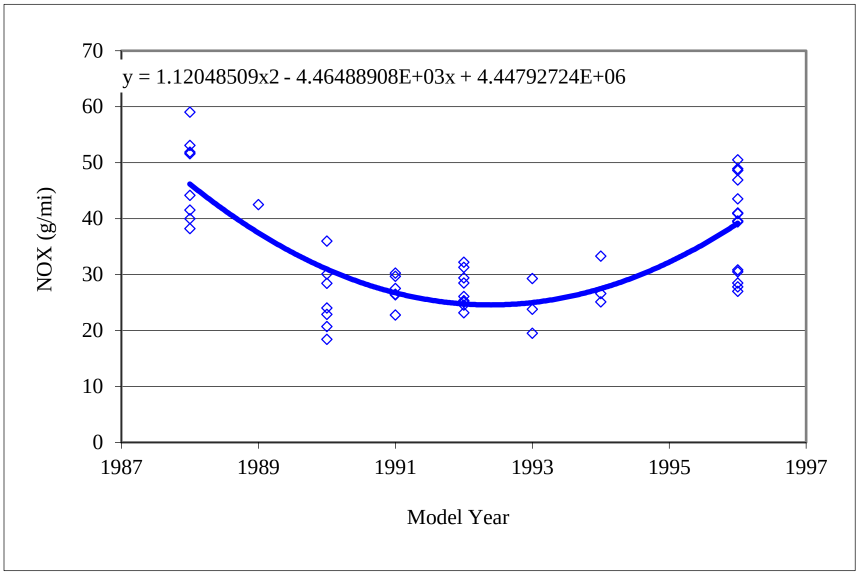


Table 10.14-2 Diesel Urban Bus - PM Emissions in g/mi

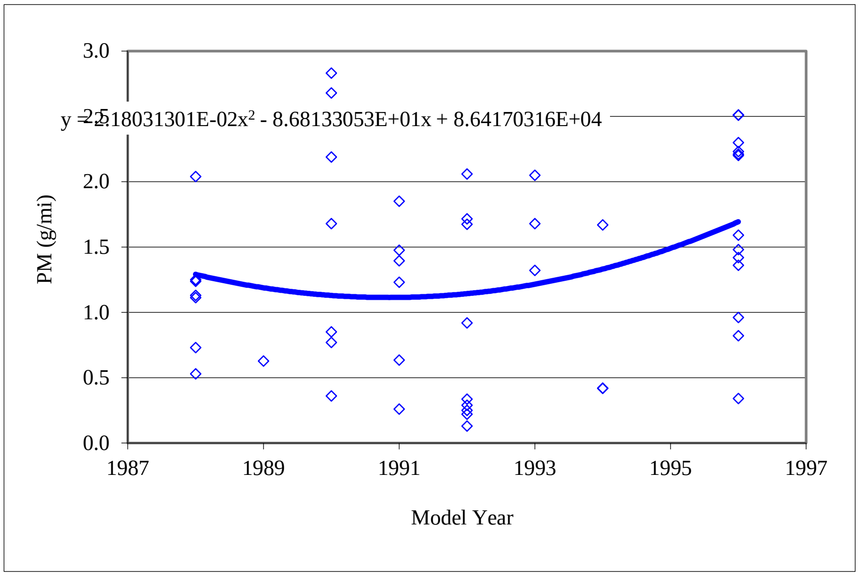


Table 10.14-3 Diesel Urban Bus - HC Emissions in g/mi

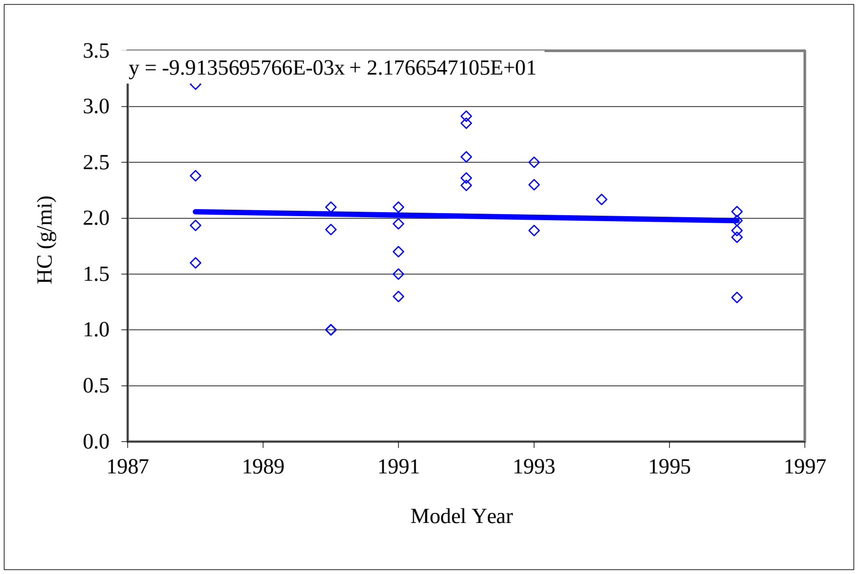


Table 10.14-4 Diesel Urban Bus - CO Emissions in g/mi

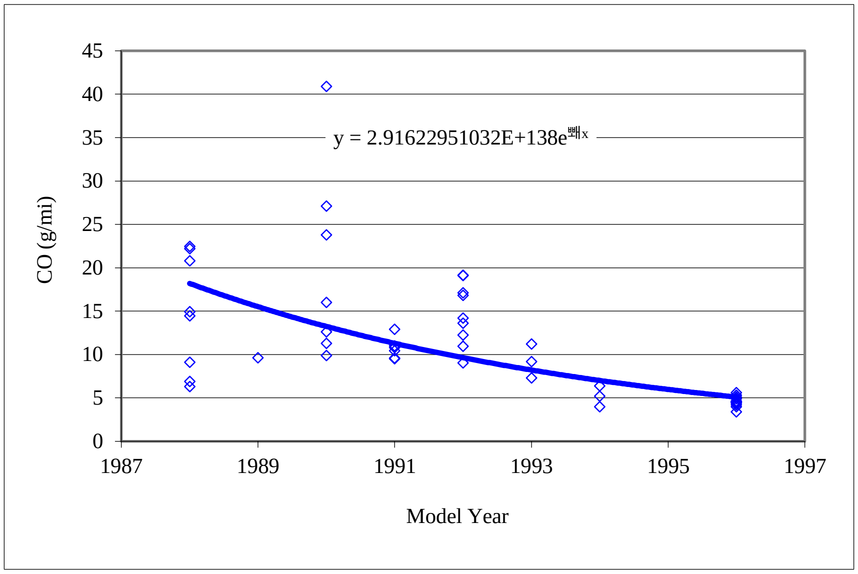


Table 10.14-1 Diesel Urban Bus Emission Factors

Model Year	HC	CO	NOX	PM
	g/mile			
PRE 1987	2.06	18.19	46.18	1.29
1987-90	2.05	16.28	40.20	1.22
1991-93	2.02	9.71	25.49	1.16
1994-95	1.99	6.50	29.84	1.41
1996-98	1.98	5.10	39.17	1.69
1999-02	1.98	5.10	20.39	0.58
2003	0.84	4.05	10.20	0.12
2004-06	0.84	4.05	2.55	0.12
2007	0.84	4.05	1.02	0.12
2008	0.75	4.05	0.90	0.10

Table 10.1-A1 Raw Data from New York Department of Energy and Conservation[1]

Vehicle ID	Engine Type	Model Year	Make	GVW (lb)	Test Weight (lb)	Odometer (miles)	Replicate Test	THC	CO	NOX	PM mg/mi	CO2 g/mi	Fuel Economy (mpg)
								g/mi					
1	Caterpillar 3116	1997	GMC	33000	23100	3500	FALSE	0.08	4.93	16.60	600	1976	4.86
1	Caterpillar 3116	1997	GMC	33000	23100	3500	TRUE	0.15	5.53	16.90	470	2011	4.77
1	Caterpillar 3116	1997	GMC	33000	23100	3500	TRUE	0.19	6.21	17.60	500	1996	4.80
1	Caterpillar 3116	1997	GMC	33000	23100	3500	TRUE	0.12	6.80	17.20	550	2026	4.73
1	Caterpillar 3116	1997	GMC	33000	23100	3500	TRUE	0.12	5.24	.	440	1957	4.90
2	Caterpillar 3208	1989	FORD	33000	23100	66300	FALSE	0.63	6.09	18.80	1840	1601	5.98
2	Caterpillar 3208	1989	FORD	33000	23100	66300	TRUE	0.60	6.05	20.50	1660	1654	5.79
2	Caterpillar 3208	1989	FORD	33000	23100	66300	TRUE	0.71	5.87	20.50	1730	1656	5.78
2	Caterpillar 3208	1989	FORD	33000	23100	66300	TRUE	0.57	5.46	20.80	1560	1599	5.99
2	Caterpillar 3208	1989	FORD	33000	23100	66300	TRUE	0.60	5.51	20.50	1520	1624	5.90
3	Caterpillar 3116	1990	GMC	30000	21000	11623	FALSE	0.81	3.35	14.00	.	1580	6.07
3	Caterpillar 3116	1990	GMC	30000	21000	11623	TRUE	0.80	3.26	14.00	1750	1608	5.97
3	Caterpillar 3116	1990	GMC	30000	21000	11623	TRUE	0.79	3.05	13.80	1510	1582	6.07
4	Caterpillar 3208	1985	FORD	50000	27000	42985	FALSE	1.66	11.70	20.50	1950	2292	4.16
4	Caterpillar 3208	1985	FORD	50000	27000	42985	TRUE	1.66	10.30	20.60	1580	2290	4.17
4	Caterpillar 3208	1985	FORD	50000	27000	42985	TRUE	1.49	9.70	20.40	1370	2259	4.23
4	Caterpillar 3208	1985	FORD	50000	27000	42985	TRUE	1.47	9.70	20.70	1360	2211	4.32
5	Cummins B5.9-190	1995	FORD	26000	18200	26100	FALSE	0.15	2.33	12.10	380	1356	7.09
5	Cummins B5.9-190	1995	FORD	26000	18200	26100	TRUE	0.13	2.03	11.90	320	1338	7.18
5	Cummins B5.9-190	1995	FORD	26000	18200	26100	TRUE	0.13	2.27	11.40	340	1346	7.14
6	Cummins B5.9-190	1994	FORD	31000	21000	8900	FALSE	0.25	1.65	14.10	.	1561	6.16
6	Cummins B5.9-190	1994	FORD	31000	21000	8900	TRUE	0.25	1.56	14.00	410	1537	6.26
6	Cummins B5.9-190	1994	FORD	31000	21000	8900	TRUE	0.28	1.54	13.80	330	1559	6.17
6	Cummins B5.9-190	1994	FORD	31000	21000	8900	TRUE	0.27	1.47	13.90	290	1520	6.33
7	Cummins C8.3-210	1993	FORD	36000	25200	2600	FALSE	1.00	2.87	11.20	920	1812	5.30
7	Cummins C8.3-210	1993	FORD	36000	25200	2600	TRUE	1.00	2.90	11.30	670	1818	5.28
7	Cummins C8.3-210	1993	FORD	36000	25200	2600	TRUE	1.13	2.96	11.40	630	1821	5.27
8	Cummins C8.3-225	1996	FORD	33000	23100	8300	FALSE	0.53	1.93	15.30	890	1885	5.10
8	Cummins C8.3-225	1996	FORD	33000	23100	8300	TRUE	0.52	1.89	15.40	760	1883	5.11
8	Cummins C8.3-225	1996	FORD	33000	23100	8300	TRUE	0.49	1.71	15.30	640	1847	5.21
8	Cummins C8.3-225	1996	FORD	33000	23100	8300	TRUE	0.48	1.60	15.20	590	1792	5.37
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	FALSE	0.51	2.70	15.10	830	1744	5.51
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	TRUE	0.52	2.53	15.50	780	1773	5.42
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	TRUE	0.62	2.38	15.90	750	1757	5.47
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	TRUE	0.55	2.37	16.20	720	1764	5.45
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	FALSE	0.56	2.78	16.50	900	1737	5.53
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	TRUE	0.73	2.67	16.30	790	1800	5.34
9	Cummins C8.3-225	1996	FORD	33000	23100	9400	TRUE	0.59	2.34	16.30	700	1807	5.32

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[1] A test program entitled "Characterization and Control of Heavy-Duty Vehicle Emissions in the New York Metropolitan Area", conducted by West Virginia University for Energy and Environmental Analysis under contract to the New York State of Environmental Conservation and Energy.

Table 10.1-A1 Raw Data from New York Department of Energy and Conservation (*Contd.*)

Vehicle ID	Engine Type	Model Year	Make	GVW (lb)	Test Weight (lb)	Odometer (miles)	Replicate Test	THC	CO	NOX	PM mg/mi	CO2 g/mi	Fuel Economy (mpg)
10	Cummins HTC-300	1984	FORD	66000	42000	275851	FALSE	1.74	5.36	27.90	1600	2167	4.42
10	Cummins HTC-300	1984	FORD	66000	42000	275851	TRUE	1.56	5.17	27.70	1570	2184	4.39
10	Cummins HTC-300	1984	FORD	66000	42000	275851	TRUE	1.68	5.47	29.10	1550	2193	4.37
11	Cummins L-10	1996	NAVISTAR	32000	28000	73393	FALSE	3.29	6.96	11.10	1410	1420	6.69
11	Cummins L-10	1996	NAVISTAR	32000	28000	73393	TRUE	3.32	6.56	11.10	1320	1463	6.50
11	Cummins L-10	1996	NAVISTAR	32000	28000	73393	TRUE	2.96	6.08	11.00	1180	1420	6.70
12	Cummins L-10	1994	INT.HARV	65000	42000	87319	FALSE	2.75	5.52	16.50	1120	2011	4.75
12	Cummins L-10	1994	INT.HARV	65000	42000	87319	TRUE	2.63	5.08	16.90	1000	1995	4.79
12	Cummins L-10	1994	INT.HARV	65000	42000	87319	TRUE	2.40	5.18	16.90	950	1996	4.79
12	Cummins L-10	1994	INT.HARV	65000	42000	87319	TRUE	2.78	5.10	16.90	900	2032	4.71
12	Cummins L-10	1994	INT.HARV	65000	50000	87319	FALSE	2.93	4.93	16.70	1210	2148	4.45
12	Cummins L-10	1994	INT.HARV	65000	50000	87319	TRUE	2.77	5.08	17.00	1010	2181	4.39
12	Cummins L-10	1994	INT.HARV	65000	50000	87319	TRUE	2.91	4.95	17.50	1010	2160	4.43
12	Cummins L-10	1994	INT.HARV	65000	27000	87319	FALSE	2.83	4.41	13.10	900	1767	5.41
12	Cummins L-10	1994	INT.HARV	65000	27000	87319	TRUE	2.89	4.25	13.50	1050	1727	5.53
12	Cummins L-10	1994	INT.HARV	65000	27000	87319	TRUE	3.05	4.38	13.60	1030	1705	5.60
13	Cummins M-11	1998	NAVISTAR	32000	36400	43000	FALSE	0.55	3.01	14.70	790	1733	5.54
13	Cummins M-11	1998	NAVISTAR	32000	36400	43000	TRUE	0.54	3.31	15.30	610	1754	5.48
13	Cummins M-11	1998	NAVISTAR	32000	36400	43000	TRUE	0.56	3.18	15.10	520	1699	5.65
14	Cummins M11-280E	1998	HEIL	65098	42000	10100	FALSE	0.70	2.75	38.00	660	2850	3.37
14	Cummins M11-280E	1998	HEIL	65098	42000	10100	TRUE	0.64	2.77	37.00	600	2890	3.33
14	Cummins M11-280E	1998	HEIL	65098	42000	10100	TRUE	0.62	2.63	37.10	590	2882	3.34
15	Cummins M11-280E	1998	FREIGHTLINER	41500	29050	800	FALSE	0.57	2.02	24.60	510	2326	4.14
15	Cummins M11-280E	1998	FREIGHTLINER	41500	29050	800	TRUE	0.55	2.07	24.90	440	2353	4.09
15	Cummins M11-280E	1998	FREIGHTLINER	41500	29050	800	TRUE	0.54	2.08	22.70	450	2256	4.26
15	Cummins M11-280E	1998	FREIGHTLINER	41500	29050	800	TRUE	0.58	2.09	21.70	400	2193	4.39
15	Cummins M11-280E	1998	FREIGHTLINER	41500	29050	800	TRUE	0.54	2.12	23.10	410	2231	4.31
16	Cummins M11-330E	1995	FREIGHTLINER	31020	21700	113300	FALSE	0.63	2.62	15.30	670	1433	6.70
16	Cummins M11-330E	1995	FREIGHTLINER	31020	21700	113300	TRUE	0.60	2.55	15.90	570	1435	6.69
16	Cummins M11-330E	1995	FREIGHTLINER	31020	21700	113300	TRUE	0.64	2.67	17.70	510	1433	6.70
16	Cummins M11-330E	1995	FREIGHTLINER	31020	21700	113300	TRUE	0.63	2.95	14.80	540	1444	6.65
17	Detroit Diesel Corp. Series 50	1966	INT.HARV	85000	48000	353000	FALSE	0.05	10.35	28.10	540	2461	3.89
17	Detroit Diesel Corp. Series 50	1966	INT.HARV	85000	48000	353000	TRUE	0.04	9.05	31.30	500	2376	4.03
17	Detroit Diesel Corp. Series 50	1966	INT.HARV	85000	48000	353000	TRUE	0.09	9.44	30.10	400	2323	4.12
18	Ford FM07 BEPCS	1988	FORD	26500	18550	199600	FALSE	0.99	4.87	21.20	960	1570	6.10
18	Ford FM07 BEPCS	1988	FORD	26500	18550	199600	TRUE	0.91	5.01	21.10	900	1639	5.84
18	Ford FM07 BEPCS	1988	FORD	26500	18550	199600	TRUE	0.90	4.39	20.30	950	1582	6.06
18	Ford FM07 BEPCS	1988	FORD	26500	18550	199600	TRUE	0.90	4.97	20.20	930	1589	6.03
18	Ford FM07 BEPCS	1988	FORD	26500	18550	199600	TRUE	0.87	5.03	19.70	910	1560	6.14

Table 10.1-A1 Raw Data from New York Department of Energy and Conservation (*Contd.*)

Vehicle ID	Engine Type	Model Year	Make	GVW (lb)	Test Weight (lb)	Odometer (miles)	Replicate Test	THC	CO	NOX	PM mg/mi	CO2 g/mi	Fuel Economy (mpg)
19	Ford KFM07-8FPEZ	1989	FORD	52000	36400	32900	FALSE	1.44	6.81	18.90	3090	2580	3.71
19	Ford KFM07-8FPEZ	1989	FORD	52000	36400	32900	TRUE	1.31	6.30	18.40	2210	2493	3.85
19	Ford KFM07-8FPEZ	1989	FORD	52000	36400	32900	TRUE	1.31	6.14	18.00	1900	2509	3.82
19	Ford KFM07-8FPEZ	1989	FORD	52000	52000	32900	FALSE	1.42	6.79	20.30	2190	2861	3.35
19	Ford KFM07-8FPEZ	1989	FORD	52000	52000	32900	TRUE	1.31	6.50	21.00	2040	2870	3.34
19	Ford KFM07-8FPEZ	1989	FORD	52000	52000	32900	TRUE	1.31	6.41	20.60	2090	2835	3.38
19	Ford KFM07-8FPEZ	1989	FORD	52000	26000	32900	FALSE	1.25	5.50	15.90	1620	2286	4.20
19	Ford KFM07-8FPEZ	1989	FORD	52000	26000	32900	TRUE	1.22	5.49	16.20	1440	2313	4.15
19	Ford KFM07-8FPEZ	1989	FORD	52000	26000	32900	TRUE	1.23	5.60	16.50	1710	2209	4.34
20	Ford LFM078EPC7	1990	FORD	24500	17150	17596	FALSE	0.69	2.30	12.20	850	1164	8.24
20	Ford LFM078EPC7	1990	FORD	24500	17150	17596	TRUE	0.68	2.24	12.20	720	1146	8.37
20	Ford LFM078EPC7	1990	FORD	24500	17150	17596	TRUE	0.70	2.24	12.90	740	1172	8.19
20	Ford LFM078EPC7	1990	FORD	24500	17150	17596	TRUE	0.72	2.45	13.20	760	1171	8.19
20	Ford LFM078EPC7	1990	FORD	24500	17150	17596	TRUE	0.77	2.46	12.30	760	1156	8.29
21	GM V8-8.2	1988	GMC	35000	24500	35586	FALSE	0.77	7.59	13.70	2830	2048	4.67
21	GM V8-8.2	1988	GMC	35000	24500	35586	TRUE	0.78	7.21	13.50	2360	2033	4.71
21	GM V8-8.2	1988	GMC	35000	24500	35586	TRUE	0.72	7.07	13.90	2170	1995	4.80
22	International 165F	1987	INT.HARV	26500	18550	19600	FALSE	0.95	3.76	19.60	1950	1400	6.84
22	International 165F	1987	INT.HARV	26500	18550	19600	TRUE	0.95	3.77	19.70	1870	1395	6.87
22	International 165F	1987	INT.HARV	26500	18550	19600	TRUE	0.91	3.56	20.40	1610	1359	7.05
23	MACK E7-250	1997	MACK	60420	42294	4800	FALSE	0.27	1.96	20.30	1650	2619	3.68
23	MACK E7-250	1997	MACK	60420	42294	4800	TRUE	0.23	1.74	20.70	550	2599	3.70
23	MACK E7-250	1997	MACK	60420	42294	4800	TRUE	0.24	1.83	20.60	420	2611	3.69
23	MACK E7-250	1997	MACK	60420	42294	4800	FALSE	0.27	1.85	20.80	400	2643	3.64
24	MACK E7-250	1985	VOLVO	27500	19250	286400	FALSE	0.74	13.50	23.10	1220	1140	8.29
24	MACK E7-250	1985	VOLVO	27500	19250	286400	TRUE	0.68	12.70	22.70	1010	1155	8.19
24	MACK E7-250	1985	VOLVO	27500	19250	286400	TRUE	0.70	12.50	22.80	1000	1161	8.15
24	MACK E7-250	1985	VOLVO	27500	19250	286400	TRUE	0.69	11.60	21.70	870	1094	8.65
24	MACK E7-250	1985	VOLVO	27500	19250	286400	TRUE	0.64	13.20	21.20	1000	1116	8.47
25	MACK EM7-275	1998	MACK	68420	47894	100	FALSE	0.42	3.47	38.40	450	2906	3.31
25	MACK EM7-275	1998	MACK	68420	47894	100	TRUE	0.36	3.18	37.60	400	2865	3.36
25	MACK EM7-275	1998	MACK	68420	47894	100	TRUE	0.29	4.04	36.90	420	2837	3.39
26	Mack/Renault Renault MIDR 060226L/2	1994	MACK/RENAULT	25500	17850	0	FALSE	0.44	2.78	12.60	920	1208	7.94
26	Mack/Renault Renault MIDR 060226L/2	1994	MACK/RENAULT	25500	17850	0	TRUE	0.37	2.28	13.00	500	1168	8.22
26	Mack/Renault Renault MIDR 060226L/2	1994	MACK/RENAULT	25500	17850	0	TRUE	0.38	2.22	13.00	450	1158	8.29
26	Mack/Renault Renault MIDR 060226L/2	1994	MACK/RENAULT	25500	17850	0	TRUE	0.43	2.44	13.00	490	1209	7.94
27	Mitsubishi 6D34-1AT2	1999	MITSUBISH	19360	13552	5892	FALSE	0.46	3.51	7.20	470	1427	6.73
27	Mitsubishi 6D34-1AT2	1999	MITSUBISH	19360	13552	5892	TRUE	0.43	3.59	7.14	300	1392	6.89
27	Mitsubishi 6D34-1AT2	1999	MITSUBISH	19360	13552	5892	TRUE	0.45	3.58	7.17	370	1424	6.74
27	Mitsubishi 6D34-1AT2	1999	MITSUBISH	19360	13552	5892	TRUE	0.31	3.46	7.20	330	1392	6.89
27	Mitsubishi 6D34-1AT2	1999	MITSUBISH	19360	13552	5892	TRUE	0.41	3.41	7.16	350	1392	6.89

Table 10.1-A1 Raw Data from New York Department of Energy and Conservation (*Contd.*)

Vehicle ID	Engine Type	Model Year	Make	GVW (lb)	Test Weight (lb)	Odometer (miles)	Replicate Test	THC	CO	NOX	PM mg/mi	CO2 g/mi	Fuel Economy (mpg)
28	Navistar A17SF	1996	NAVISTAR	16000	11200	277084	FALSE	0.22	1.37	9.90	340	938	10.20
28	Navistar A17SF	1996	NAVISTAR	16000	11200	277084	TRUE	0.25	1.41	9.79	270	928	10.40
28	Navistar A17SF	1996	NAVISTAR	16000	11200	277084	TRUE	0.21	1.36	9.98	300	972	9.90
28	Navistar A17SF	1996	NAVISTAR	16000	11200	277084	TRUE	0.19	1.39	9.77	260	939	10.20
28	Navistar A17SF	1996	NAVISTAR	16000	11200	277084	TRUE	0.20	1.35	9.83	240	918	10.50
29	Navistar A320	1996	NAVISTAR	33000	23100	7100	FALSE	0.15	1.22	17.30	390	1613	5.97
29	Navistar A320	1996	NAVISTAR	33000	23100	7100	TRUE	0.15	1.22	16.90	320	1594	6.04
29	Navistar A320	1996	NAVISTAR	33000	23100	7100	TRUE	0.17	1.23	17.30	290	1616	5.96
29	Navistar A320	1996	NAVISTAR	33000	23100	7100	TRUE	0.16	1.20	16.90	250	1605	6.00
30	Navistar B210F	1988	NAVISTAR	36000	25200	83500	FALSE	0.72	15.60	22.30	2790	1728	5.50
30	Navistar B210F	1988	NAVISTAR	36000	25200	83500	TRUE	0.74	14.90	21.70	2690	1720	5.52
30	Navistar B210F	1988	NAVISTAR	36000	25200	83500	TRUE	0.80	14.60	21.60	2560	1705	5.57
30	Navistar B210F	1988	NAVISTAR	36000	25200	83500	TRUE	0.73	13.60	21.50	2430	1668	5.70
31	Navistar E195 DTA466	1992	INT.HARV	32200	22540	133600	FALSE	0.94	2.43	10.70	1630	1772	5.42
31	Navistar E195 DTA466	1992	INT.HARV	32200	22540	133600	TRUE	0.87	2.24	11.20	880	1654	5.81
31	Navistar E195 DTA466	1992	INT.HARV	32200	22540	133600	TRUE	0.98	2.43	10.90	700	1720	5.58
32	Not Available	1993	INT.HARV	31020	21700	31020	FALSE	0.38	3.50	12.00	920	1545	6.21
32	Not Available	1993	INT.HARV	31020	21700	31020	TRUE	0.35	3.52	11.70	1070	1576	6.09
32	Not Available	1993	INT.HARV	31020	21700	31020	TRUE	0.36	3.53	11.80	940	1555	6.17
33	Not Available	1992	INT.HARV	25000	17500	48795	FALSE	0.69	4.74	14.20	1070	1567	6.12
33	Not Available	1992	INT.HARV	25000	17500	48795	TRUE	0.64	4.75	13.50	1020	1600	5.99
33	Not Available	1992	INT.HARV	25000	17500	48795	TRUE	0.66	4.94	13.50	990	1602	5.98
33	Not Available	1992	INT.HARV	25000	17500	48795	TRUE	0.68	5.26	13.40	990	1604	5.97
33	Not Available	1992	INT.HARV	25000	17500	48795	TRUE	0.67	5.10	13.30	890	1560	6.14
34	Renault 06-02-12	1993	MACK	32500	22750	113341	FALSE	0.21	7.51	11.00	1080	1325	7.21
34	Renault 06-02-12	1993	MACK	32500	22750	113341	TRUE	0.36	6.78	10.60	960	1333	7.17
34	Renault 06-02-12	1993	MACK	32500	22750	113341	TRUE	0.21	7.09	10.70	880	1319	7.24
34	Renault 06-02-12	1993	MACK	32500	22750	113341	TRUE	0.20	7.14	10.50	890	1276	7.48
34	Renault 06-02-12	1993	MACK	32500	22750	113341	TRUE	0.31	7.33	10.60	970	1350	7.08
35	Renault -25EM	1991	MACK	44900	31485	187960	FALSE	0.32	2.31	12.60	770	1692	5.68
35	Renault -25EM	1991	MACK	44900	31485	187960	TRUE	0.32	2.40	13.40	740	1856	5.18
35	Renault -25EM	1991	MACK	44900	31485	187960	TRUE	0.30	2.47	13.70	700	1884	5.10
35	Renault -25EM	1991	MACK	44900	31485	187960	TRUE	0.28	2.32	14.50	590	1818	5.29
35	Renault -25EM	1991	MACK	44900	31485	187960	TRUE	0.30	2.32	13.80	620	1833	5.25

Table 10.1-A2 Raw Data from Colorado School of Mines – Colorado Institute of Fuels and High-Altitude Engine Research[1]

Vehicle No.	Engine Model	Model Year	Engine Make	GVW (lb)	Inertial Weight	Odometer (miles)	Run No.	Start Hot/Cold	PM	HC	NOX	CO	CO2	Fuel
									g/mi					mpg
2	DT466	1990	Navistar	33000	23667	142242	556	H	1.46	0.26	15.41	4.93	N/A	N/A
3	DT4660.088	1993	Navistar	25500	18049	122406	564	C	1.38	1.24	14.97	18.41	1821	5.5
3	DT4660.088	1993	Navistar	25500	18049	122406	565	H	1.02	0.56	13.82	N/A	1829	N
3	DT4660.088	1993	Navistar	25500	18049	122406	566	H	0.93	0.62	13.39	N/A	1653	N
5	DT466	1987	Navistar	28000	23667	89528	593	H	2.46	2.03	9.93	14.79	1564	6.39
5	DT466	1987	Navistar	28000	23667	89528	594	H	2.19	2.39	9.84	N/A	1474	N
5	DT466	1987	Navistar	28000	23667	89528	597	H	2.29	1.79	10.02	13.93	1521	6.58
12	6BG1XN	1993	Isuzu	22000	17120	150788	724	H	1.15	1.17	19.65	6.10	1410	7.16
12	6BG1XN	1993	Isuzu	22000	17120	150788	725	H	1.10	1.35	18.81	5.71	1504	6.72
12	6BG1XN	1993	Isuzu	22000	17120	150788	726	H	1.30	1.48	14.19	6.45	1683	6
14	DT466	1995	Navistar	36220	29010	5320	747	C	1.54	0.73	20.81	12.63	1990	5.75
14	DT466	1995	Navistar	36220	29010	5320	748	H	0.80	0.55	18.08	8.17	1802	5.61
14	DT466	1995	Navistar	36220	29010	5320	752	H	0.76	0.57	18.15	8.69	1755	5.75
14	DT466	1995	Navistar	36220	29010	5320	753	H	0.76	0.55	17.83	7.17	1747	5.79
15	L10	1990	Cummins	50000	44237	72251	783	H	3.67	0.92	27.91	41.19	2373	4.17
15	L10	1990	Cummins	50000	44237	72251	784	H	4.12	0.91	27.87	49.17	2386	4.13
16	DT466	1989	Navistar	33000	24800	101925	792	C	2.56	1.90	39.08	30.46	2063	4.81
16	DT466	1989	Navistar	33000	24800	101925	793	H	2.20	1.23	36.39	30.36	1855	5.34
16	DT466	1989	Navistar	33000	24800	101925	794	H	2.14	1.19	35.20	28.50	1813	5.47
17	NTC400	1983	Cummins	80000	50800	80876	823	H	3.55	4.54	25.27	50.44	2690	3.66
17	NTC400	1983	Cummins	80000	50800	80876	824	H	3.47	4.31	24.78	49.65	2617	3.76
17	NTC400	1983	Cummins	80000	50800	80876	825	H	3.49	4.08	24.07	52.03	2571	3.82
18	V8-8-2T	1989	GMC	28000	18500	13518	848	H	1.29	0.60	13.68	5.99	1512	6.69
18	V8-8-2T	1989	GMC	28000	18500	13518	849	H	1.09	0.45	13.26	5.79	1431	7.07
18	V8-8-2T	1989	GMC	28000	18500	13518	850	H	1.11	0.50	13.15	63.81	1473	6.47
19	NTC400	1981	Cummins	49560	35000	17867	863	C	4.73	7.57	21.09	25.46	2354	4.21
19	NTC400	1981	Cummins	49560	35000	17867	869	C	4.23	9.58	20.70	26.00	2499	3.96
19	NTC400	1981	Cummins	49560	35000	17867	870	H	3.07	6.83	19.85	26.71	2226	4.45
19	NTC400	1981	Cummins	49560	35000	17867	871	H	3.42	6.83	19.94	29.89	2202	4.49
20	DT466	1993	Navistar	36220	25000	37009	881	C	0.82	0.25	12.59	5.87	1913	5.3
20	DT466	1993	Navistar	36220	25000	37009	882	H	0.72	0.28	12.36	4.95	1906	5.32
20	DT466	1993	Navistar	36220	25000	37009	883	H	0.72	0.24	12.14	4.44	1896	5.35

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[1] From a report entitled "Heavy-Duty Diesel vehicle Testing for the Northern Front Range Air Quality Study", Colorado Institute for Fuels and High-Altitude Engine Research, February 24, 1998.

Table 10.1-A3 Test Data from West Virginia University

Test ID	Model Year	Year Tested	Test Wght (lbs)	CO g/mi	NOx g/mi	HC g/mi	PM g/mi
1093	1982	1998	46400	21.7	29.07	3.04	4.62
3089	1985	1999	42000	20.5	33.17	2.96	3.03
3090	1985	1999	42000	20.4	32.33	2.62	3.1
1360	1995	1999	42000	2.2	18.34	0.64	
1125	1998	1998	46400	4.2	19.75	1.59	0.66
1154	1998	1998	46400	4.3	20.36	1.38	

Note: Test ID 3089 is the same vehicle as Test ID 3090.
Test ID 1125 is the same vehicle as Test ID 1154.

Figure 10.2-A1 Heavy-Duty Dynamometer Driving Schedule (UDDS)

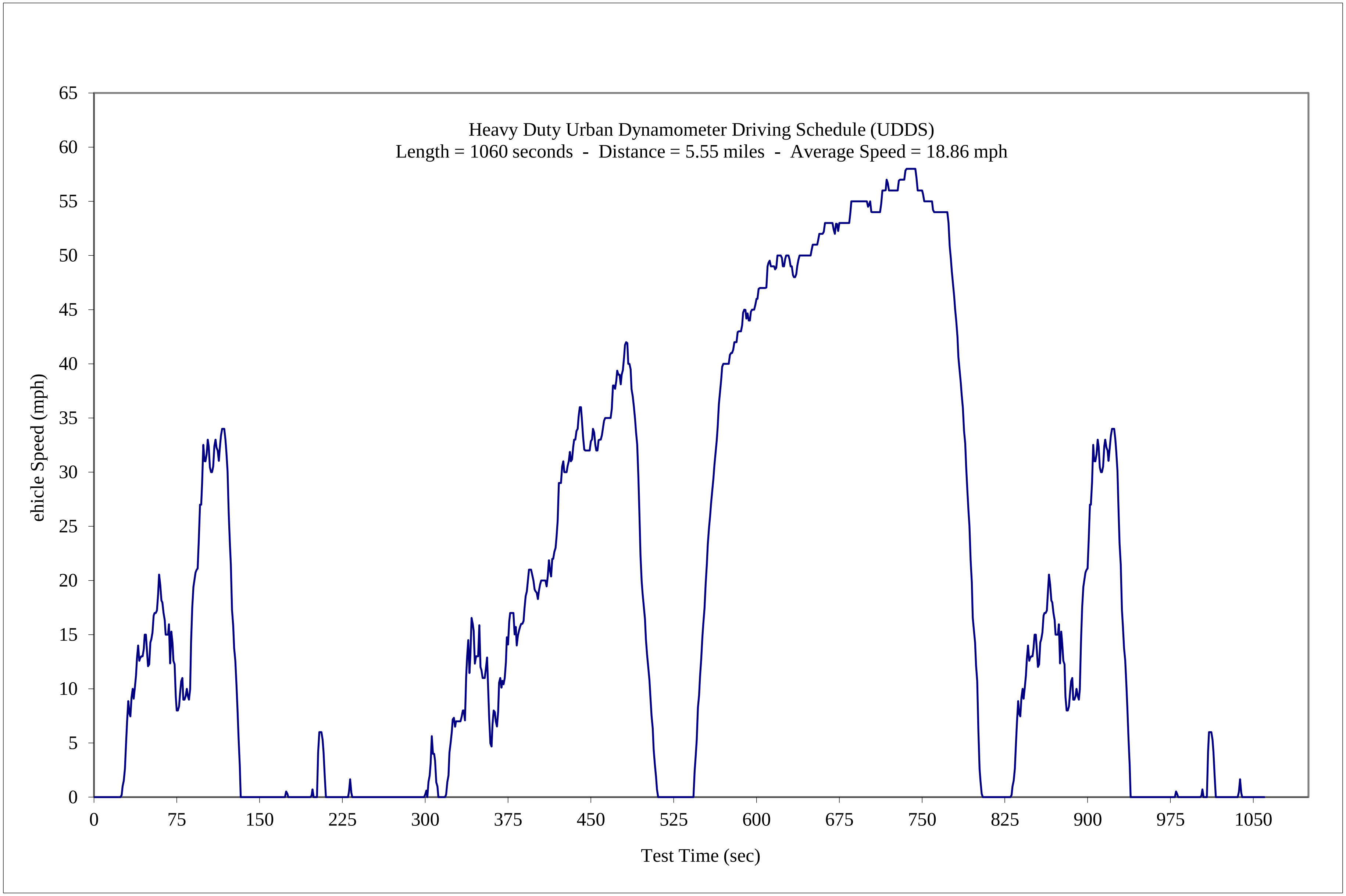


Table 10.1-A4 Raw Data for Light Heavy Diesel Trucks from U.S. EPA[1]

MODEL YEAR	MAKE	MODEL NAME	GVWR (lb)	Curb Weihght (lb)	Test weight (lb)	Odometer (mi)	BAG 1					BAG 2					BAG 3				
							THC	CO	NOX	PM	CO2	THC	CO	NOX	PM	CO2	THC	CO	NOX	PM	CO2
							g/mi					g/mi					g/mi				
TWGT = EMPTY + 300 LBS																					
1988	FORD	F-250 PU	8800	6500	**6500**	80152	0.93	3.43	3.97	0.572	817	0.32	2.03	5.41	0.454	693	0.61	2.80	4.40	0.395	700
1991	DODGE	RAM 250 PU	8510	5610	**5610**	67598	0.46	2.17	7.43	0.296	606	0.50	1.83	7.62	0.210	552	0.36	1.23	6.05	0.255	499
1993	DODGE	RAM 250 PU	8510	5800	**5800**	110435	0.46	2.26	6.52	0.174	608	0.50	1.77	6.49	0.112	518	0.34	1.21	5.32	0.147	474
1994	FORD	F-350 PU	9200	7500	**7500**	47666	0.55	3.40	7.37	0.063	595	1.31	3.95	5.28	0.076	602	0.66	2.00	5.28	0.110	512
1995	DODGE	RAM 2500 PU	8800	6000	**6000**	114006	0.45	2.80	6.44	0.120	560	0.43	1.89	7.61	0.066	517	0.30	1.16	5.77	0.069	471
TWGT = FULLY LOADED (GVW)																					
1988	FORD	F-250 PU	8800	6500	**8800**	80152	0.60	2.93	3.93	0.832	829	0.25	1.79	5.25	0.558	716	0.54	2.31	4.43	0.597	726
1991	DODGE	RAM 250 PU	8510	5610	**8510**	67598	0.26	1.75	8.09	0.372	680	0.30	1.63	8.08	0.289	644	0.33	1.08	6.50	0.519	580
1993	DODGE	RAM 250 PU	8510	5800	**8510**	110435	0.43	1.93	6.91	0.496	674	0.53	1.57	7.32	0.362	601	0.33	1.08	6.01	0.160	556
1994	FORD	F-350 PU	9200	7500	**9200**	47666	0.72	4.01	7.42	0.079	643	1.28	4.06	6.29	0.080	601	0.66	2.13	5.45	0.153	525
1995	DODGE	RAM 2500 PU	8800	6000	**8800**	114006	0.41	2.48	7.00	0.249	653	0.38	1.58	8.50	0.073	626	0.26	1.01	6.49	0.106	579

[1] A test program conducted by CE-CERT for U.S. EPA to investigate the effect of payload on exhaust emission, 1999.

Table 10.1-A5 Raw Data for Light Heavy Diesel Trucks from SCAQMD - CE-CERT Report[1]

Model Year	Make	Model	GVW (lbs)	Odometer (miles)	BAG1					BAG2					BAG3				
					THC	NMHC	CO	NOx	Parts.	THC	NMHC	CO	NOx	Parts.	THC	NMHC	CO	NOx	Parts.
					g/mi					g/mi					g/mi				
1982	GMC	Sierra 3500 PU	10000	66355	0.56	0.57	1.76	4.61	0.259	0.27	0.28	1.37	4.09	0.112	0.29	0.29	1.50	3.36	0.186
1984	Ford	F250 PU	8600	84386	0.35	0.36	1.64	4.13	0.640	0.48	0.51	1.79	4.42	0.502	0.37	0.37	1.32	3.80	0.577
1985	Ford	F350 PU	8600	87930	0.33	0.33	1.76	3.83	0.460	0.16	0.18	0.88	4.63	0.214	0.29	0.29	1.39	3.53	0.298
1985	GMC	1500 PU	N/A	32321	1.46	1.45	2.70	2.27	0.896	0.82	0.84	1.98	2.83	0.257	0.63	0.63	1.57	2.24	0.343
1986	Ford	F250 PU	8800	57484	0.69	0.69	2.14	2.77	1.160	0.33	0.35	1.66	3.58	0.541	0.65	0.64	1.95	2.63	0.903
1987	Ford	F250 PU	8800	80342	0.57	0.58	1.67	4.28	0.918	0.50	0.52	1.34	4.34	0.518	0.49	0.49	1.47	3.90	0.836
1987	Ford	F250 PU	8800	91564	0.79	0.79	2.55	2.86	0.228	0.93	0.94	2.98	2.87	0.218	0.59	0.59	1.84	2.40	0.212
1989	Ford	F350 Stakebed	11000	58483	0.26	0.28	1.05	4.29	0.510	0.21	0.26	1.29	4.82	0.122	0.23	0.23	1.16	3.58	0.167
1992	Dodge	Ram 250 PU	8510	50405	0.52	0.53	1.61	9.29	0.209	0.58	0.58	1.40	7.68	0.145	0.35	0.35	0.95	5.29	0.165
1994	Ford	F350 PU	9200	22364	0.31	0.31	1.43	5.02	0.175	0.49	0.50	1.45	3.82	0.165	0.29	0.29	0.98	3.32	0.143
1994	Dodge	Ram 2500 PU	8800	59444	0.50	0.50	1.79	6.41	0.077	0.51	0.53	1.36	7.38	0.053	0.31	0.32	0.84	5.79	0.054
1994	Dodge	Ram 2500 PU	8800	96457	0.40	0.39	1.90	6.11	0.115	0.47	0.48	1.43	7.49	0.062	0.33	0.34	0.91	5.83	0.069
1995	Dodge	Ram 3500 PU	10500	40103	0.62	0.63	2.93	6.17	0.083	0.60	0.62	1.87	7.33	0.057	0.37	0.38	1.27	5.48	0.062
1996	Dodge	Ram 2500 PU	8800	9838	0.56	0.58	1.97	6.93	0.116	0.47	0.49	1.49	9.26	0.065	0.29	0.29	0.90	6.53	0.068
1996	Dodge	Ram 3500 PU	10500	56139	0.36	0.36	2.04	5.87	0.066	0.44	0.45	1.57	7.05	0.053	0.30	0.30	0.92	5.33	0.063

[1] From a report entitled “Characterizing Particulate Emissions from Medium- and Light Heavy-Duty Diesel-Fueled Vehicles”, CE-CERT, SCAQMD, September 1998.

Figure 10.2-A2 EPA Federal Test Procedure (FTP)

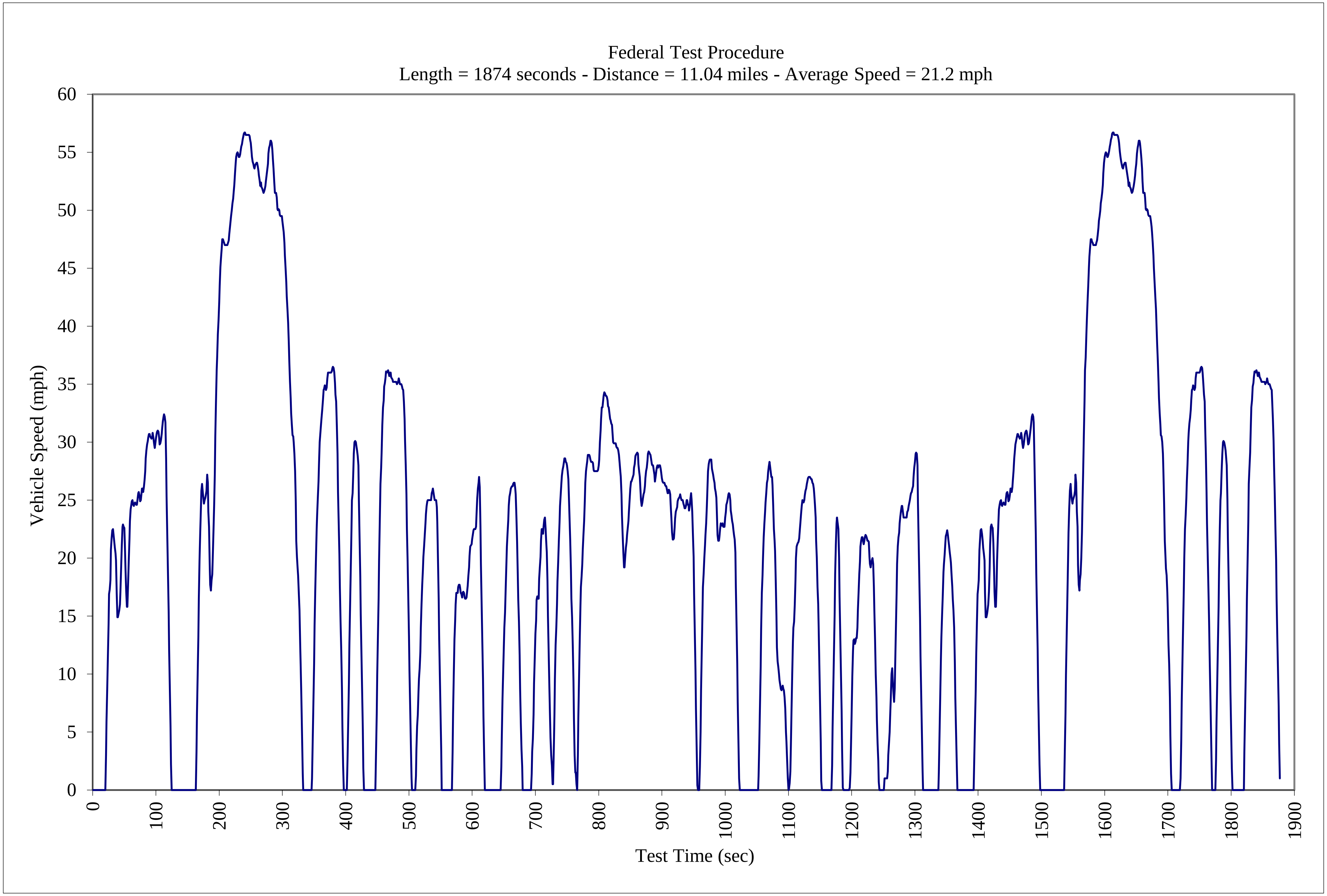


Table 10.2-A5 California and EPA On-Road Heavy-Duty Diesel Standards

FEDERAL HEAVY-DUTY TRUCK STANDARDS						CALIFORNIA HEAVY-DUTY TRUCK STANDARDS					
MODEL YEAR	HC[1]	CO	NOX	PM	HC+NOX	MODEL YEAR	HC[1]	CO	NOX	PM	HC+NOX
	g/bhp-hr						g/bhp-hr				
						1975-76	---	30.0	---	---	10.0
1974-78	---	40.0	---	---	16.0	1977-79	1.0	25.0	7.5	---	---
1979-83	1.5	25.0	---	---	10.0	1980-83	1.0	25.0	---	---	6.0
1984-87	1.3	15.5	10.7	---	---	1984-86	1.3	15.5	5.1	---	---
1988-90	1.3	15.5	10.7	0.60	---	1987-90	1.3	15.5	6.0	0.60	---
1991-93	1.3	15.5	5.0	0.25	---	1991-93	1.3	15.5	5.0	0.25	---
1994-97	1.3	15.5	5.0	0.10	---	1994-97	1.3	15.5	5.0	0.10	---
1998-02	1.3	15.5	4.0	0.10	---	1998-02	1.3	15.5	4.0	0.10	---
2003+	0.5[2]	15.5	2.0	0.10	---	2003+	0.5[2]	15.5	2.0	0.10	---

[1] **Note:** the HC standards shown are total hydrocarbons except for model year 2003+ which is NMHC.

[2] Assumes 2.5 g/bhp-hr (NOx+NMHC) with a 0.5 g/bhp-hr NMHC cap effective October 2002.

Low Emission Vehicle (LEV), Ultra-Low Emission Vehicle (ULEV) and Medium-Duty Vehicle (MDV) Emission Standards (g/bhp-hr) for Light-Heavy Diesel Trucks			
	MDV	LEV	ULEV
NMHC+NO_X	3.900	3.000	2.500
NMHC*	0.195	0.150	0.125
CO	14.400	14.400	14.400
NO_X*	3.705	2.850	2.375
PM	0.100	0.100	0.100

***Assumption**: 5% NMHC and 95% NO_x

Implementation Schedule for Light-Heavy Trucks
Sales Fraction by Model Year

Model Year	Pre 1995	MED	LEV	ULEV
1994	1.0	---	---	---
1995	0.5	0.5	---	---
1996-2001	---	1.0	---	---
2002-2003	---	---	1.0	---
2004+	---	---	---	1.0

Table 10.13-A1 Transit Bus - General Specification Data

Bus_Num	Transit Agency	Bus Mfgr.	Bus Model	Engine Mfgr	Engine Model	Engine Year	Start Mileage	GVW	Curb Weight
SL002DFDC	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	171235	39500	28250
SL003BFD	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	254255	39500	28250
SL004DFDC	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	159692	39500	28250
SL005DFDC	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	80510	39500	28250
SL006DFDC	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	160996	39500	28250
SL007BFD	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	2174	39500	28250
SL009BFD	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	204869	39500	28250
SL010BFD	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1988	28448	39500	28250
SL008DFDC	St. Louis MO (Bi-State Transit)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1989	128395	39500	28250
MF001DFCC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1990	135376	39500	27280
MF003DFCC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1990	99753	39500	27280
MF004DFCC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1990	133214	39500	27280
MF006DFDC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1990	118895	39500	27240
MF007DFDC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	DETROIT DIESEL	6V92TA	1990	143465	39500	27240
MF011DFCC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1990	104759	39500	27080
MF012DFCC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1990	111569	39500	27080
MM001DGDC	Minneapolis Minnesota (MTC)	GILLIG	Phantom	DETROIT DIESEL	6V92TA	1991	1500	39600	29180
PT001DBCC	Pierce Transit (Tacoma WA)	BIA	Orion	CUMMINS ENGINE CO	L10	1991	3500	38013	26190
PT002DBCC	Pierce Transit (Tacoma WA)	BIA	Orion	CUMMINS ENGINE CO	L10	1991	3500	38013	26190
PT003DBCC	Pierce Transit (Tacoma WA)	BIA	Orion	CUMMINS ENGINE CO	L10	1991	3500	38013	26190
PT004DBCC	Pierce Transit (Tacoma WA)	BIA	Orion	CUMMINS ENGINE CO	L10	1991	3500	38013	26190
PT005DBCC	Pierce Transit (Tacoma WA)	BIA	Orion	CUMMINS ENGINE CO	L10	1991	3500	38013	26190
MF011TFC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1992	12815	39500	28460
MF012TFC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1992	11204	39500	28460
MF013TFC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1992	9531	39500	28460
MF014TFC	Miami Florida (Metro-Dade)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10	1992	13471	39500	28460
TM001DFCC	Tri-Met (Portland OR)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10 Celect 280	1992	0	39500	27690
TM002DFCC	Tri-Met (Portland OR)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10 Celect 280	1992	0	39500	27690
TM003DFCC	Tri-Met (Portland OR)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10 Celect 280	1992	0	39500	27690
TM004DFCC	Tri-Met (Portland OR)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10 Celect 280	1992	0	39500	27690
TM005DFCC	Tri-Met (Portland OR)	FLXIBLE	Metro	CUMMINS ENGINE CO	L10 Celect 280	1992	0	39500	27690
MM006TGD	Minneapolis Minnesota (MTC)	GILLIG	Phantom	DETROIT DIESEL	6V92TA	1993	1500	39600	29400
MM007TGD	Minneapolis Minnesota (MTC)	GILLIG	Phantom	DETROIT DIESEL	6V92TA	1993	1500	39600	29400
MM010TGD	Minneapolis Minnesota (MTC)	GILLIG	Phantom	DETROIT DIESEL	6V92TA	1993	1500	39600	29400
AT011DNDC	Metro Atlanta Rapid Transit Authority	NEW FLYER		Detroit Diesel	Series 50	1994		37920	26800
AT012DNDC	Metro Atlanta Rapid Transit Authority	NEW FLYER		Detroit Diesel	Series 50	1994		37920	26800
AT013DNDC	Metro Atlanta Rapid Transit Authority	NEW FLYER		Detroit Diesel	Series 50	1994		37920	26800

Table 10.13-A1 Transit Bus - General Specification Data (*contd.*)

Bus_Num	Trans_Agency	Bus Mfgr.	Bus Model	Engine Mfgr	Engine Model	Engine Year	Start Mileage	GVW	Curb Weight
CI004DGCC	Southwest Ohio Regional Transit Author	GILLIG	Phantom	Cummins Engine Co.	M11	1996		39600	29020
CI005DGCC	Southwest Ohio Regional Transit Author	GILLIG	Phantom	Cummins Engine Co.	M11	1996		39600	29020
CI006DGCC	Southwest Ohio Regional Transit Author	GILLIG	Phantom	Cummins Engine Co.	M11	1996		39600	29020
CI008DGCC	Southwest Ohio Regional Transit Author	GILLIG	Phantom	Cummins Engine Co.	M11	1996		39600	29020
CI009DGCC	Southwest Ohio Regional Transit Author	GILLIG	Phantom	Cummins Engine Co.	M11	1996		39600	29020
CI010DGCC	Southwest Ohio Regional Transit Author	GILLIG	Phantom	Cummins Engine Co.	M11	1996		39600	29020
FL001DNDC	Flint Mass Transit Authority (MTA)	NEW FLYER		Detroit Diesel	Series 50	1996		37920	27500
FL002DNDC	Flint Mass Transit Authority (MTA)	NEW FLYER		Detroit Diesel	Series 50	1996		37920	27500
FL003DNDC	Flint Mass Transit Authority (MTA)	NEW FLYER		Detroit Diesel	Series 50	1996		37920	27500
FL004DNDC	Flint Mass Transit Authority (MTA)	NEW FLYER		Detroit Diesel	Series 50	1996		37920	27500
FL005DNDC	Flint Mass Transit Authority (MTA)	NEW FLYER		Detroit Diesel	Series 50	1996		37920	27500
FL006DNDC	Flint Mass Transit Authority (MTA)	NEW FLYER		Detroit Diesel	Series 50	1996		37920	27500
FL007DNDC	Flint Mass Transit Authority (MTA)	NEW FLYER		Detroit Diesel	Series 50	1996		37920	27500
FL008DNDC	Flint Mass Transit Authority (MTA)	NEW FLYER		Detroit Diesel	Series 50	1996		37920	27500

Table 10.13-A2 Transit Bus - Chassis Dynamometer Emissions

Bus_Num	Engine Mfgr	Engine Model	Engine Year	Test Cycle	Fuel	Odometer	Setup Date	Num Runs	THC	CO	NOX	PM	CO2
SL002DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	178798	06/04/94	4	3.20	22.30	38.30	3.10	3226
SL002DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2		04/17/96	3		7.60	38.10	0.98	2991
SL003BFD	DETROIT DIESEL	6V92TA	1988	CBD	D2	37224	04/22/96	4		6.90	51.60	0.73	3353
SL004DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2		06/06/94	4	2.10	25.40	41.40	1.09	2977
SL004DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	19611	03/18/95	5	2.66	9.30	49.30	0.90	2945
SL004DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	245418	04/16/96	4		46.30	40.00	1.85	3078
SL004DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	141193	04/20/96	4		7.80	46.00	1.16	3185
SL005DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	121732	06/06/94	4	1.80	39.90	42.60	1.24	3116
SL005DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	135147	03/13/95	5	2.07	21.10	50.10	1.59	3100
SL005DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	190235	04/18/96	4		6.40	27.20	0.88	3214
SL006DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2	168587	06/07/94	6	1.60	33.30	39.80	1.53	2912
SL006DFDC	DETROIT DIESEL	6V92TA	1988	CBD	D2		04/19/96	4		8.30	43.20	0.73	3059
SL007BFD	DETROIT DIESEL	6V92TA	1988	CBD	D2	238065	04/22/96	4		6.30	53.10	0.53	3257
SL009BFD	DETROIT DIESEL	6V92TA	1988	CBD	D2	221096	04/25/96	4		9.10	59.00		3048
SL010BFD	DETROIT DIESEL	6V92TA	1988	CBD	D2	100952	04/23/96	4		11.70	47.40	1.23	3162
SL010BFD	DETROIT DIESEL	6V92TA	1988	CBD	D2	100960	04/23/96	4		14.30	49.50	1.15	3114
SL010BFD	DETROIT DIESEL	6V92TA	1988	CBD	D2	100994	04/24/96	4		17.40	58.80	0.96	3053
SL008DFDC	DETROIT DIESEL	6V92TA	1989	CBD	D2	136541	06/07/94	4	1.70	14.00	33.00	0.53	2561
SL008DFDC	DETROIT DIESEL	6V92TA	1989	CBD	D2	179543	03/20/95	4	2.29	7.40	49.10	0.72	2668
SL008DFDC	DETROIT DIESEL	6V92TA	1989	CBD	D2	230395	04/17/96	4		7.50	45.40	0.63	2730
MF001DFCC	CUMMINS ENGINE CO	L10	1990	CBD	D2		02/07/94	4		40.90	36.00	0.36	3138
MF003DFCC	CUMMINS ENGINE CO	L10	1990	CBD	D2		02/07/94	4		23.80	30.10	0.85	2853
MF004DFCC	CUMMINS ENGINE CO	L10	1990	CBD	D2		02/08/94	4		27.10	28.40	0.77	2968
MF006DFDC	DETROIT DIESEL	6V92TA	1990	CBD	D2	181385	01/18/94	4	2.10	9.90	18.40	2.83	2663
MF007DFDC	DETROIT DIESEL	6V92TA	1990	CBD	D2	206506	01/19/94	4	1.00	12.60	22.90	1.68	2397
MF011DFCC	CUMMINS ENGINE CO	L10	1990	CBD	D2		02/08/94	4	1.00	16.00	24.00	2.19	2734
MF012DFCC	CUMMINS ENGINE CO	L10	1990	CBD	D2	68251	02/09/94	4	1.90	11.30	20.70	2.68	3028
MM001DGDC	DETROIT DIESEL	6V92TA	1991	CBD	D2	55948	03/14/94	4	1.70	9.50	27.50	1.85	3189
PT001DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	43027	10/23/92	4	1.50	8.50	24.30	1.20	2733
PT001DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2		07/03/95	6	1.50	13.10	21.20	1.26	2475
PT002DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	164006	08/18/94	4	3.00	12.50	23.60	1.50	2698
PT002DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2		07/15/95	4	1.20	9.50	29.40	1.29	2693
PT003DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	107943	08/19/94	4	2.00	11.70	26.90	1.42	2933
PT003DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2		07/17/95	4	1.90	9.20	25.80	1.53	2703
PT004DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	155815	08/20/94	4	1.30	13.00	29.50	0.95	2696
PT004DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2		07/18/95	4		12.80	29.90	0.32	2627
PT005DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2	144051	08/22/94	4		11.10	31.40	0.30	2783
PT005DBCC	CUMMINS ENGINE CO	L10	1991	CBD	D2		07/20/95	4		8.10	29.10	0.22	2568

Table 10.13-A2 Transit Bus - Chassis Dynamometer Emissions *(contd.)*

Bus_Num	Engine Mfgr	Engine Model	Engine Year	Test Cycle	Fuel	Odometer	Setup Date	Num Runs	THC	CO	NOX	PM	CO2
MF011TFC	CUMMINS ENGINE CO	L10	1992	CBD	D2	30721	02/17/93	3		17.40	29.40	0.27	2477
MF011TFC	CUMMINS ENGINE CO	L10	1992	CBD	D2	63126	02/03/94	4		20.90	29.40	0.40	2751
MF012TFC	CUMMINS ENGINE CO	L10	1992	CBD	D2	6684	02/17/93	3		19.10	31.30	0.29	2660
MF013TFC	CUMMINS ENGINE CO	L10	1992	CBD	D2	9531	02/01/94	4		17.10	32.20	0.22	2592
MF014TFC	CUMMINS ENGINE CO	L10	1992	CBD	D2		02/10/94	4		16.80	28.50	0.25	2431
TM001DFCC	CUMMINS ENGINE CO	L10 Celect 280	1992	CBD	D2	117207	07/25/95	5	2.80	15.10	25.80	1.65	3761
TM001DFCC	CUMMINS ENGINE CO	L10 Celect 280	1992	CBD	D2	140629	08/05/96	3	2.90	13.30	24.90	0.19	3702
TM002DFCC	CUMMINS ENGINE CO	L10 Celect 280	1992	CBD	D2	153295	08/02/95	3	2.30	14.20	25.60	0.09	3648
TM002DFCC	CUMMINS ENGINE CO	L10 Celect 280	1992	CBD	D2	198505	08/05/96	4	2.80	13.00	26.60	0.17	3622
TM003DFCC	CUMMINS ENGINE CO	L10 Celect 280	1992	CBD	D2	8735	08/02/95	3	2.70	12.60	22.20	1.95	2403
TM003DFCC	CUMMINS ENGINE CO	L10 Celect 280	1992	CBD	D2	54461	07/18/96	3	1.89	9.30	27.90	1.48	2566
TM004DFCC	CUMMINS ENGINE CO	L10 Celect 280	1992	CBD	D2	75381	08/03/95	5	3.20	13.00	20.00	2.29	2606
TM004DFCC	CUMMINS ENGINE CO	L10 Celect 280	1992	CBD	D2	125569	08/06/96	3	2.63	11.50	26.30	1.83	2610
TM005DFCC	CUMMINS ENGINE CO	L10 Celect 280	1992	CBD	D2	158095	08/03/95	4	2.60	12.00	21.90	1.91	2548
TM005DFCC	CUMMINS ENGINE CO	L10 Celect 280	1992	CBD	D2	210051	08/06/96	4	2.12	6.10	27.20	1.44	2645
MM006TGD	DETROIT DIESEL	6V92TA	1993	CBD	D2		03/16/94	4	2.30	9.20	23.80	1.68	2579
MM007TGD	DETROIT DIESEL	6V92TA	1993	CBD	D2	10986	03/17/94	5	1.89	11.20	29.30	1.32	2510
MM010TGD	DETROIT DIESEL	6V92TA	1993	CBD	D2	6748	03/17/94	6	2.50	7.30	19.50	2.05	2562
AT011DNDC	Detroit Diesel	Series 50	1994	CBD	D2	128600	03/03/97	5		5.20	26.60	0.42	2389
AT012DNDC	Detroit Diesel	Series 50	1994	CBD	D2	132500	03/01/97	5		6.40	33.30	0.42	2646
AT013DNDC	Detroit Diesel	Series 50	1994	CBD	D2	143800	03/04/97	6	2.17	4.00	25.10	1.67	2515
CI004DGCC	Cummins Engine Co.	M11	1996	CBD	D2	62000	11/07/97	6	1.29	3.40	40.90	1.36	2421
CI005DGCC	Cummins Engine Co.	M11	1996	CBD	D2	60300	11/08/97	4		4.50	46.90	1.48	2343
CI007DGCC	Cummins Engine Co.	M11	1996	CBD	D2	53500	11/11/97	4	1.98	4.00	41.00	2.51	2299
CI008DGCC	Cummins Engine Co.	M11	1996	CBD	D2	58300	11/13/97	4		4.20	48.90	2.21	2443
CI009DGCC	Cummins Engine Co.	M11	1996	CBD	D2	31900	11/14/97	5	2.06	4.60	43.50	2.51	2534
CI010DGCC	Cummins Engine Co.	M11	1996	CBD	D2	60700	11/14/97	5		4.60	50.50	1.42	2412
FL001DNDC	Detroit Diesel	Series 50	1996	CBD	D2	43100	05/23/97	4		5.60	27.00	0.34	2374
FL002DNDC	Detroit Diesel	Series 50	1996	CBD	D2	36700	05/24/97	4		4.90	27.80	0.96	2445
FL003DNDC	Detroit Diesel	Series 50	1996	CBD	D2	37400	05/26/97	5		5.10	28.50	1.59	2461
FL004DNDC	Detroit Diesel	Series 50	1996	CBD	D2	37400	05/27/97	4		4.60	30.50	0.82	2439
FL005DNDC	Detroit Diesel	Series 50	1996	CBD	D2	27500	05/28/97	6	1.83	4.40	39.60	2.30	2382
FL006DNDC	Detroit Diesel	Series 50	1996	CBD	D2	34300	05/30/97	6		4.50	48.60	2.20	2535
FL007DNDC	Detroit Diesel	Series 50	1996	CBD	D2	40900	06/02/97	5	1.89	4.50	39.40	2.23	2510
FL008DNDC	Detroit Diesel	Series 50	1996	CBD	D2	40000	06/05/97	4		5.30	30.80	2.51	2429

Table 10.14-A1 Urban Transit Diesel Bus Standards in g/bhp-hr

YEAR	HC	CO	NOX	PM	HC+NOx
1973-74	---	40.0	---	---	16.0
1975-76	---	30.0	---	---	10.0
1977-79	1.00	25.0	7.5	---	---
1980-83	1.00	25.0	---	---	6.0
1984-86	1.30	15.5	5.1	---	---
1987-90	1.30	15.5	6.0	0.60	---
1991-93	1.30	15.5	5.0	0.10	---
1994-95	1.30	15.5	5.0	0.07	---
1996-98	1.30	15.5	4.0	0.05	---
1999-02	1.30	15.5	4.0	0.05	---
10/2002-03	---	15.5	2.5 (NOx+NMHC)	0.01	---
	---		(with 0.5 g/bhp-hr NMHC cap)		---
7/2002	Low sulfur diesel fuel				
10/2002	4.8 NOx fleet average				
2003-07	PM Retrofit Requirements				
7/2003	3 bus demo of ZEBs for large fleets (>200)				
2004-06		15.5	0.5	0.01	---
2007		15.5	0.2	0.01	---
2008+	15% of new purchases are ZEBs for large fleets (>200)				

Figure 10.14-A1 NOx Emission Rates – MVEI7G v EMFAC2000

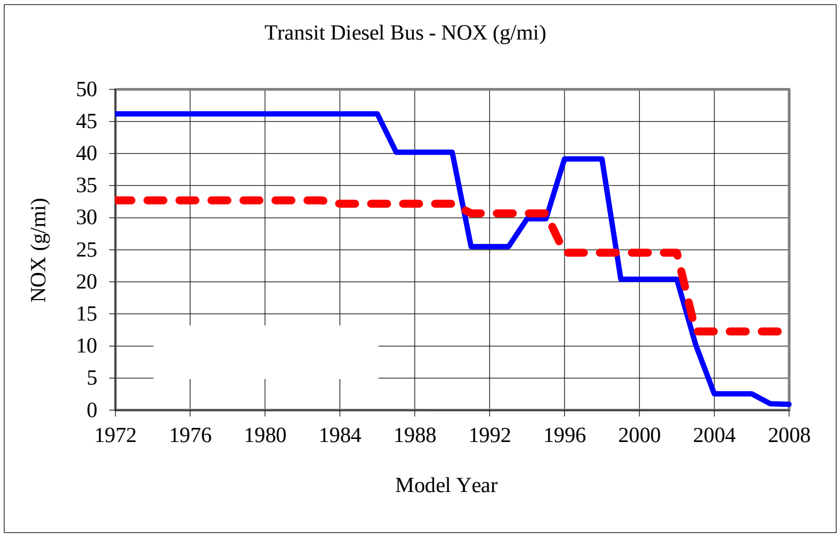


Figure 10.14-A2 PM Emission Rates – MVEI7G v EMFAC2000

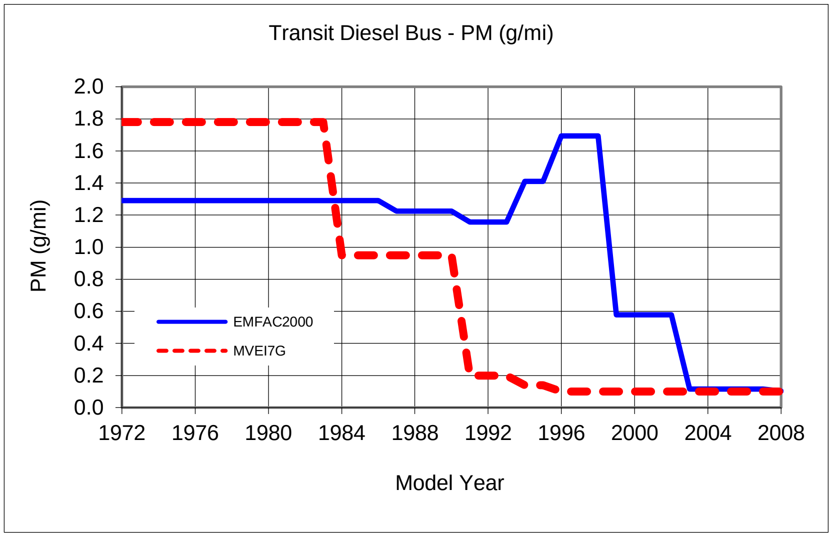


Figure 10.14-A3 HC Emission Rates – MVEI7G v EMFAC2000

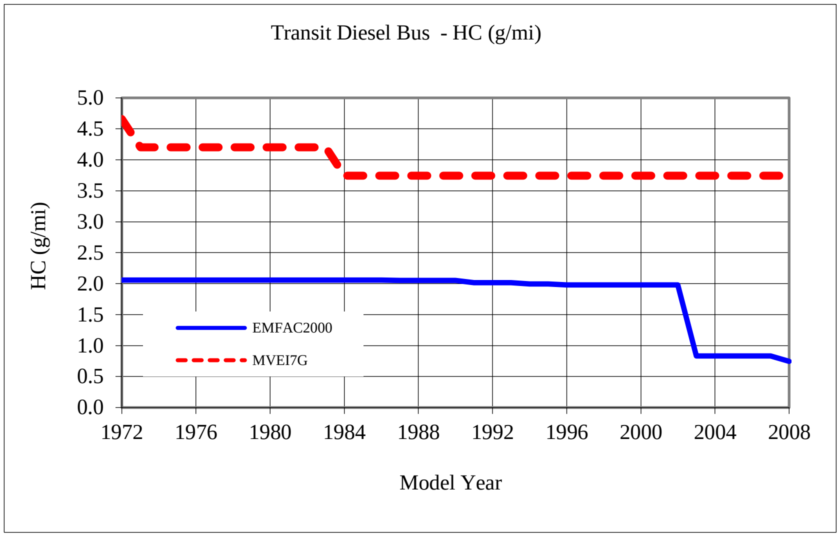
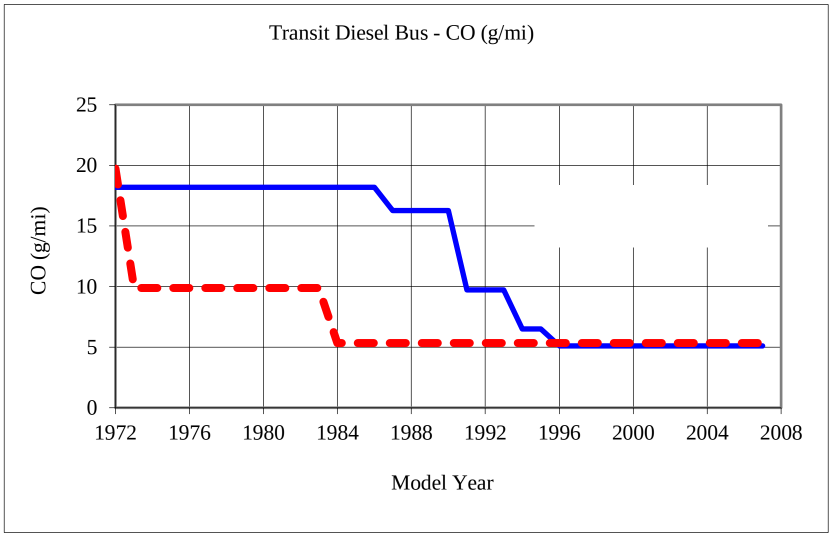


Figure 10.14-A4 CO Emission Rates – MVEI7G v EMFAC2000



Section 9.0 INCORPORATION OF LATEST STANDARDS

EMFAC2000 includes the effects of the latest adopted standards on the emissions of the on-road fleet. The model has been modified to include those standards adopted since the completion of MVEI7G.

Supplemental Federal Test Procedure

Two supplemental test procedures to the FTP were adopted by the Board in July of 1997. These new standards are applicable to passenger cars, light-duty trucks, and medium-duty vehicles weighing 8,500 pounds or less. These standards require the control of excess emission of hydrocarbon and oxides of nitrogen during “off-cycle” operations, (high speed and hard acceleration), and excess emissions associated with the use of air conditioning. The new standards are to be phased-in between 2001 and 2005.

Low Emission Vehicles (LEVII)

The second phase of Low Emission Vehicle Standards (LEVII) was adopted by the Board in November of 1998. This action imposed more stringent hydrocarbon, carbon monoxide, oxides of nitrogen and exhaust particulate matter emissions standards for passenger cars, light-duty trucks and medium-duty vehicles up to 14,000 pounds sold in California beginning in 2003.

Near Zero Evaporative Standards

At the same hearing, the Board adopted new standards for the emissions of evaporative hydrocarbons (diurnal, hot soak and resting loss). The standards were reduced from two grams per test (hot soak plus diurnal) for passenger cars, to 0.5 grams per test.

New On-Road Motorcycle Standards

In December of 1998, the Board adopted lower exhaust emission standards for on-road motorcycles. These standards, which may require future motorcycles to utilize catalytic converters, are applicable to new motorcycles sold in California beginning in 2004.

Off-Cycle NOx Mitigation

In a settlement reached between the federal Government, the Air Resources Board and heavy-duty engine manufacturers, several mitigation measures were agreed to regarding off-cycle NOx emissions. In addition to ending the practice of defaulting to an advanced timing condition during extended cruise operation, several manufacturer have agreed to perform “low emission” rebuilds for in-use engines. These rebuilds will lower the emissions of the in-use fleet and the projected effects have been reflected in EMFAC2000.

New Exhaust Emissions Standards for Urban Transit Buses

In February of 2000, the Board adopted a regulation that allows transit agencies the flexibility of choosing between either a diesel or alternative fuel “path” to lower emissions. Beginning in 2002, over the course of 10 years, this regulation requires increased introduction of cleaner engine buses in transit agencies’ fleet, use of cleaner diesel fuel, retrofit to reduce exhaust particulate matter (PM) emissions from older diesel buses and use of zero-emission buses (ZEBs).

Section 4.8 METHODOLOGY USED IN ESTIMATING EMISSION RATES FOR VEHICLES CERTIFIED TO THE LEV_I STANDARDS

This section discusses how the basic emissions rates in grams per mile were estimated for vehicles certified to the Low Emission Vehicle phase 1 (LEV_I) emission standards.

4.8.1 Introduction

In 1990 the California Air Resources Board (CARB) adopted a proposal that required manufacturers to produce vehicles, beginning with the 1994 model year, that met the LEV_I standards. Table 4.8-1 shows the LEV_I standards for vehicles tested using the Federal Test Procedure.

Table 4.8-1 LEV_I Standards (grams per mile)

Vehicle Class	Emission Category	grams per mile		
		NMHC	CO	NOx
Passenger Cars & Light-Duty Trucks	TLEV	0.125	3.40	0.40
	LEV	0.075	3.40	0.20
	ULEV	0.040	1.70	0.20
Light-Duty Trucks 3751-5750 lbs (T2)	TLEV	0.160	4.40	0.70
	LEV	0.100	4.40	0.40
	ULEV	0.050	2.20	0.40
Medium-Duty Trucks 3751-5750 lbs (T3)-M2	LEV	0.160	4.40	0.40
	ULEV	0.100	4.40	0.40
Medium-Duty Trucks 5751-8500 lbs (T3)-M3	LEV	0.195	5.00	0.60
	ULEV	0.117	5.00	0.60

The notation used in this memorandum is:

TLEV = Vehicles certified to the Transitional Low Emitting Vehicle (TLEV) standard as defined in CARB's 1990 LEV regulation.

LEV = Vehicles certified to the Low Emission Vehicle (LEV) standard as defined in CARB's 1990 LEV regulation.

ULEV = Vehicles certified to the Ultra Low Emission Vehicle (ULEV) standards as defined in CARB's 1990 LEV regulation.

Table 4.8-2 shows the suggested implementation schedule in order to meet the fleet average Non-Methane Organic Gas (NMOG) standard.

Table 4.8-2 Implementation Schedules for Vehicles Certified to the LEV I Emission Standards

	Passenger Cars & Light-Duty Trucks <3750 lbs				
Model Year	Other	TLEV	LEV	ULEV	ZEV
1994	90	10	0	0	0
1995	85	15	0	0	0
1996	80	20	0	0	0
1997	73	0	25	2	0
1998	48	0	46	6	0
1999	23	0	71	6	0
2000	0	0	94	6	0
2001	0	0	85	15	0
2002	0	0	80	20	0
2003	0	0	75	15	10

	Light-Duty Trucks 3751-5750lbs				
Model Year	Other	TLEV	LEV	ULEV	ZEV
1994	90	10	0	0	0
1995	85	15	0	0	0
1996	80	20	0	0	0
1997	73	0	25	2	0
1998	48	0	46	6	0
1999	23	0	71	6	0
2000	0	0	94	6	0
2001	0	0	85	15	0
2002	0	0	80	20	0
2003	0	0	80	20	0

	Medium-Duty Trucks 5751-8500 lbs				
Model Year	Other	TLEV	LEV	ULEV	ZEV
1994	100	0	0	0	0
1995	100	0	0	0	0
1996	100	0	0	0	0
1997	73	0	25	2	0
1998	48	0	50	2	0
1999	23	0	75	2	0
2000	0	0	98	2	0
2001	0	0	95	5	0
2002	0	0	90	10	0
2003	0	0	85	15	0

4.8.2 Methodology

In EMFAC2000, technology groups 21, 22, 23 and 24 represent multi-point fuel-injected vehicles certified to the LEV_I standards. Table 4.8-3 shows the technology group definitions.

Table 4.8-3 LEV_I Technology Groups

Groups	Technology Group Definitions
21	TLEV, Three-Way Catalyst, MPFI
22	TLEV, Three-Way Catalyst, MPFI with OBD2
23	LEV, Three-Way Catalyst, MPFI with OBD2
24	ULEV, Three-Way Catalyst, MPFI with OBD2
25	Zero Emitting Vehicle

The basic emission rates for these groups were cloned from technology group 15 which represents multi-point fuel injected vehicles certified to the 0.25 grams per mile (g/mi.) hydrocarbon (HC), 3.4 g/mi. carbon monoxide (CO) and 0.4 g/mi. oxides of nitrogen (NOx) standards. This is referred to as the Tier 1 standard in this memorandum. Since technology groups 15, 21, 22, 23 and 24 have 50,000 mile durability emission standards, the LEV_I emission rates were estimated by taking the ratio of the LEV_I/Tier 1 standards and applying this ratio to the technology 15 emission rates. This methodology was also used in MVEI7G for estimating the emission rates for LEV_I vehicles. In EMFAC2000, the zero mile rates for LEV_I vehicles are based on test data collected during CARB's new vehicle audit or Title 13 program. In this program, new vehicles are randomly tested to ensure compliance with the appropriate emission standards. Table 4.8-4 shows the emission rates for vehicles certified to the TLEV and LEV emission standards. Also shown are emission rates from a Honda ULEV that was tested with approximately 4,400 miles on the odometer. These emission rates were assumed to be representative of the zero mile rates from LEV_I vehicles in the normal emissions regime. Since the NOx standard is the same for both LEV and ULEV vehicles, the NOx emission rate from LEV vehicles was also applied to ULEV vehicles. Table 4.8-5 shows the basic emission rates for technology groups 22-24. Modes 1-3 represent bag 1-3 emission rates as measured during the FTP. Modes 4 and 5 represent emission rates from the first two bags of the Unified Cycle test procedure.

The regime growth rates for LEV_I vehicles are also based on the behavior of technology group 15. This assumes that the distribution of normal, moderate, high, very high and super emitters as a function of vehicle mileage is the same in both technology groups. This assumption is predicated on the fact that vehicles with like technologies will exhibit similar malfunctions (as a function a vehicle mileage), and hence have similar regime growth (deterioration) rates. The regime growth rates for LEV_I vehicles equipped with On-Board Diagnostic (OBD2) systems were further modified by restricting the growth of high, very-high and super emitting vehicles for the first 70,000 miles. This is predicated on the assumption that the vehicle will be repaired immediately during the 70,000-mile warranty period. This will prevent the growth of high, very high and super emitting vehicles during the 70,000-mile warranty period. This same assumption was used also used in MVEI7G to estimate the emission rates from LEV_I vehicles.

4.8.3 Discussion

The methodology used in estimating the LEV_I emission rates in EMFAC2000 is the same as that used in MVEI7G. The only exception being the usage of new vehicle audit data to represent zero mile rates from normal emitting LEV_I vehicles. There was considerable internal debate whether the high, very-high and super emission levels should be adjusted by the ratio of the LEV_I/Tier 1-emission standards or should be at the same emission levels as Tier 1. However, staff is of the opinion that malfunctions in LEV_I vehicles will result in small emissions increases due to the OBD2 system, which will reduce/prevent catastrophic failures.

Category	MFG	MODEL	YEAR	Wt-HC	WT-CO	WT-NOX	Bag1-HC	Bag1-CO	Bag1-NOx	Bag2-HC	Bag2-CO	Bag2-NOx	Bag3-HC	Bag3-CO	Bag3-NOx
TLEV	Mazda	626LX	95	0.112	1.07	0.042	0.3	2.984	0.189	0.018	0.237	0.003	0.149	1.198	0.004
TLEV	Mazda	626LX	95	0.127	1.197	0.055	0.37	3.196	0.224	0.013	0.229	0.003	0.157	1.513	0.025
TLEV	Mazda	626LX	95	0.1	0.897	0.059	0.333	2.72	0.206	0.008	0.21	0.02	0.096	0.813	0.023
TLEV	Mazda	MX-6	95	0.105	1.035	0.038	0.304	2.761	0.181	0.017	0.268	0.001	0.122	1.18	0.002
TLEV	Mazda	MX-6	95	0.062	0.519	0.08	0.271	1.992	0.114	0.007	0.15	0.082	0.007	0.108	0.052
TLEV	Chry	Neon	96	0.103	0.674	0.121	0.315	2.983	0.22	0.056	0.029	0.132	0.031	0.147	0.024
TLEV	Chry	Neon	96	0.126	0.876	0.111	0.382	3.877	0.237	0.074	0.04	0.105	0.032	0.188	0.029
TLEV	Chry	Neon	96	0.118	0.732	0.178	0.342	3.189	0.355	0.071	0.044	0.163	0.035	0.174	0.072
TLEV	Chry	Neon	96	0.094	0.619	0.119	0.34	2.722	0.365	0.03	0.025	0.074	0.028	0.149	0.02
TLEV	Chry	Neon	96	0.114	0.762	0.198	0.354	3.431	0.234	0.062	0.028	0.259	0.031	0.135	0.055
TLEV	Nissan	Altimagxe	95	0.136	1.53	0.123	0.514	6.271	0.227	0.037	0.302	0.053	0.038	0.264	0.178
TLEV	Nissan	Altimagxe	95	0.082	1.368	0.169	0.342	5.827	0.198	0.01	0.166	0.17	0.23	0.274	0.145
TLEV	Nissan	Altimagxe	95	0.126	1.417	0.103	0.473	5.656	0.25	0.036	0.317	0.039	0.033	0.294	0.112
TLEV	Nissan	Altimagxe	95	0.109	1.26	0.119	0.39	5.063	0.282	0.039	0.307	0.028	0.03	0.02	0.168
TLEV	Nissan	Altimagxe	95	0.112	1.569	0.213	0.463	6.917	0.209	0.019	0.0163	0.204	0.022	0.189	0.234
TLEV	Hynd	Scoupels	95	0.4	0.357	0.108	0.182	1.199	0.093	0.002	0.144	0.088	0.004	0.123	0.156
TLEV	Hynd	Scoupels	95	0.038	0.396	0.142	0.175	1.476	0.131	0.002	0.128	0.123	0.004	0.088	0.187
TLEV	Hynd	Scoupels	95	0.066	0.566	0.048	0.314	1.694	0.077	0	0.306	0.018	0.003	0.204	0.082
TLEV	Hynd	Scoupels	95	0.048	0.358	0.395	0.225	1.208	0.169	0.002	0.143	0.523	0.003	0.123	0.322
TLEV	Hynd	Scoupels	95	0.038	0.316	0.482	0.169	1.064	0.497	0.002	0.129	0.414	0.004	0.103	0.597
			Average	**0.1108**	**0.8759**	**0.14515**	**0.3279**	**3.3115**	**0.2229**	**0.02525**	**0.160915**	**0.1251**	**0.05295**	**0.36435**	**0.12435**
Emission rates for Normals In Calimfac				0.104	0.803	0.305	0.295	4.323	0.499	0.027	0.625	0.147	0.05	1.161	0.214
Category	MFR	MODEL	YEAR	WT_HC	WT_CO	WT_NOx	Bag1_HC	Bag1_CO	Bag1_NO	Bag2_HC	Bag2_CO	Bag2_NO	Bag3_HC	Bag3_CO	Bag3_NO
LEV	HONDA	DELSOL	96	0.05730	0.74257	0.01929	0.19391	1.56344	0.02291	0.01023	0.48086	0.01103	0.04328	0.61812	0.03224
LEV	HONDA	DELSOL	96	0.06285	1.84885	0.02875	0.20304	3.47593	0.04805	0.02551	1.61191	0.02689	0.02804	1.06898	0.01767
LEV	HONDA	DELSOL	96	0.02905	0.38554	0.06153	0.09059	0.57322	0.11059	0.00984	0.35220	0.02730	0.01908	0.30740	0.08936
LEV	HONDA	DELSOL	96	0.04222	0.50320	0.04398	0.12436	0.98164	0.06970	0.01230	0.31058	0.01674	0.03664	0.50541	0.07598
LEV	HONDA	DELSOL	96	0.03245	0.77128	0.02684	0.10373	1.40896	0.04564	0.01042	0.46997	0.01754	0.02061	0.86380	0.03034
			Average	**0.04478**	**0.85029**	**0.03608**	**0.14313**	**1.60064**	**0.05938**	**0.01366**	**0.64511**	**0.01990**	**0.02953**	**0.67274**	**0.04912**
Emission rates for Normals In Calimfac				0.045	0.404	0.153	0.177	4.323	0.25	0.016	0.625	0.074	0.03	1.161	0.107
Category	MFR	MODEL	YEAR	WT_HC	WT_CO	WT_NOx	Bag1_HC	Bag1_CO	Bag1_NO	Bag2_HC	Bag2_CO	Bag2_NO	Bag3_HC	Bag3_CO	Bag3_NO
ULEV	HONDA	ACCORD	98	0.03200	0.50800	0.05100	0.12700	0.80400	0.23100	0.00700	0.46600	0.00100	0.00600	0.36300	0.01000
ULEV	HONDA	ACCORD	98	0.03100	0.45400	0.05100	0.11600	0.75700	0.22100	0.00900	0.38500	0.00000	0.00900	0.35400	0.01800
ULEV	HONDA	ACCORD	98	0.03300	0.54700	0.06300	0.13000	0.95400	0.25900	0.00800	0.49700	0.00600	0.00600	0.33400	0.02300
ULEV	HONDA	ACCORD	98	0.03000	0.60000	0.05200	0.12700	1.09900	0.22000	0.00500	0.52200	0.00400	0.00400	0.36900	0.01600
			Average	**0.03150**	**0.52725**	**0.05425**	**0.12500**	**0.90350**	**0.23275**	**0.00725**	**0.46750**	**0.00275**	**0.00625**	**0.35500**	**0.01675**
Emission rates for Normals In Calimfac				0.027	0.258	0.153	0.094	2.162	0.25	0.009	0.313	0.074	0.016	0.581	0.107

Table 4.8-4 **Zero Mile Emission Rates for LEV I Vehicles**

Table 4.8-4 Basic Emission Rates for LEV_I Vehicles

Transitional Low Emission Vehicles				Low Emission Vehicles				Ultra Low Emission Vehicles			
Tech Gp22		Normals		Tech Gp23		Normals		Tech Gp24		Normals	
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.323	3.312	0.223	1	0.143	1.601	0.059	1	0.125	0.904	0.059
2	0.025	0.161	0.125	2	0.014	0.645	0.020	2	0.007	0.468	0.020
3	0.053	0.364	0.124	3	0.030	0.673	0.049	3	0.006	0.355	0.049
4	1.027	10.772	0.567	4	0.493	5.797	0.155	4	0.437	3.561	0.155
5	0.046	0.591	0.229	5	0.034	1.360	0.082	5	0.024	1.122	0.082
c				c				c			
Tech Gp22	Deterioration of Normals			Tech Gp23	Deterioration of Normals			Tech Gp24	Deterioration of Normals		
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.010	0.132	0.000	1	0.006	0.132	0.000	1	0.003	0.066	0.000
2	0.000	0.072	0.000	2	0.000	0.072	0.000	2	0.000	0.036	0.000
3	0.000	0.000	0.000	3	0.000	0.000	0.000	3	0.000	0.000	0.000
4	0.010	0.132	0.000	4	0.006	0.132	0.000	4	0.003	0.066	0.000
5	0.000	0.072	0.000	5	0.000	0.072	0.000	5	0.000	0.036	0.000
c				c				c			
Tech Gp22		Moderates		Tech Gp23		Moderates		Tech Gp24		Moderates	
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.522	7.973	1.116	1	0.313	7.973	0.558	1	0.167	3.987	0.558
2	0.087	3.857	0.341	2	0.052	3.857	0.171	2	0.028	1.929	0.171
3	0.130	4.659	0.613	3	0.078	4.659	0.307	3	0.042	2.329	0.307
4	1.583	22.777	2.722	4	0.999	22.777	1.386	4	0.567	12.617	1.386
5	0.087	3.978	0.403	5	0.067	3.978	0.273	5	0.048	2.625	0.273
c				c				c			
Tech Gp22		High		Tech Gp23		High		Tech Gp24		High	
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.827	12.766	1.481	1	0.496	12.766	0.741	1	0.265	6.383	0.741
2	0.466	10.451	0.727	2	0.280	10.451	0.364	2	0.149	5.226	0.364
3	0.477	8.658	1.125	3	0.286	8.658	0.563	3	0.153	4.329	0.563
4	2.397	34.023	3.586	4	1.512	34.023	1.827	4	0.859	18.844	1.827
5	0.208	7.237	0.616	5	0.160	7.237	0.418	5	0.115	4.774	0.418
c				c				c			
Tech Gp22		V_Highs		Tech Gp23		V_Highs		Tech Gp24		V_Highs	
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	1.595	27.110	2.338	1	0.957	27.110	1.169	1	0.510	13.555	1.169
2	1.079	30.439	1.208	2	0.647	30.439	0.604	2	0.345	15.220	0.604
3	0.796	24.088	1.768	3	0.478	24.088	0.884	3	0.255	12.044	0.884
4	4.334	64.650	5.594	4	2.735	64.650	2.848	4	1.551	35.807	2.848
5	0.321	13.746	0.820	5	0.246	13.746	0.555	5	0.178	9.068	0.555
c				c				c			
Tech Gp22		Super		Tech Gp23		Super		Tech Gp24		Super	
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	3.386	57.209	3.318	1	2.032	57.209	1.659	1	1.084	28.605	1.659
2	3.314	60.817	2.195	2	1.988	60.817	1.098	2	1.060	30.409	1.098
3	2.427	43.962	3.173	3	1.456	43.962	1.587	3	0.777	21.981	1.587
4	8.542	122.191	7.866	4	5.391	122.191	4.005	4	3.060	67.677	4.005
5	0.575	20.825	1.146	5	0.441	20.825	0.777	5	0.318	13.738	0.777

Section 4.9 METHODOLOGY USED IN ESTIMATING EMISSION RATES FOR VEHICLES CERTIFIED TO THE LEV_II STANDARDS

This section details how the basic emission rates in grams per mile were estimated for vehicles certifying to the Low Emission Vehicle phase II (LEV_II) emission standards. The LEV_II regulation requires that these vehicles be phased in beginning with the 2004 model year.

4.9.1 Introduction

In November 1998 the California Air Resources Board (CARB) adopted a proposal that requires manufacturers to produce vehicles, beginning with the 2004 model year, that meet the LEV II standards. Table 4.9-1 shows the LEV II standards for vehicles tested using the Federal Test Procedure (FTP).

Table 4.9-1 LEV_I and LEV_II FTP Standards (grams per mile)

	HC	CO	NOx	Durability
LEV_I	0.075	3.40	0.20	50K
LEV_II	0.090	4.20	0.07	120K
ULEV_I	0.040	1.70	0.20	50K
ULEV_II	0.055	2.10	0.07	120K
SULEV	0.010	1.00	0.02	120K

The notation used in this memorandum is:

LEV_I = Vehicles certified to the Low Emission Vehicle (LEV) standard as defined in CARB's 1990 LEV regulation.

LEV_II = Vehicles certified to the LEV 120,000 mile durability standards as defined in the 1998 LEV II regulation.

ULEV_I = Vehicles certified to the Ultra Low Emission Vehicle (ULEV) standard as defined in CARB's 1990 LEV regulation.

ULEV_II = Vehicles certified to the ULEV 120,000 mile durability standards as defined in the 1998 LEV II regulation.

SULEV = Vehicles certified to the Super Ultra Low Emission Vehicle (SULEV) 120,000 mile durability standards as defined in the LEV II regulation.

Table 4.9-2 shows the suggested implementation schedules for vehicles certified to both the LEV_I and LEV_II standards. The implementation schedules vary by vehicle class. As an example, the schedule requires that 47 percent of the 2010 model year passenger cars and light-duty trucks (with inertia weights less than 3,500 lbs.) meet the ULEV_II standards. Similarly, 62 percent of the 2010 model year light- and medium-duty trucks should meet the ULEV_II standards.

Table 4.9-2 Implementation Schedules – Percent of Vehicles by Model Year Certifying to the LEV II Emission Standards

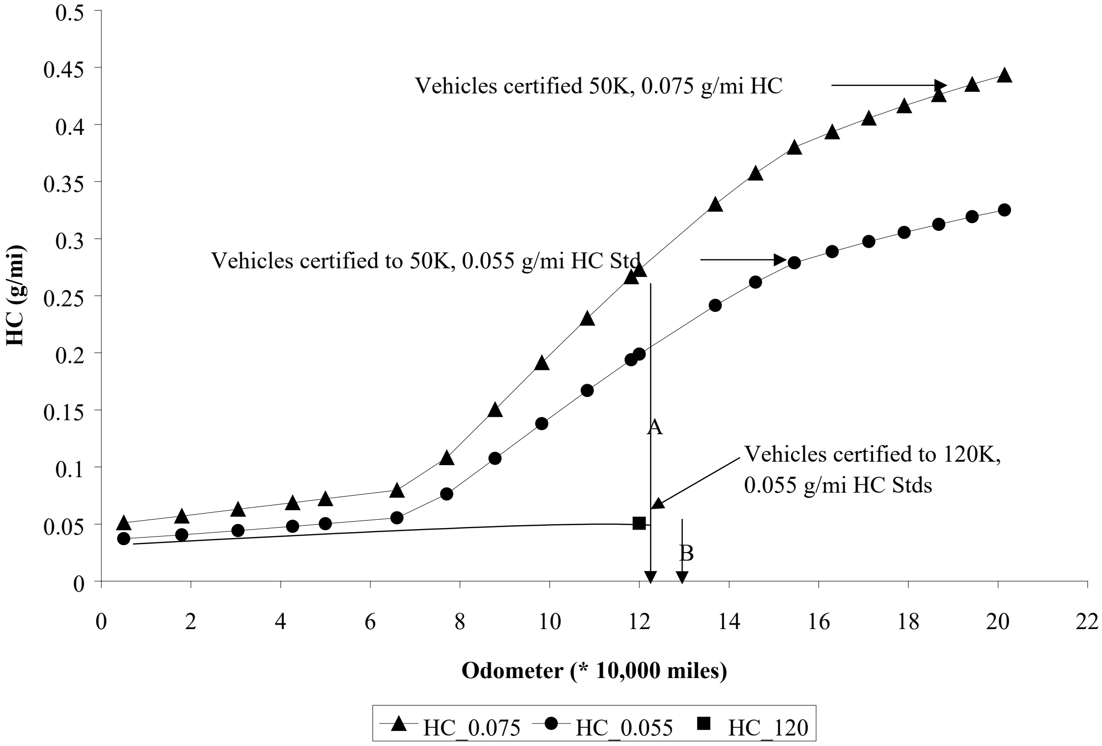
PCs and LDTs < 3501 lbs						
C_Year	**LEV I**	**LEV II**	**ULEV I**	**ULEV II**	**SULEV**	**ZEV**
2004	39.0	13.0	25.0	8.0	5.0	10.0
2005	23.0	23.0	17.0	17.0	10.0	10.0
2006	9.0	27.0	11.0	33.0	10.0	10.0
2007	0.0	31.0	0.0	45.0	14.0	10.0
2008	0.0	28.0	0.0	42.0	20.0	10.0
2009	0.0	22.0	0.0	48.0	20.0	10.0
2010	0.0	18.0	0.0	47.0	25.0	10.0
LDTs > 3501 and MDTs < 8500 lbs						
C_Year	**LEV I**	**LEV II**	**ULEV I**	**ULEV II**	**SULEV**	**ZEV**
2004	61.0	20.0	14.0	5.0	0.0	0.0
2005	37.0	37.0	13.0	13.0	0.0	0.0
2006	13.5	40.5	10.5	31.5	4.0	0.0
2007	0.0	47.0	0.0	48.0	5.0	0.0
2008	0.0	36.0	0.0	54.0	10.0	0.0
2009	0.0	28.0	0.0	62.0	10.0	0.0
2010	0.0	21.0	0.0	64.0	15.0	0.0

4.9.2 Methodology

In EMFAC2000, technology group 23 represents multi-point fuel injected vehicles certified to the LEV_I emission standards. The basic emission rates for this group were cloned from technology group 18 which represents multi-point fuel-injected vehicles certified to the 0.4 grams per mile (g/mi.) NOx standard. The zero mile emission rates for vehicles certified to the LEV_I standards are based on testing performed during CARB's Title 13 program. In this program, new vehicles are randomly selected and tested using the FTP test to ensure compliance with California's emission standards. In this memorandum, the regime growth rates for vehicles certified to the LEV_I standards are based on the behavior of technology group 18 vehicles. This assumes that the distribution of normal, moderate, high, very high and super emitters as a function of vehicle mileage is the same in both technology groups. This methodology assumes that vehicles with like technologies will exhibit similar malfunctions (as a function a vehicle mileage), and hence have similar regime growth and deterioration rates.

Figure 4.9-1 shows the basic emission rate curve for vehicles certified to the 50,000-mile (50K) 0.075 g/mi. LEV_I HC standard. If the ULEV_II standards were also 50K durability standards then it would be relatively simple to calculate the ULEV_II emission rates by taking the ratio of the ULEV_II/LEV_I standards and applying this ratio to the technology group 23 emission rates. However, the ULEV_II emission standards are 120,000-mile (120K) durability standards. Further, the additional constraint or assumption is that the percentage difference between the emission rate and the standard at 50K should be the same at 120K for vehicles certified to the same numerical standards. That is, if vehicles certified to the 50K standards exceed them by ***x*** percent then it is assumed that vehicles certified to the 120K standards will also exceed this emission standard by ***x*** percent.

Figure 4.9-1 <u>Basic Emission Rate Curves for Vehicles Certified to 0.075, 0.055 g/mi. HC Standards</u>



Staff investigated two methodologies for developing LEV_II emissions rates. These were:

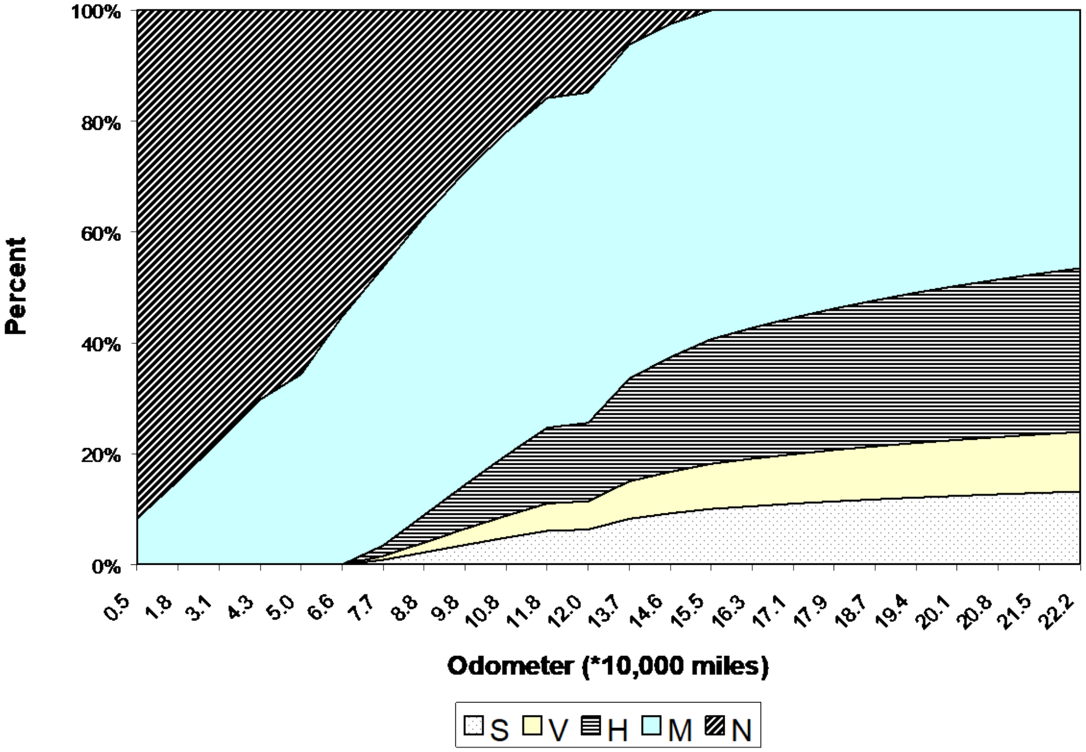
Method A: The first method requires calculating a ratio based on the emission rate for vehicles certified to 120K standard at 120K miles divided by the emission rate for vehicles certified to the 50K standard at 120K miles. This ratio (B/A) as shown in Figure 4.9-1 is then applied to LEV_I basic emission rates. This approach lowers the zero mile emission rates, and results in very low emission rates for LEV_II vehicles early in their useful life.

Method B: The second methodology requires manipulating the regime growth rates such that the standards are met at 120K. By changing the regime growth rates, one can be assured that the zero mile emission levels, for vehicles certified to the same numerical emission standards, would remain the same. However, staff wanted to ensure that the new regime growth rates were not simply manufactured but were based on a sound methodology, and preserved most of regime growth rate and deterioration rate patterns from the technology group used in cloning the new emission rates. Figure 4.9-2 shows the regime growth rates for vehicles certified to the 0.075 g/mi. LEV_I HC standard. The following four methods were considered for modifying the regime growth rates:

1. Try all combinations of regime sizes such that the standards are met at 120K.
2. Increase the size of normal emitters until the standard is met at 120K.
3. Assume that there are no high, very high and super emitters for the first 120K miles, and maintain the same regime growth rates for normal and moderate emitters.
4. Assume that there are no high, very high and super emitters for the first 120K miles. Further the regime size of normal and moderate emitters at 120K in the cloned technology group are the same as those at 50K in the original technology group.

The first method was considered but not used since there were many combinations of regime sizes that could be used to meet the standards. With the second approach, the standards could only be met by increasing the normal regime growth rate by the large factor. This assumption resulted in more normal emitters at 120,000 miles than at zero miles. This approach was also dropped from further consideration. The standards could not be met using the third approach. The fourth approach yielded the closest results to the standards, however, in order to meet the LEV_II standards one had to assume that the emissions from normal emitters would also be reduced. Staff considered this to be a reasonable assumption, given that the 120K durability standard will require manufacturers to develop more durable vehicles with lower deterioration rates.

Figure 4.9-2 Regime Growth Rates for Vehicles Certified to the 0.075 g/mi., 50K LEV_1 Hydrocarbon Standard



The following calculation illustrates how the HC emission rate was estimated for vehicles certified to the 120K LEV_II HC standard of 0.09 g/mi.

1. Determine the percentage by which the LEV_I vehicles are below or above the standard at 50K miles. For example, if the LEV_I vehicle HC emission rate is 3.733 percent below the 0.075 g/mi. HC standard at 50K miles. Then one can estimate the LEV_II HC emission rate 120K miles by assuming that this rate will be 3.733 percent below the 120K mile standard. This results in a LEV_II HC rate of 0.0866 g/mi. at 120K. This is a pseudo standard that LEV_II vehicles must meet in order to maintain their emissions below the standard by 3.733 percent.
2. Calculate a ratio of the LEV_II / LEV_I HC emission standards or (0.09/0.075).
3. Modify the existing regime growth rate coefficients such that the size of super, very high and highs are zero at 120,000 miles. Further, modify the regime growth rate coefficients for moderate and normal emitters such that the normal and moderate regime sizes at zero miles and 120,000 miles in the cloned technology group are the same as the normal and moderate regime sizes at zero and 50,000-miles in the LEV_I technology group.
4. In EMFAC2000, emissions of normal vehicles deteriorate with vehicle mileage. This deterioration rate is lowered until the LEV_II vehicles meet the pseudo standards.

4.9.3 Results

Table 4.9-3 shows the basic emission rates for LEV_II, ULEV_II and SULEV vehicles developed using Method A. The modes 1, 2 and 3 represent emissions from bags 1, 2 and 3 of the FTP. Modes 4 and 5 represent emissions from bags 1 and 2 of the Unified Cycle. Figures 4.9-3, 4.9-4 and 4.9-5 show the resulting FTP composite HC, CO and NOx emission rates, respectively.

Table 4.9-3 Basic Emission Rates for Vehicles Certified to the LEV_II Standards Developed using Method A

LEV certified to Stds of HC=0.09 g/mi, C0=4.2 g/mi, NOx=0.07 g/mi stds 120K				ULEV certified to Stds of HC=0.055 g/mi, C0=2.1 g/mi, NOx=0.07 g/mi stds 120K				SULEV certified to Stds of HC=0.01 g/mi, C0=1.0 g/mi, NOx=0.02 g/mi stds 120K			
Tech Gp28	Normals			Tech Gp29	Normals			Tech Gp30	Normals		
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.04540	0.50513	0.00959	1	0.02775	0.25257	0.00959	1	0.00504	0.12027	0.00274
2	0.00445	0.20350	0.00325	2	0.00272	0.10175	0.00325	2	0.00049	0.04845	0.00093
3	0.00953	0.21234	0.00797	3	0.00582	0.10617	0.00797	3	0.00106	0.05056	0.00228
4	0.17524	2.16833	0.02649	4	0.11242	1.20094	0.02649	4	0.02418	0.63806	0.00782
5	0.01860	0.68058	0.02952	5	0.01441	0.44896	0.02952	5	0.00595	0.28762	0.01461
c				c				c			
Tech Gp28	Deterioration of Normals			Tech Gp29	Deterioration of Normals			Tech Gp30	Deterioration of Normals		
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.00187	0.04152	0.00000	1	0.00114	0.02076	0.00000	1	0.00021	0.00989	0.00000
2	0.00000	0.02278	0.00000	2	0.00000	0.01139	0.00000	2	0.00000	0.00542	0.00000
3	0.00000	0.00000	0.00000	3	0.00000	0.00000	0.00000	3	0.00000	0.00000	0.00000
4	0.00187	0.04152	0.00000	4	0.00114	0.02076	0.00000	4	0.00021	0.00989	0.00000
5	0.00000	0.02278	0.00000	5	0.00000	0.01139	0.00000	5	0.00000	0.00542	0.00000
c				c				c			
Tech Gp28	Moderates			Tech Gp29	Moderates			Tech Gp30	Moderates		
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.09938	2.51557	0.09073	1	0.06073	1.25779	0.09073	1	0.01104	0.59895	0.02592
2	0.01651	1.21693	0.02780	2	0.01009	0.60846	0.02780	2	0.00183	0.28975	0.00794
3	0.02477	1.46997	0.04992	3	0.01513	0.73499	0.04992	3	0.00275	0.34999	0.01426
4	0.35504	8.52032	0.23629	4	0.22777	4.71904	0.23629	4	0.04899	2.50720	0.06975
5	0.03675	1.99083	0.09854	5	0.02846	1.31330	0.09854	5	0.01175	0.84135	0.04876
c				c				c			
Tech Gp28	High			Tech Gp29	High			Tech Gp30	High		
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.15748	4.02781	0.12048	1	0.09624	2.01391	0.12048	1	0.01750	0.95901	0.03442
2	0.08890	3.29741	0.05918	2	0.05433	1.64871	0.05918	2	0.00988	0.78510	0.01691
3	0.09081	2.73169	0.09154	3	0.05549	1.36585	0.09154	3	0.01009	0.65041	0.02615
4	0.53765	12.72677	0.31146	4	0.34492	7.04882	0.31146	4	0.07419	3.74500	0.09195
5	0.08800	3.62122	0.15062	5	0.06816	2.38883	0.15062	5	0.02815	1.53037	0.07453
c				c				c			
Tech Gp28	V_Highs			Tech Gp29	V_Highs			Tech Gp30	V_Highs		
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.30385	8.55350	0.19007	1	0.18569	4.27677	0.19007	1	0.03376	2.03656	0.05431
2	0.20543	9.60384	0.09821	2	0.12554	4.80193	0.09821	2	0.02282	2.28664	0.02806
3	0.15177	7.60003	0.14373	3	0.09275	3.80003	0.14373	3	0.01686	1.80954	0.04107
4	0.97226	24.18367	0.48555	4	0.62373	13.39431	0.48555	4	0.13417	7.11632	0.14334
5	0.13589	6.87861	0.20017	5	0.10525	4.53764	0.20017	5	0.04347	2.90698	0.09904
c				c				c			
Tech Gp28	Super			Tech Gp29	Super			Tech Gp30	Super		
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.64517	18.05007	0.26975	1	0.39427	9.02506	0.26975	1	0.07168	4.29765	0.07707
2	0.63120	19.18843	0.17853	2	0.38573	9.59425	0.17853	2	0.07013	4.56869	0.05101
3	0.46229	13.87049	0.25804	3	0.28251	6.93527	0.25804	3	0.05136	3.30251	0.07373
4	1.91666	45.70784	0.68280	4	1.22958	25.31563	0.68280	4	0.26449	13.45005	0.20157
5	0.24326	10.42104	0.28002	5	0.18842	6.87449	0.28002	5	0.07781	4.40405	0.13855

Figure 4.9-3 FTP Composite HC Emission Rates Developed Using Method A

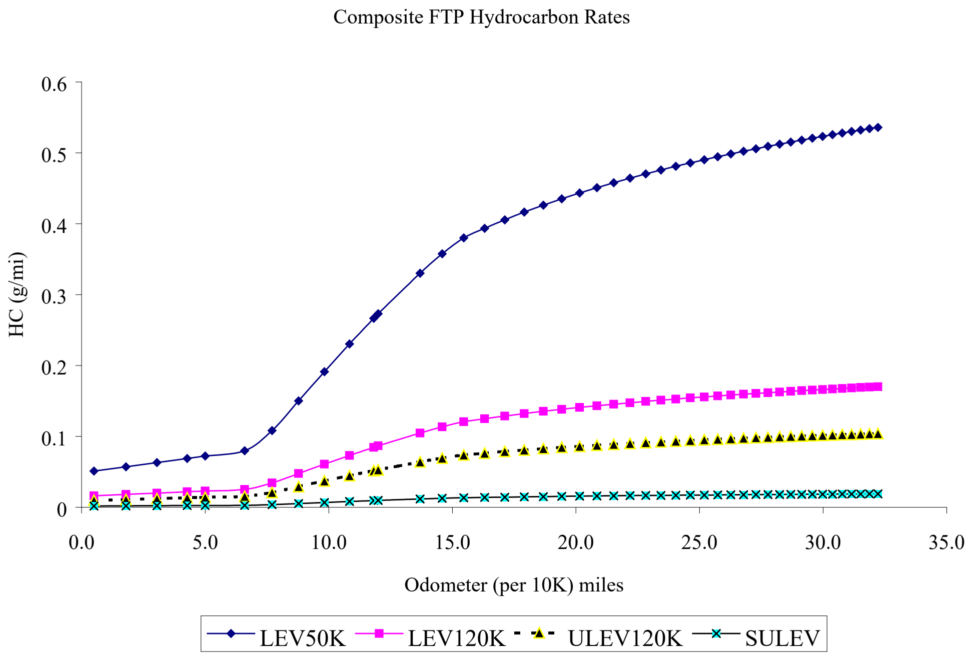
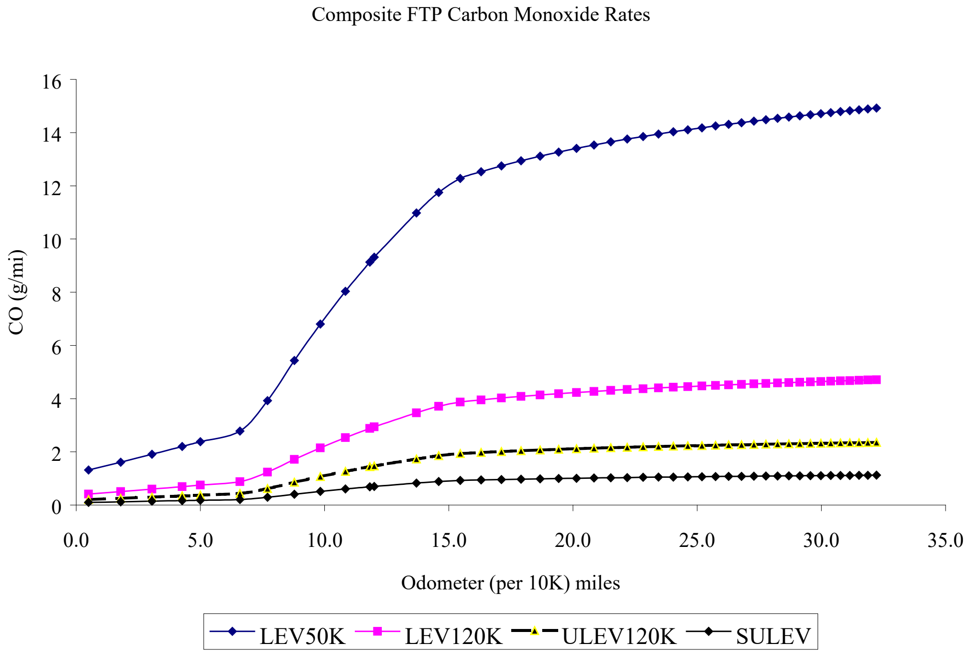


Figure 4.9-4 FTP Composite CO Emission Rates Developed Using Method A



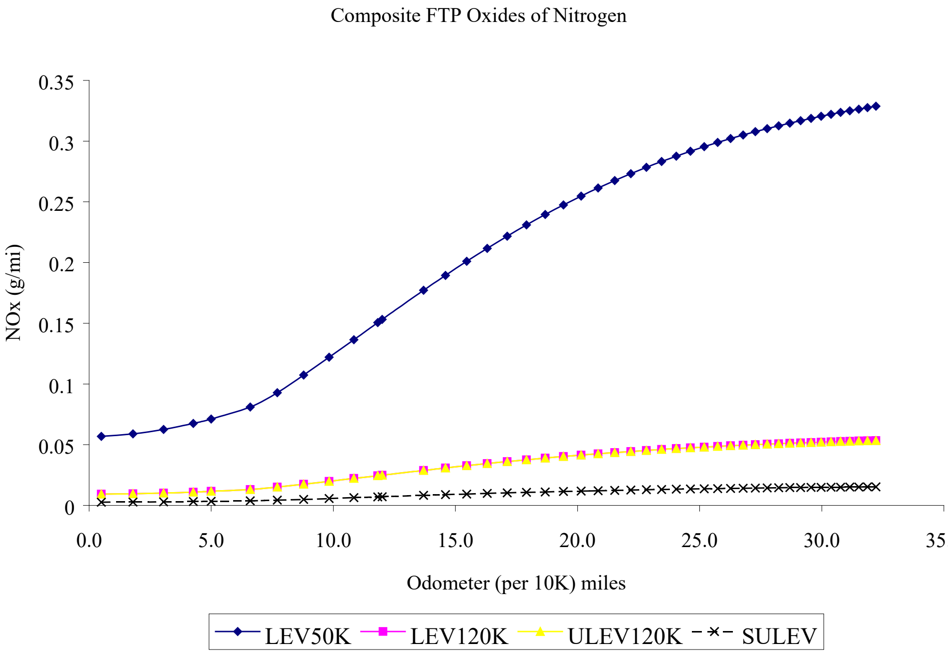


Figure 4.9-5 FTP Composite NOx Emission Rates Developed Using Method A

Table 4.9-4 shows the basic emission rates for LEV_II vehicles developed using Method B that requires manipulating the regime growth rates. Table 4.9-5 shows the corresponding regime growth rate coefficients applicable to technology groups 28, 29, 30 (vehicles certified to 120K standards).

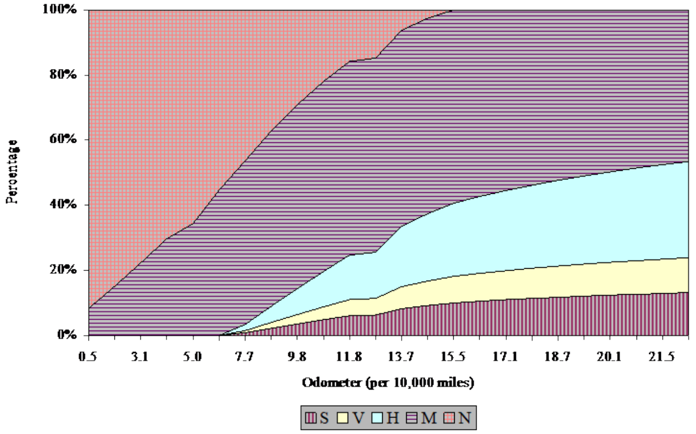
Table 4.9-4 Basic Emission Rates For Vehicles Certified to the LEV II Standards Developed using Method B

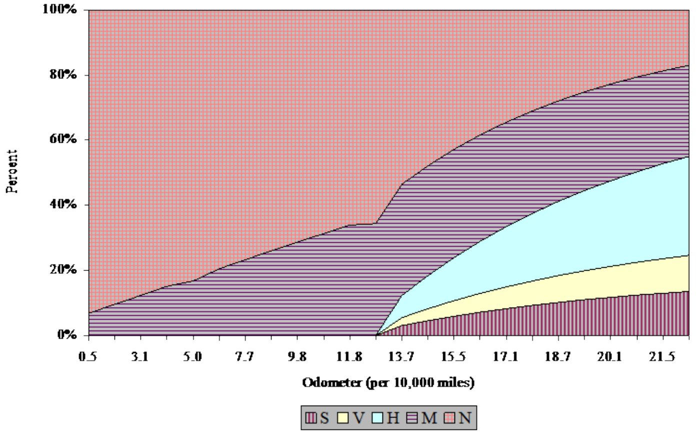
LEV_II	LEV_II	LEV_II	LEV_II	ULEV_II	ULEV_II	ULEV_II	ULEV_II	SULEV	SULEV	SULEV	SULEV
Tech Gp28		Normals		Tech Gp29		Normals		Tech Gp30		Normals	
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.17160	1.97771	0.02065	1	0.10487	0.98885	0.02065	1	0.01907	0.47088	0.00590
2	0.01680	0.79676	0.00700	2	0.01027	0.39838	0.00700	2	0.00187	0.18971	0.00200
3	0.03600	0.83135	0.01715	3	0.02200	0.41568	0.01715	3	0.00400	0.19794	0.00490
4	0.58091	6.94065	0.05590	4	0.37267	3.84412	0.05590	4	0.08016	2.04236	0.01650
5	0.03708	1.54398	0.04541	5	0.02872	1.01852	0.04541	5	0.01186	0.65250	0.02247
c				c				c			
Tech Gp28	Deterioration of Normals			Tech Gp29	Deterioration of Normals			Tech Gp30	Deterioration of Normals		
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.00290	0.06826	0.00000	1	0.00177	0.03333	0.00000	1	0.00032	0.01548	0.00000
2	0.00000	0.03745	0.00000	2	0.00000	0.01828	0.00000	2	0.00000	0.00849	0.00000
3	0.00000	0.00000	0.00000	3	0.00000	0.00000	0.00000	3	0.00000	0.00000	0.00000
4	0.00290	0.06826	0.00000	4	0.00177	0.03333	0.00000	4	0.00032	0.01548	0.00000
5	0.00000	0.03745	0.00000	5	0.00000	0.01828	0.00000	5	0.00000	0.00849	0.00000
c				c				c			
Tech Gp28		Moderates		Tech Gp29		Moderates		Tech Gp30		Moderates	
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.37560	9.84900	0.19530	1	0.22953	4.92450	0.19530	1	0.04173	2.34500	0.05580
2	0.06240	4.76453	0.05985	2	0.03813	2.38226	0.05985	2	0.00693	1.13441	0.01710
3	0.09360	5.75524	0.10745	3	0.05720	2.87762	0.10745	3	0.01040	1.37029	0.03070
4	1.17697	27.27289	0.49855	4	0.75506	15.10525	0.49855	4	0.16242	8.02533	0.14718
5	0.07324	4.51640	0.15157	5	0.05673	2.97935	0.15157	5	0.02343	1.90868	0.07499
c				c				c			
Tech Gp28		High		Tech Gp29		High		Tech Gp30		High	
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	0.59520	15.76976	0.25935	1	0.36373	7.88488	0.25935	1	0.06613	3.75471	0.07410
2	0.33600	12.91006	0.12740	2	0.20533	6.45503	0.12740	2	0.03733	3.07382	0.03640
3	0.34320	10.69518	0.19705	3	0.20973	5.34759	0.19705	3	0.03813	2.54647	0.05630
4	1.78232	40.73740	0.65716	4	1.14340	22.56266	0.65716	4	0.24595	11.98740	0.19400
5	0.17540	8.21512	0.23168	5	0.13585	5.41929	0.23168	5	0.05611	3.47179	0.11463
c				c				c			
Tech Gp28		V_Highs		Tech Gp29		V_Highs		Tech Gp30		V_Highs	
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	1.14840	33.48882	0.40915	1	0.70180	16.74441	0.40915	1	0.12760	7.97353	0.11690
2	0.77640	37.60112	0.21140	2	0.47447	18.80056	0.21140	2	0.08627	8.95265	0.06040
3	0.57360	29.75576	0.30940	3	0.35053	14.87788	0.30940	3	0.06373	7.08471	0.08840
4	3.22305	77.41005	1.02448	4	2.06766	42.87402	1.02448	4	0.44477	22.77871	0.30244
5	0.27084	15.60484	0.30791	5	0.20978	10.29409	0.30791	5	0.08664	6.59477	0.15235
c				c				c			
Tech Gp28		Super		Tech Gp29		Super		Tech Gp30		Super	
Mode	HC	CO	NOx	Mode	HC	CO	NOx	Mode	HC	CO	NOx
1	2.43840	70.66994	0.58065	1	1.49013	35.33497	0.58065	1	0.27093	16.82618	0.16590
2	2.38560	75.12688	0.38430	2	1.45787	37.56344	0.38430	2	0.26507	17.88735	0.10980
3	1.74720	54.30600	0.55545	3	1.06773	27.15300	0.55545	3	0.19413	12.93000	0.15870
4	6.35374	146.30726	1.44067	4	4.07608	81.03316	1.44067	4	0.87679	43.05242	0.42530
5	0.48485	23.64119	0.43073	5	0.37554	15.59546	0.43073	5	0.15510	9.99101	0.21312

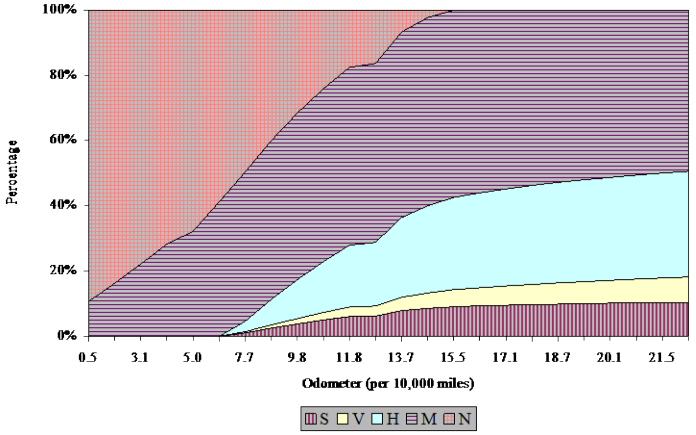
Table 4.9-5 Regime Growth Rates for Emission Rates Developed Using Method B

Tech groups=28, 29, 30				
HC	A	B	C	D
S	-9.81936	0.00000	0.06819	0.00000
V	-7.99632	0.00000	0.05553	0.00000
H	-22.00896	0.00000	0.15284	0.00000
M	7.73600	1.85833	0.00000	0.00000
N	134.04700	0.00000	0.00000	-22.14167
CO				
S	-13.06560	1.08880	0.00000	0.00000
V	-4.01760	0.00000	0.02790	0.00000
H	-40.76520	3.39710	0.00000	0.00000
M	11.41800	1.26321	0.00000	0.00000
N	131.96200	0.00000	0.00000	-21.93012
NOx				
S	-1.41432	0.11786	0.00000	0.00000
V	-3.17880	0.26490	0.00000	0.00000
H	-4.21344	0.00000	0.02926	0.00000
M	8.53500	0.00000	0.03364	0.00000
N	95.85200	-1.13367	0.00000	0.00000

Figure 4.9-6 shows a comparison of the old and new regime growth rates for HC and CO. These figures show that the non-linear nature of the new regime growth rates was maintained in the development of the new technology groups. Further, it is evident from these figures that with the advent of the 120K durability standards, normal and moderate emitters are projected to dominate future vehicle fleets. Figures 4.9-7, 4.9-8 and 4.9-9 show the HC, CO and NOx composite FTP emission rates, respectively, for various LEV vehicles.


Old HC Regime Growth Rates


New HC Regime Growth Rates


Old CO Regime Growth Rates

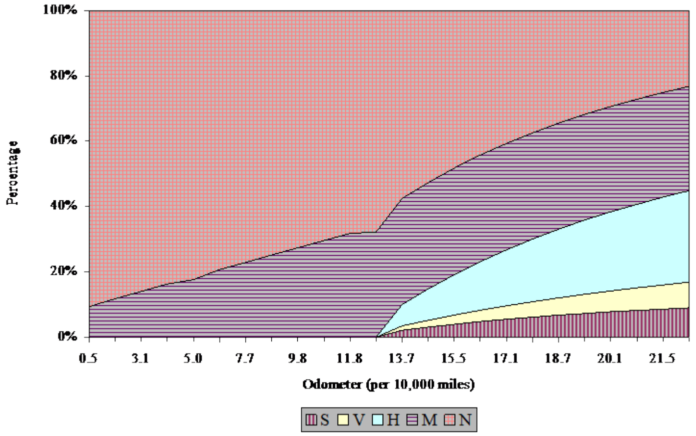

New CO Regime Growth Rates

Figure 4.9-6 Comparison of the Old and New Regime Growth Rates

Figure 4.9-7 Composite FTP_HC Emission Rates Developed Using Method B

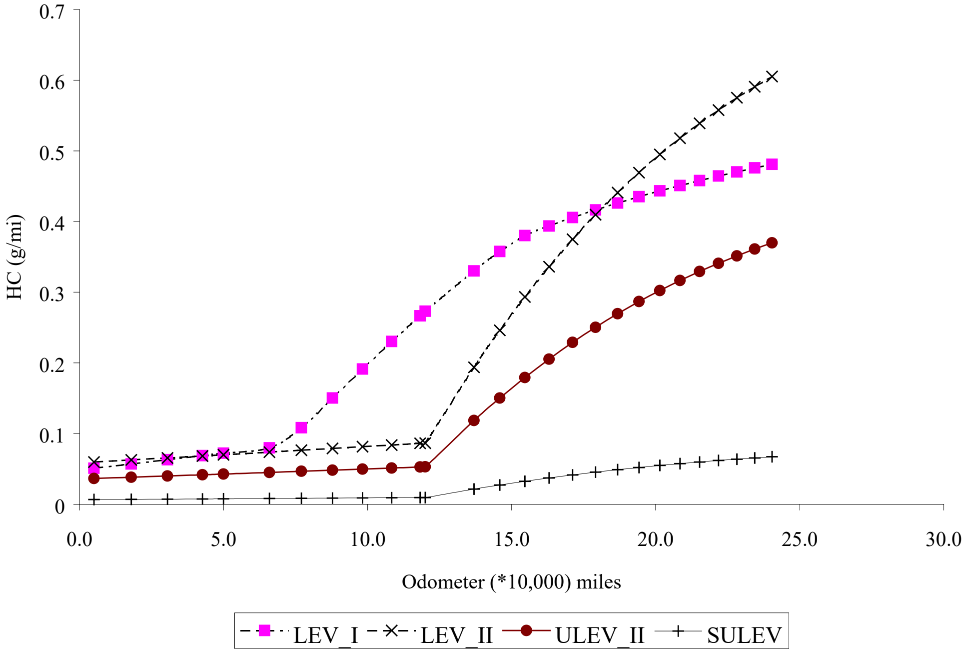


Figure 4.9-8 Composite FTP CO Emission Rates Developed Using Method B

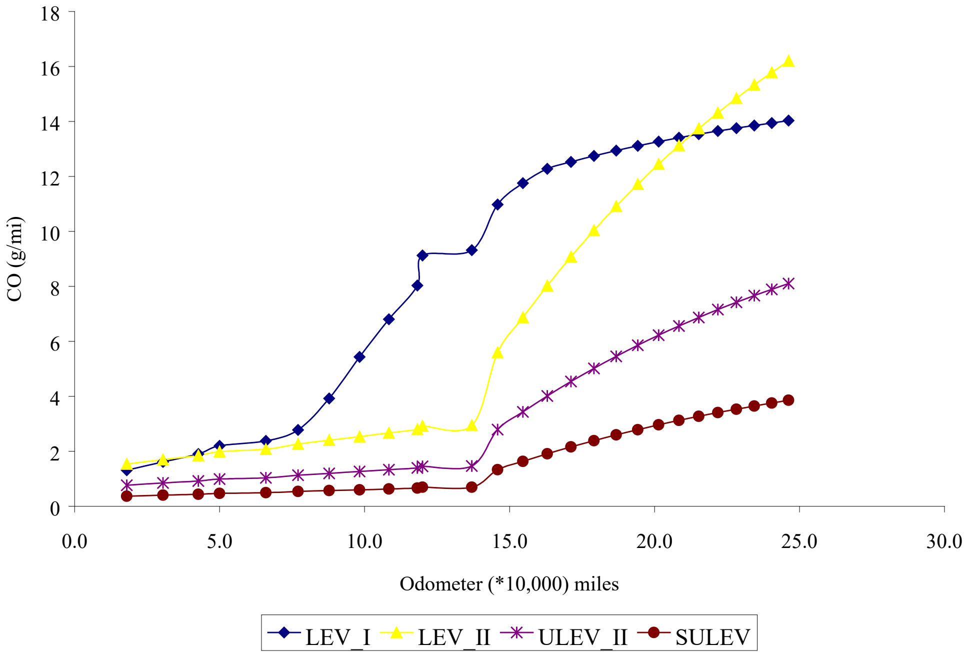
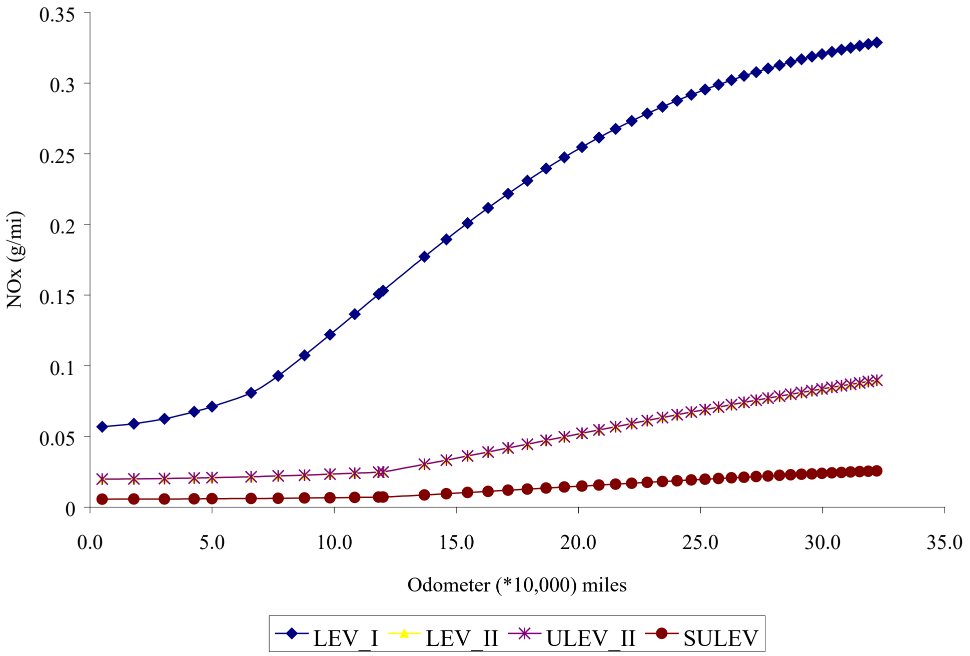


Figure 4.9-9 <u>**Composite FTP NOx Emission Rates Developed Using Method B**</u>



4.9.4 <u>Recommendations</u>

Staff recommends that Method A be used in estimating the emission rates for vehicles certified to the LEVII standards. The emission rates generated using Method A will meet the 120K durability standards. However, these rates will have proportionately lower zero mile rates resulting from the ratios of the LEVII/LEVI standards. Method B though elegant produces composite rates that are contrary to engineering judgement. For example it results in LEVII vehicles having higher emission rates, at mileage's above 170K, than LEVI vehicles. This results from the constraints placed on the regime growth rates in order to meet the standards at 120K and maintaining the same zero mile rates as vehicles certified to the same numerical standards.

Section 7.7 GASOLINE FUEL REID VAPOR PRESSURES

This section details how the Reid Vapor Pressures (RVP), in pounds per square inch, were determined for gasoline fuel sold in the 14 California air basins. The gasoline fuel RVP varies by geographic area, calendar year, month, and by months that result in winter carbon monoxide and summer ozone episodes.

7.7.1 Introduction

Variations in the fuel RVP effect the magnitude of hot soak, diurnal, resting loss and running loss emissions. The basic emission rates of these evaporative emission processes are adjusted according to the RVP of the fuel used. This adjustment is necessary to account for differences in RVP between the fuel used during laboratory testing, to that used on the road. In the MVEI7G model the fuel RVP varied by summer and winter months, as shown in Table 1, and other changes that coincided with the introduction of phase 1[1] and phase 2[2] fuels.

Table 7.7-1 Gasoline Fuel RVPs in MVEI7G

	Summer	Winter
Pre-1992	9.00	11.70
1992-96	7.80	10.00
>=1996	7.00	9.00

The wintertime RVP values also vary by calendar year, however, these values are calculated assuming that a similar reduction in the wintertime RVP would occur due to the introduction of phase 1 and phase 2 fuels. Additionally, these values do not reflect geographic variations in RVP, i.e., higher RVPs in colder regions to prevent cold starting problems and lower RVPs in the desert regions to prevent vapor lock. In EMFAC2000, the user can request an emissions estimate for any region of the state (to the county level) and month. This requires an RVP file that details the variation in RVP by region (air basin level), by calendar year (CY) and month.

7.7.2 Methodology

Staff contacted members of the Western States Petroleum Association (WSPA) to ascertain the regional, seasonal and historic variations in the RVP. In most cases, members of WSPA (local refineries) mentioned that they produce fuel that follows the American Society for Testing and Materials (ASTM) standard specification for automotive spark-ignition engine fuel (ASTM D 4814). The ASTM D 4814 defines six

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[1] Phase 1 fuel with a maximum 7.8 psi RVP was sold during the regulatory periods as defined in Title 13, section 2251.5 of the California Code of Regulations. This fuel was sold during the regulatory periods after January 1, 1992 and before March 1, 1996.

[2] Phase 2 fuel with a maximum 7.0 psi RVP is sold during the regulatory periods as defined in Title 13, section 2262.1 of the CCR. This fuel was sold after March 1, 1996

volatility classes in terms of maximum RVP, and recommends which class should be used based on geographic area and month. For California, there are ASTM RVP specifications for four geographic areas: North Coast, South Coast, Southeast and Interior. These areas encompass the following counties:

North Coast:	Alameda, Contra Costa, Del Norte, Humbolt, Lake, Marin, Mendocino, Monterey, Napa, San Benito, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, Sonoma and Trinity
South Coast:	Orange, San Diego, San Luis Obispo, Santa Barbara, Ventura, Los Angeles (except that portion north of the San Gabriel Mountain range and east of the Los Angeles county aqueduct)
Southeast:	Imperial, Riverside, San Bernardino, Los Angeles (that portion north of the San Gabriel mountain range and east of the Los Angeles county aqueduct), Mono, Inyo, Kern (that portion lying east of the Los Angeles county aqueduct)
Interior:	Lassen, Modoc, Plumas, Sierra, Siskiyou, Alpine, Amador, Butte, Calaveras, Colusa, El Dorado, Fresno, Glenn, Kern (except that portion lying east of Los Angeles county aqueduct), Kings, Madera, Mariposa, Merced, Placer, Sacramento, San Joaquin, Shasta, Stainlaus, Sutter, Tehama, Tulane, Tuolumne, Yolo, Yuba, Nevada

Staff received comments indicating that some of the refiners produce fuel up to the maximum allowable ASTM limits while others produced fuel that is less volatile but still met the ASTM guidelines. In addition to the ASTM RVP specifications, California regulates fuel RVP during the summer months. Sections 2251, 2251.5 and 2262.1 of Title 13 of the California Code of Regulations (CCR) specifies RVP limits, for each air basin, for calendar years prior to 1992, from 1992 to 1996, and 1996 and later, respectively. These regulations coincide with the introduction of 9.0, 7.8 and 7.0 pound RVP fuel. Please note the summer RVP control period also varies by air basin. Table 1 in Appendix 7.7-A shows the maximum allowable RVP specifications for each air basin and by calendar year. This table was created using the ASTM[3] RVP guidelines and the CCR specifications for summertime RVP.

Additionally, staff obtained RVP data from two refineries that supply fuel for sale in the South Coast Air Basin (SCAB). The first data set contained RVP data from the 1975 through 1992 calendar years, while the other contained data for 1992 and later calendar years. Table 7.7-2 shows the combined RVP data from these two suppliers.

Two methodologies were used in estimating the actual RVPs for each air basin. The first technique involved calculating a ratio, for each month and calendar year, of the actual fuel RVP sold in SCAB (Table 7.7-2) to the ASTM/CCR RVP specification for fuel sold in SCAB (Table 1 of Appendix 7.7-A). These ratios (Table 7.7-3) were then applied to ASTM/CCR RVP specification for each air basin listed in Table 1 of Appendix 7.7-A to predict the actual RVPs. The problem with this method is that it leads to instances where

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[3] ASTM D 439-81 Standard Specifications For Automotive Gasoline
ASTM D 4814 -95b Standard Specification For Automotive Spark-Ignition Engine Fuel

the predicted RVP for March (1990 and later calendar years) is significantly less than that for April even though the ASTM/CCR RVP specifications for March are higher than that for April. For example, the ratios for March and April for 1990 are 0.68 and 0.97, respectively. If these ratios are applied to the months of March (RVP=12) and April (RVP=11), then the predicted RVPs for March and April are 7.11 and 10.64 RVP, respectively. The underlying reason for this discrepancy appears to be that in order to meet the summertime RVP specifications; refineries are producing fuel that meets these specifications at least one month ahead of schedule. This production schedule leads to smaller ratios for the month of March, indicating a larger difference between the actual RVP to that specified in the ASTM specifications.

The second method investigated involved developing a regression equation that can predict the fuel RVP given the ASTM/CCR RVP specification by month and calendar year. This regression equation (equation 7.7-1) was developed by comparing the actual RVP specifications to the ASTM/CCR RVP specifications for SCAB. Please note, for the purposes of this regression the months were converted to numeric values, i.e., Jan=1, Feb=2, etc., and the calendar years are represented according to their four digit numeric values.

Table 7.7-2 RVP data For Gasoline Fuel Sold In The South Coast Air Basin

	January	February	March	April	May	June	July	August	September	October	November	December
1975	11.3	11.7	8.6	9	9	9	8.8	9	8.9	8.8	10.7	11.6
1976	11.6	11.4	9.7	9	8.6	9	8.8	8.9	8.8	8.8	11	11.6
1977	11.3	10.4	9	9	8.8	8.8	8.8	9	8.8	8.6	10.7	12.3
1978	12.5	13	13.4	8.7	8.7	8.5	8.7	8.8	8.7	8.8	11.2	12.6
1979	13	11.1	8.2	8.5	8.5	8.7	8.6	8.8	8.7	8.6	11.3	11.4
1980	12.2	11.5	8.2	8.4	8.8	8.6	8.6	8.7	8.8	8.8	11.2	12.2
1981	12.2	8.3	8.8	8.8	8.5	8.8	8.8	8.75	8.7	8.5	11.4	12.6
1982	12.7	12.2	8.6	8.8	8.8	8.7	8.7	8.8	8.6	8.8	11.2	12.7
1983	13.2	10.6	8.8	8.9	8	8.7	8.8	8.7	8.8	8.8	11.4	13
1984	13	9.2	8.7	8.7	8.6	8.6	8.9	8.7	8.9	8.9	11.5	12.4
1985	13	12.5	8.7	8.5	8.7	8.8	8.7	8.7	8.7	8.8	11.5	12.4
1986	13	11.7	8.8	8.7	8.3	8.8	8.6	8.4	8.8	8.3	11.4	13
1987	11.2	8.8	8.5	8.5	8.9	8.8	8.9	8.7	8.8	8.7	11.2	11.5
1988	12.6	8.3	8.5	8.9	8.9	8.7	8.9	8.7	8.5	8.8	11	11.1
1989	12.7	11.2	8.5	8.7	8.4	8.3	8.1	8.4	8	8.2	11	11.1
1990	11.45	8.3	8.45	8.15	8.15	8.15	8.3	8.15	8.4	8.3	10.45	11.25
1991	9.7	9.1	8.35	8.45	8.45	8.2	8.35	8.4	8.4	8.7	11.15	12.2
1992	11.2	7.35	7.35	7.35	7.35	7.4	7.25	7.25	7.3	7.5	11.6	12.2
1993	10.7	7.2	6.8	7.1	7.2	7.2	7.2	7.3	7.3	8.2	11.5	12.3
1994	10.5	7.4	7.4	7.4	7.5	7.5	7.5	7.6	7.5	7.6	11.2	11.3
1995	8.7	7.4	7.5	7.1	7	7	7	7.1	7.2	7.5	10.5	11.1
1996	10.4	7.6	6.9	6.8	6.8	6.8						

Table 7.7-3 Ratio of The Actual RVP to the ASTM/CCR RVP Specification For Fuel Sold in SCAB

	January	February	March	April	May	June	July	August	September	October	November	December
1975	0.84	0.87	0.69	0.78	0.78	0.84	0.88	0.90	0.89	0.82	0.93	0.86
1976	0.86	0.84	0.78	0.78	0.75	0.84	0.88	0.89	0.88	0.82	0.96	0.86
1977	0.84	0.77	0.72	0.78	0.77	0.82	0.88	0.90	0.88	0.80	0.93	0.91
1978	0.93	0.96	1.07	0.76	0.76	0.79	0.87	0.88	0.87	0.82	0.97	0.93
1979	0.96	0.82	0.66	0.74	0.74	0.81	0.86	0.88	0.87	0.80	0.98	0.84
1980	0.90	0.85	0.66	0.73	0.77	0.80	0.86	0.87	0.88	0.82	0.97	0.90
1981	0.90	0.61	0.70	0.77	0.74	0.98	0.98	0.97	0.97	0.94	0.91	0.93
1982	0.94	0.90	0.69	0.98	0.98	0.97	0.97	0.98	0.96	0.98	0.90	0.94
1983	0.98	0.79	0.70	0.99	0.89	0.97	0.98	0.97	0.98	0.98	0.91	0.96
1984	0.96	0.68	0.70	0.97	0.96	0.96	0.99	0.97	0.99	0.99	0.92	0.92
1985	0.96	0.93	0.70	0.94	0.97	0.98	0.97	0.97	0.97	0.98	0.92	0.92
1986	0.96	0.87	0.70	0.97	0.92	0.98	0.96	0.93	0.98	0.92	0.91	0.96
1987	0.83	0.65	0.68	0.94	0.99	0.98	0.99	0.97	0.98	0.97	0.90	0.85
1988	0.93	0.61	0.68	0.99	0.99	0.97	0.99	0.97	0.94	0.98	0.88	0.82
1989	0.94	0.83	0.68	0.97	0.93	0.92	0.90	0.93	0.89	0.91	0.88	0.82
1990	0.85	0.61	0.68	0.91	0.91	0.91	0.92	0.91	0.93	0.92	0.84	0.83
1991	0.72	0.67	0.67	0.94	0.94	0.91	0.93	0.93	0.93	0.97	0.89	0.90
1992	0.83	0.54	0.94	0.94	0.94	0.95	0.93	0.93	0.94	0.96	0.93	0.90
1993	0.79	0.53	0.87	0.91	0.92	0.92	0.92	0.94	0.94	1.05	0.92	0.91
1994	0.78	0.55	0.95	0.95	0.96	0.96	0.96	0.97	0.96	0.97	0.90	0.84
1995	0.64	0.55	0.96	0.91	0.90	0.90	0.90	0.91	0.92	0.96	0.84	0.82
1996+	0.77	0.56	0.99	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.84	0.82

$$\text{Actual RVP} = -29.538*S1 + 0.490*S2 + 125.014*S3 + 0.083*M2 - 0.069*Y1 - 0.997*M1 \qquad \textbf{(7.7-1)}$$

Where:

S1=RVP S2=RVP^2 S3=SQRT(RVP)
M1=Month M2=$Month^2$ Y1=Calendar Year

Table 7.7-4 shows the predicted RVP for SCAB using the regression equation above. Table 7.7-5 shows the difference between the actual RVP sold in SCAB (Table 7.7-2) and the predicted RVP (Table 7.7-4). Figure 7.7-1 shows the comparison of the actual and predicted RVPs for fuel sold in SCAB for calendar years 1975 and 1994.

Table 7.7-5 shows that the regression equation predicts higher RVPs during the month of February. This is the also the month where the difference between the ASTM RVP specs and the actual RVP produced is the highest. Table 2 in Appendix 7.7-A shows the predicted RVPs (except for SCAB), using equation 1, for various air basins in California. The RVPs in the months of July and December are also used to represent the RVPs during summer ozone and winter carbon monoxide episodes, respectively. Further, the annual average inventory is calculated using an RVP value that is based on the average of the monthly RVPs.

Figure 7.7-1 Comparison of the Actual and Predicted RVPs in SCAB

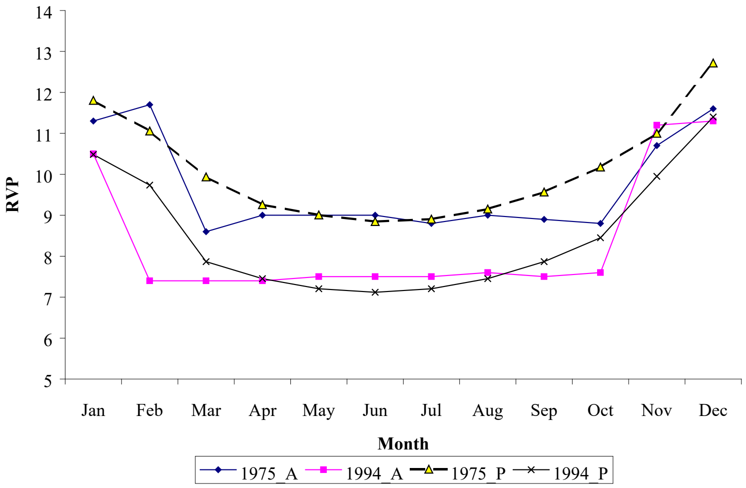


Table 7.7-4 Predicted RVP For SCAB Using Equation 7.7-1

	January	February	March	April	May	June	July	August	September	October	November	December
1975	11.80	11.06	9.94	9.26	9.01	8.85	8.90	9.15	9.57	10.18	11.00	12.72
1976	11.73	10.99	9.87	9.19	8.94	8.78	8.83	9.08	9.50	10.11	10.93	12.65
1977	11.66	10.92	9.80	9.12	8.87	8.71	8.77	9.01	9.43	10.04	10.86	12.58
1978	11.60	10.85	9.73	9.05	8.80	8.64	8.70	8.95	9.36	9.97	10.79	12.51
1979	11.53	10.78	9.66	8.98	8.73	8.57	8.63	8.88	9.29	9.90	10.72	12.44
1980	11.46	10.71	9.59	8.91	8.66	8.50	8.56	8.81	9.22	9.83	10.65	12.37
1981	11.39	10.64	9.52	8.84	8.59	8.35	8.43	8.68	9.10	9.68	10.85	12.30
1982	11.32	10.57	9.45	8.61	8.36	8.28	8.36	8.61	9.03	9.61	10.78	12.23
1983	11.25	10.50	9.38	8.54	8.29	8.21	8.29	8.54	8.96	9.54	10.71	12.16
1984	11.18	10.43	9.31	8.47	8.22	8.14	8.22	8.47	8.89	9.47	10.64	12.09
1985	11.11	10.36	9.24	8.40	8.15	8.07	8.15	8.40	8.82	9.40	10.57	12.02
1986	11.04	10.29	9.17	8.33	8.08	8.00	8.08	8.33	8.75	9.33	10.50	11.95
1987	10.97	10.22	9.10	8.26	8.02	7.93	8.02	8.26	8.68	9.26	10.43	11.88
1988	10.90	10.15	9.04	8.20	7.95	7.86	7.95	8.20	8.61	9.19	10.36	11.82
1989	10.83	10.08	8.97	8.13	7.88	7.79	7.88	8.13	8.54	9.12	10.30	11.75
1990	10.76	10.01	8.90	8.06	7.81	7.72	7.81	8.06	8.47	9.05	10.23	11.68
1991	10.69	9.95	8.83	7.99	7.74	7.65	7.74	7.99	8.40	8.98	10.16	11.61
1992	10.62	9.88	8.01	7.59	7.34	7.26	7.34	7.59	8.01	8.59	10.09	11.54
1993	10.55	9.81	7.94	7.52	7.27	7.19	7.27	7.52	7.94	8.52	10.02	11.47
1994	10.48	9.74	7.87	7.45	7.20	7.12	7.20	7.45	7.87	8.45	9.95	11.40
1995	10.42	9.67	7.80	7.38	7.13	7.05	7.13	7.38	7.80	8.38	9.88	11.33
1996	10.35	9.60	7.17	6.76	6.51	6.42	6.51	6.76	7.17	7.75	9.81	11.26

Table 7.7-5 The Difference Between The Actual Minus The Predicted RVPs For SCAB

	January	February	March	April	May	June	July	August	September	October	November	December
1975	-0.50	0.64	-1.34	-0.26	-0.01	0.15	-0.10	-0.15	-0.67	-1.38	-0.30	-1.12
1976	-0.13	0.41	-0.17	-0.19	-0.34	0.22	-0.03	-0.18	-0.70	-1.31	0.07	-1.05
1977	-0.36	-0.52	-0.80	-0.12	-0.07	0.09	0.03	-0.01	-0.63	-1.44	-0.16	-0.28
1978	0.90	2.15	3.67	-0.35	-0.10	-0.14	0.00	-0.15	-0.66	-1.17	0.41	0.09
1979	1.47	0.32	-1.46	-0.48	-0.23	0.13	-0.03	-0.08	-0.59	-1.30	0.58	-1.04
1980	0.74	0.79	-1.39	-0.51	0.14	0.10	0.04	-0.11	-0.42	-1.03	0.55	-0.17
1981	0.81	-2.34	-0.72	-0.04	-0.09	0.45	0.37	0.07	-0.40	-1.18	0.55	0.30
1982	1.38	1.63	-0.85	0.19	0.44	0.42	0.34	0.19	-0.43	-0.81	0.42	0.47
1983	1.95	0.10	-0.58	0.36	-0.29	0.49	0.51	0.16	-0.16	-0.74	0.69	0.84
1984	1.82	-1.23	-0.61	0.23	0.38	0.46	0.68	0.23	0.01	-0.57	0.86	0.31
1985	1.89	2.14	-0.54	0.10	0.55	0.73	0.55	0.30	-0.12	-0.60	0.93	0.38
1986	1.96	1.41	-0.37	0.37	0.22	0.80	0.52	0.07	0.05	-1.03	0.90	1.05
1987	0.23	-1.42	-0.60	0.24	0.88	0.87	0.88	0.44	0.12	-0.56	0.77	-0.38
1988	1.70	-1.85	-0.54	0.70	0.95	0.84	0.95	0.50	-0.11	-0.39	0.64	-0.72
1989	1.87	1.12	-0.47	0.57	0.52	0.51	0.22	0.27	-0.54	-0.92	0.70	-0.65
1990	0.69	-1.71	-0.45	0.09	0.34	0.43	0.49	0.09	-0.07	-0.75	0.22	-0.43
1991	-0.99	-0.85	-0.48	0.46	0.71	0.55	0.61	0.41	0.00	-0.28	0.99	0.59
1992	0.58	-2.53	-0.66	-0.24	0.01	0.14	-0.09	-0.34	-0.71	-1.09	1.51	0.66
1993	0.15	-2.61	-1.14	-0.42	-0.07	0.01	-0.07	-0.22	-0.64	-0.32	1.48	0.83
1994	0.02	-2.34	-0.47	-0.05	0.30	0.38	0.30	0.15	-0.37	-0.85	1.25	-0.10
1995	-1.72	-2.27	-0.30	-0.28	-0.13	-0.05	-0.13	-0.28	-0.60	-0.88	0.62	-0.23
1996	0.05	-2.00	-0.27	0.04	0.29	0.38	0.29	0.04	-0.37	-0.95	0.69	-0.16

7.7.3 Discussion

There are two main uncertainties in predicting RVPs for various air basins:

- The lack of actual RVP data from all the fuel suppliers in SCAB. Staff received data from only two of the six major fuel suppliers in SCAB. Additionally, the data from both refiners did not cover the same calendar year, resulting in RVP data that is representative of the RVP from a particular refinery. In talking to the refiners, staff ascertained that some refiners produce RVP that closely met the ASTM specifications while others produced fuel that easily met the same specifications. This variation should be accounted for in creating table 7.7-2. This would subsequently lead to better predictions of RVP for SCAB.
- The lack of actual RVP data from fuel suppliers to the North Coast or the interior regions of California.

Staff recommends that the RVPs shown Table 2 of Appendix 7.7-A should be used in EMFAC2000 to show the variation in RVPs by geographic areas, month and calendar years. This table also contains the actual RVP for fuel sold in SCAB and predicted RVPs for other regions of the state. The predicted RVPs, for other air basins, closely follow the ASTM and CCR RVP specifications; however, it may not adequately represent the early introduction low RVP fuel in summertime.

Appendix 7.7-A

Table 1 Maximum Allowable ASTM RVP Specifications

South Coast Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1976	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1977	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1978	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1979	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1980	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1981	13.5	13.5	12.5	11.5	11.5	9	9	9	9	9	12.5	13.5
1982	13.5	13.5	12.5	9	9	9	9	9	9	9	12.5	13.5
1983	13.5	13.5	12.5	9	9	9	9	9	9	9	12.5	13.5
1984	13.5	13.5	12.5	9	9	9	9	9	9	9	12.5	13.5
1985	13.5	13.5	12.5	9	9	9	9	9	9	9	12.5	13.5
1986	13.5	13.5	12.5	9	9	9	9	9	9	9	12.5	13.5
1987	13.5	13.5	12.5	9	9	9	9	9	9	9	12.5	13.5
1988	13.5	13.5	12.5	9	9	9	9	9	9	9	12.5	13.5
1989	13.5	13.5	12.5	9	9	9	9	9	9	9	12.5	13.5
1990	13.5	13.5	12.5	9	9	9	9	9	9	9	12.5	13.5
1991	13.5	13.5	12.5	9	9	9	9	9	9	9	12.5	13.5
1992	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	13.5
1993	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	13.5
1994	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	13.5
1995	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	13.5
1996+	13.5	13.5	7	7	7	7	7	7	7	7	12.5	13.5

Southeast Desert Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	12.5	11.5	10.75	10	9.5	9	9	9	9	9.5	10.75	12.5
1976	12.5	11.5	10.75	10	9.5	9	9	9	9	9.5	10.75	12.5
1977	12.5	11.5	10.75	10	9.5	9	9	9	9	9.5	10.75	12.5
1978	12.5	11.5	10.75	10	9.5	9	9	9	9	9.5	10.75	12.5
1979	12.5	11.5	10.75	10	9.5	9	9	9	9	9.5	10.75	12.5
1980	12.5	11.5	10.75	10	9.5	9	9	9	9	9.5	10.75	12.5
1981	12.5	11.5	10.75	10	9	9	9	9	9	9	10.75	12.5
1982	13.5	12.5	10.75	9	9	9	9	9	9	9	10.75	12.5
1983	13.5	12.5	10.75	9	9	9	9	9	9	9	10.75	12.5
1984	13.5	12.5	10.75	9	9	9	9	9	9	9	10.75	12.5
1985	13.5	12.5	10.75	9	9	9	9	9	9	9	10.75	12.5
1986	13.5	12.5	10.75	9	9	9	9	9	9	9	10.75	12.5
1987	13.5	12.5	10.75	9	9	9	9	9	9	9	10.75	12.5
1988	13.5	12.5	10.75	9	9	9	9	9	9	9	10.75	12.5
1989	13.5	12.5	10.75	9	9	9	9	9	9	9	10.75	12.5
1990	13.5	12.5	10.75	9	9	9	9	9	9	9	10.75	12.5
1991	13.5	12.5	10.75	9	9	9	9	9	9	9	10.75	12.5
1992	13.5	12.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	10.75	12.5
1993	13.5	12.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	10.75	12.5
1994	13.5	12.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	10.75	12.5
1995	13.5	12.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	10.75	12.5

1996 +	13.5	12.5	7	7	7	7	7	7	7	7	10.75	12.5

Great Basin
Valley air
basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	12.5	11.5	10.75	10	9.5	9	9	9	9	9.5	10.75	12.5
1976	12.5	11.5	10.75	10	9.5	9	9	9	9	9.5	10.75	12.5
1977	12.5	11.5	10.75	10	9.5	9	9	9	9	9.5	10.75	12.5
1978	12.5	11.5	10.75	10	9.5	9	9	9	9	9.5	10.75	12.5
1979	12.5	11.5	10.75	10	9.5	9	9	9	9	9.5	10.75	12.5
1980	12.5	11.5	10.75	10	9.5	9	9	9	9	9.5	10.75	12.5
1981	12.5	11.5	10.75	10	9	9	9	9	9	9.5	10.75	12.5
1982	13.5	12.5	10.75	9.5	9	9	9	9	9	9.5	10.75	12.5
1983	13.5	12.5	10.75	9.5	9	9	9	9	9	9.5	10.75	12.5
1984	13.5	12.5	10.75	9.5	9	9	9	9	9	9.5	10.75	12.5
1985	13.5	12.5	10.75	9.5	9	9	9	9	9	9.5	10.75	12.5
1986	13.5	12.5	10.75	9.5	9	9	9	9	9	9.5	10.75	12.5
1987	13.5	12.5	10.75	9.5	9	9	9	9	9	9.5	10.75	12.5
1988	13.5	12.5	10.75	9.5	9	9	9	9	9	9.5	10.75	12.5
1989	13.5	12.5	10.75	9.5	9	9	9	9	9	9.5	10.75	12.5
1990	13.5	12.5	10.75	9.5	9	9	9	9	9	9.5	10.75	12.5
1991	13.5	12.5	10.75	9.5	9	9	9	9	9	9.5	10.75	12.5
1992	13.5	12.5	10.75	7.8	7.8	7.8	7.8	7.8	7.8	9.5	10.75	12.5
1993	13.5	12.5	10.75	7.8	7.8	7.8	7.8	7.8	7.8	9.5	10.75	12.5
1994	13.5	12.5	10.75	7.8	7.8	7.8	7.8	7.8	7.8	9.5	10.75	12.5
1995	13.5	12.5	10.75	7.8	7.8	7.8	7.8	7.8	7.8	9.5	10.75	12.5
1996 +	13.5	12.5	10.75	7	7	7	7	7	7	9.5	10.75	12.5

San Francisco
Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1976	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1977	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1978	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1979	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1980	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1981	13.5	13.5	13.5	12.5	11.5	9	9	9	9	9	12.5	14.25
1982	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1983	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1984	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1985	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1986	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1987	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1988	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1989	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1990	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1991	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1992	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1993	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1994	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1995	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1996 +	14.25	13.5	13.5	7	7	7	7	7	7	7	12.5	14.25

San Diego Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1976	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1977	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1978	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1979	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1980	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1981	13.5	13.5	12.5	11.5	11.5	9	9	9	9	9	12.5	13.5
1982	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1983	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1984	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1985	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1986	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1987	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1988	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1989	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1990	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1991	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1992	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	13.5
1993	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	13.5
1994	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	13.5
1995	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	13.5
1996 +	13.5	13.5	7	7	7	7	7	7	7	7	12.5	13.5

Sacramento Valley Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1976	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1977	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1978	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1979	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1980	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1981	13.5	13.5	12.5	11.5	10.75	9	9	9	9	9	12.5	14.25
1982	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1983	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1984	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1985	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1986	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1987	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1988	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1989	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1990	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1991	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1992	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1993	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1994	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1995	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1996 +	14.25	13.5	13.5	7	7	7	7	7	7	7	12.5	14.25

San Joaquin Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

1975	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1976	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1977	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1978	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1979	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1980	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1981	13.5	13.5	12.5	11.5	10.75	9	9	9	9	9	12.5	14.25
1982	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1983	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1984	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1985	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1986	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1987	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1988	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1989	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1990	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1991	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1992	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1993	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1994	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1995	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1996 +	14.25	13.5	13.5	7	7	7	7	7	7	7	12.5	14.25

Mountain Counties Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1976	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1977	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1978	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1979	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1980	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1981	13.5	13.5	12.5	11.5	10.75	9	9	9	9	9	12.5	14.25
1982	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1983	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1984	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1985	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1986	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1987	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1988	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1989	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1990	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1991	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1992	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1993	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1994	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1995	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1996 +	14.25	13.5	13.5	7	7	7	7	7	7	7	12.5	14.25

Lake Tahoe Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1976	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1977	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5

1978	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1979	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1980	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1981	13.5	13.5	12.5	11.5	10.75	9	9	9	9	9	12.5	14.25
1982	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1983	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1984	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1985	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1986	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1987	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1988	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1989	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1990	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1991	14.25	13.5	13.5	11.25	9	9	9	9	9	9	12.5	14.25
1992	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1993	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1994	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1995	14.25	13.5	13.5	7.8	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1996 +	14.25	13.5	13.5	7	7	7	7	7	7	7	12.5	14.25

North Coast
Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1976	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1977	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1978	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1979	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1980	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1981	13.5	13.5	13.5	12.5	11.5	9	9	9	9	10.75	12.5	14.25
1982	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1983	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1984	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1985	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1986	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1987	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1988	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1989	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1990	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1991	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1992	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	10.75	12.5	14.25
1993	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	10.75	12.5	14.25
1994	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	10.75	12.5	14.25
1995	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	10.75	12.5	14.25
1996 +	14.25	13.5	13.5	11.25	7	7	7	7	7	10.75	12.5	14.25

Lake County
Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1976	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1977	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1978	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1979	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1980	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5

1981	13.5	13.5	13.5	12.5	11.5	9	9	9	9	10.75	12.5	14.25
1982	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1983	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1984	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1985	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1986	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1987	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1988	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1989	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1990	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1991	14.25	13.5	13.5	11.25	10.25	9	9	9	9	10.75	12.5	14.25
1992	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	10.75	12.5	14.25
1993	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	10.75	12.5	14.25
1994	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	10.75	12.5	14.25
1995	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	10.75	12.5	14.25
1996 +	14.25	13.5	13.5	11.25	7	7	7	7	7	10.75	12.5	14.25

North East Plateau Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1976	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1977	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1978	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1979	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1980	13.5	13.5	12.5	11.5	10.75	10	10	10	10	10.75	12.5	13.5
1981	13.5	13.5	12.5	11.5	10.75	9	9	9	9.25	10.75	12.5	14.25
1982	14.25	13.5	13.5	11.25	10.25	9	9	9	9.25	10.75	12.5	14.25
1983	14.25	13.5	13.5	11.25	10.25	9	9	9	9.25	10.75	12.5	14.25
1984	14.25	13.5	13.5	11.25	10.25	9	9	9	9.25	10.75	12.5	14.25
1985	14.25	13.5	13.5	11.25	10.25	9	9	9	9.25	10.75	12.5	14.25
1986	14.25	13.5	13.5	11.25	10.25	9	9	9	9.25	10.75	12.5	14.25
1987	14.25	13.5	13.5	11.25	10.25	9	9	9	9.25	10.75	12.5	14.25
1988	14.25	13.5	13.5	11.25	10.25	9	9	9	9.25	10.75	12.5	14.25
1989	14.25	13.5	13.5	11.25	10.25	9	9	9	9.25	10.75	12.5	14.25
1990	14.25	13.5	13.5	11.25	10.25	9	9	9	9.25	10.75	12.5	14.25
1991	14.25	13.5	13.5	11.25	10.25	9	9	9	9.25	10.75	12.5	14.25
1992	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	10.75	12.5	14.25
1993	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	10.75	12.5	14.25
1994	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	10.75	12.5	14.25
1995	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	10.75	12.5	14.25
1996 +	14.25	13.5	13.5	11.25	7	7	7	7	7	10.75	12.5	14.25

North Central Coast Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1976	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1977	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1978	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1979	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1980	13.5	13.5	13.5	12.5	11.5	11.5	11.5	11.5	11.5	11.5	12.5	13.5
1981	13.5	13.5	13.5	12.5	11.5	9	9	9	9	9	12.5	14.25
1982	14.25	13.5	13.5	11.25	10.25	9	9	9	9	9	12.5	14.25
1983	14.25	13.5	13.5	11.25	10.25	9	9	9	9	9	12.5	14.25

1984	14.25	13.5	13.5	11.25	10.25	9	9	9	9	9	12.5	14.25
1985	14.25	13.5	13.5	11.25	10.25	9	9	9	9	9	12.5	14.25
1986	14.25	13.5	13.5	11.25	10.25	9	9	9	9	9	12.5	14.25
1987	14.25	13.5	13.5	11.25	10.25	9	9	9	9	9	12.5	14.25
1988	14.25	13.5	13.5	11.25	10.25	9	9	9	9	9	12.5	14.25
1989	14.25	13.5	13.5	11.25	10.25	9	9	9	9	9	12.5	14.25
1990	14.25	13.5	13.5	11.25	10.25	9	9	9	9	9	12.5	14.25
1991	14.25	13.5	13.5	11.25	10.25	9	9	9	9	9	12.5	14.25
1992	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1993	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1994	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1995	14.25	13.5	13.5	11.25	7.8	7.8	7.8	7.8	7.8	7.8	12.5	14.25
1996 +	14.25	13.5	13.5	11.25	7	7	7	7	7	7	12.5	14.25

South Central Coast
Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1976	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1977	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1978	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1979	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1980	13.5	13.5	12.5	11.5	11.5	10.75	10	10	10	10.75	11.5	13.5
1981	13.5	13.5	12.5	11.5	11.5	9	9	9	9	9	12.5	13.5
1982	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1983	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1984	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1985	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1986	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1987	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1988	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1989	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1990	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1991	13.5	13.5	12.5	10.25	9	9	9	9	9	9	12.5	13.5
1992	13.5	13.5	12.5	10.25	7.8	7.8	7.8	7.8	7.8	7.8	12.5	13.5
1993	13.5	13.5	12.5	10.25	7.8	7.8	7.8	7.8	7.8	7.8	12.5	13.5
1994	13.5	13.5	12.5	10.25	7.8	7.8	7.8	7.8	7.8	7.8	12.5	13.5
1995	13.5	13.5	12.5	10.25	7.8	7.8	7.8	7.8	7.8	7.8	12.5	13.5
1996 +	13.5	13.5	12.5	10.25	7	7	7	7	7	7	12.5	13.5

Table 2 Predicted RVPs by Air Basin

South Coast Air Basin- actual RVPs

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.3	11.7	8.6	9.0	9.0	9.0	8.8	9.0	8.9	8.8	10.7	11.6
1976	11.6	11.4	9.7	9.0	8.6	9.0	8.8	8.9	8.8	8.8	11.0	11.6
1977	11.3	10.4	9.0	9.0	8.8	8.8	8.8	9.0	8.8	8.6	10.7	12.3
1978	12.5	13.0	13.4	8.7	8.7	8.5	8.7	8.8	8.7	8.8	11.2	12.6
1979	13.0	11.1	8.2	8.5	8.5	8.7	8.6	8.8	8.7	8.6	11.3	11.4
1980	12.2	11.5	8.2	8.4	8.8	8.6	8.6	8.7	8.8	8.8	11.2	12.2
1981	12.2	8.3	8.8	8.8	8.5	8.8	8.8	8.8	8.7	8.5	11.4	12.6
1982	12.7	12.2	8.6	8.8	8.8	8.7	8.7	8.8	8.6	8.8	11.2	12.7
1983	13.2	10.6	8.8	8.9	8.0	8.7	8.8	8.7	8.8	8.8	11.4	13.0
1984	13.0	9.2	8.7	8.7	8.6	8.6	8.9	8.7	8.9	8.9	11.5	12.4
1985	13.0	12.5	8.7	8.5	8.7	8.8	8.7	8.7	8.7	8.8	11.5	12.4
1986	13.0	11.7	8.8	8.7	8.3	8.8	8.6	8.4	8.8	8.3	11.4	13.0
1987	11.2	8.8	8.5	8.5	8.9	8.8	8.9	8.7	8.8	8.7	11.2	11.5
1988	12.6	8.3	8.5	8.9	8.9	8.7	8.9	8.7	8.5	8.8	11.0	11.1
1989	12.7	11.2	8.5	8.7	8.4	8.3	8.1	8.4	8.0	8.2	11.0	11.1
1990	11.5	8.3	8.5	8.2	8.2	8.2	8.3	8.2	8.4	8.3	10.5	11.3
1991	9.7	9.1	8.4	8.5	8.5	8.2	8.4	8.4	8.4	8.7	11.2	12.2
1992	11.2	7.4	7.4	7.4	7.4	7.4	7.3	7.3	7.3	7.5	11.6	12.2
1993	10.7	7.2	6.8	7.1	7.2	7.2	7.2	7.3	7.3	8.2	11.5	12.3
1994	10.5	7.4	7.4	7.4	7.5	7.5	7.5	7.6	7.5	7.6	11.2	11.3
1995	8.7	7.4	7.5	7.1	7.0	7.0	7.0	7.1	7.2	7.5	10.5	11.1
1996+	10.4	7.6	6.9	6.8	6.8	6.8	6.8	6.8	6.8	6.8	10.5	11.1

Southeast Desert Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.3	10.3	9.6	9.2	8.9	8.8	8.8	9.1	9.5	10.1	10.9	12.2
1976	11.2	10.2	9.5	9.1	8.8	8.7	8.8	9.0	9.4	10.1	10.9	12.1
1977	11.1	10.1	9.5	9.0	8.7	8.6	8.7	9.0	9.4	10.0	10.8	12.0
1978	11.1	10.0	9.4	8.9	8.7	8.6	8.6	8.9	9.3	9.9	10.7	12.0
1979	11.0	10.0	9.3	8.9	8.6	8.5	8.6	8.8	9.2	9.9	10.6	11.9
1980	10.9	9.9	9.2	8.8	8.5	8.4	8.5	8.8	9.2	9.8	10.6	11.8
1981	10.9	9.8	9.2	8.7	8.4	8.3	8.4	8.7	9.1	9.7	10.5	11.8
1982	11.3	10.0	9.1	8.6	8.4	8.3	8.4	8.6	9.0	9.6	10.4	11.7
1983	11.2	10.0	9.0	8.5	8.3	8.2	8.3	8.5	9.0	9.5	10.4	11.6
1984	11.2	9.9	9.0	8.5	8.2	8.1	8.2	8.5	8.9	9.5	10.3	11.6
1985	11.1	9.8	8.9	8.4	8.2	8.1	8.2	8.4	8.8	9.4	10.2	11.5
1986	11.0	9.8	8.8	8.3	8.1	8.0	8.1	8.3	8.7	9.3	10.2	11.4
1987	11.0	9.7	8.8	8.3	8.0	7.9	8.0	8.3	8.7	9.3	10.1	11.3
1988	10.9	9.6	8.7	8.2	7.9	7.9	7.9	8.2	8.6	9.2	10.0	11.3
1989	10.8	9.5	8.6	8.1	7.9	7.8	7.9	8.1	8.5	9.1	10.0	11.2
1990	10.8	9.5	8.6	8.1	7.8	7.7	7.8	8.1	8.5	9.1	9.9	11.1
1991	10.7	9.4	8.5	8.0	7.7	7.7	7.7	8.0	8.4	9.0	9.8	11.1
1992	10.6	9.3	8.0	7.6	7.3	7.3	7.3	7.6	8.0	8.6	9.7	11.0
1993	10.6	9.3	7.9	7.5	7.3	7.2	7.3	7.5	7.9	8.5	9.7	10.9
1994	10.5	9.2	7.9	7.5	7.2	7.1	7.2	7.5	7.9	8.4	9.6	10.9
1995	10.4	9.1	7.8	7.4	7.1	7.1	7.1	7.4	7.8	8.4	9.5	10.8
1996+	10.3	9.1	7.2	6.8	6.5	6.4	6.5	6.8	7.2	7.8	9.5	10.7

Great Basin Valley Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.3	10.3	9.6	9.2	8.9	8.8	8.8	9.1	9.5	10.1	10.9	12.2
1976	11.2	10.2	9.5	9.1	8.8	8.7	8.8	9.0	9.4	10.1	10.9	12.1
1977	11.1	10.1	9.5	9.0	8.7	8.6	8.7	9.0	9.4	10.0	10.8	12.0
1978	11.1	10.0	9.4	8.9	8.7	8.6	8.6	8.9	9.3	9.9	10.7	12.0
1979	11.0	10.0	9.3	8.9	8.6	8.5	8.6	8.8	9.2	9.9	10.6	11.9
1980	10.9	9.9	9.2	8.8	8.5	8.4	8.5	8.8	9.2	9.8	10.6	11.8
1981	10.9	9.8	9.2	8.7	8.4	8.3	8.4	8.7	9.1	9.7	10.5	11.8
1982	11.3	10.0	9.1	8.7	8.4	8.3	8.4	8.6	9.0	9.6	10.4	11.7
1983	11.2	10.0	9.0	8.6	8.3	8.2	8.3	8.5	9.0	9.6	10.4	11.6
1984	11.2	9.9	9.0	8.5	8.2	8.1	8.2	8.5	8.9	9.5	10.3	11.6
1985	11.1	9.8	8.9	8.4	8.2	8.1	8.2	8.4	8.8	9.4	10.2	11.5
1986	11.0	9.8	8.8	8.4	8.1	8.0	8.1	8.3	8.7	9.4	10.2	11.4
1987	11.0	9.7	8.8	8.3	8.0	7.9	8.0	8.3	8.7	9.3	10.1	11.3
1988	10.9	9.6	8.7	8.2	7.9	7.9	7.9	8.2	8.6	9.2	10.0	11.3
1989	10.8	9.5	8.6	8.2	7.9	7.8	7.9	8.1	8.5	9.2	10.0	11.2
1990	10.8	9.5	8.6	8.1	7.8	7.7	7.8	8.1	8.5	9.1	9.9	11.1
1991	10.7	9.4	8.5	8.0	7.7	7.7	7.7	8.0	8.4	9.0	9.8	11.1
1992	10.6	9.3	8.4	7.6	7.3	7.3	7.3	7.6	8.0	9.0	9.7	11.0
1993	10.6	9.3	8.3	7.5	7.3	7.2	7.3	7.5	7.9	8.9	9.7	10.9
1994	10.5	9.2	8.3	7.5	7.2	7.1	7.2	7.5	7.9	8.8	9.6	10.9
1995	10.4	9.1	8.2	7.4	7.1	7.1	7.1	7.4	7.8	8.7	9.5	10.8
1996 +	10.3	9.1	8.1	6.8	6.5	6.4	6.5	6.8	7.2	8.7	9.5	10.7

San Francisco Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.8	11.1	10.5	9.5	9.0	8.9	9.0	9.3	9.7	10.3	11.3	12.7
1976	11.7	11.0	10.4	9.5	8.9	8.9	8.9	9.2	9.6	10.2	11.2	12.6
1977	11.7	10.9	10.3	9.4	8.9	8.8	8.9	9.1	9.5	10.1	11.1	12.6
1978	11.6	10.8	10.3	9.3	8.8	8.7	8.8	9.0	9.5	10.0	11.1	12.5
1979	11.5	10.8	10.2	9.2	8.7	8.6	8.7	9.0	9.4	10.0	11.0	12.4
1980	11.5	10.7	10.1	9.2	8.7	8.6	8.7	8.9	9.3	9.9	10.9	12.4
1981	11.4	10.6	10.1	9.1	8.6	8.3	8.4	8.7	9.1	9.7	10.9	12.9
1982	11.9	10.6	10.0	8.7	8.4	8.3	8.4	8.6	9.0	9.6	10.8	12.9
1983	11.9	10.5	9.9	8.7	8.3	8.2	8.3	8.5	9.0	9.5	10.7	12.8
1984	11.8	10.4	9.8	8.6	8.2	8.1	8.2	8.5	8.9	9.5	10.6	12.7
1985	11.7	10.4	9.8	8.5	8.2	8.1	8.2	8.4	8.8	9.4	10.6	12.7
1986	11.7	10.3	9.7	8.5	8.1	8.0	8.1	8.3	8.7	9.3	10.5	12.6
1987	11.6	10.2	9.6	8.4	8.0	7.9	8.0	8.3	8.7	9.3	10.4	12.5
1988	11.5	10.2	9.6	8.3	7.9	7.9	7.9	8.2	8.6	9.2	10.4	12.4
1989	11.5	10.1	9.5	8.3	7.9	7.8	7.9	8.1	8.5	9.1	10.3	12.4
1990	11.4	10.0	9.4	8.2	7.8	7.7	7.8	8.1	8.5	9.1	10.2	12.3
1991	11.3	9.9	9.4	8.1	7.7	7.7	7.7	8.0	8.4	9.0	10.2	12.2
1992	11.3	9.9	9.3	7.6	7.3	7.3	7.3	7.6	8.0	8.6	10.1	12.2
1993	11.2	9.8	9.2	7.5	7.3	7.2	7.3	7.5	7.9	8.5	10.0	12.1
1994	11.1	9.7	9.2	7.5	7.2	7.1	7.2	7.5	7.9	8.4	9.9	12.0
1995	11.0	9.7	9.1	7.4	7.1	7.1	7.1	7.4	7.8	8.4	9.9	12.0
1996 +	11.0	9.6	9.0	6.8	6.5	6.4	6.5	6.8	7.2	7.8	9.8	11.9

San Diego Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.8	11.1	9.9	9.3	9.0	8.8	8.9	9.2	9.6	10.2	11.0	12.7
1976	11.7	11.0	9.9	9.2	8.9	8.8	8.8	9.1	9.5	10.1	10.9	12.6
1977	11.7	10.9	9.8	9.1	8.9	8.7	8.8	9.0	9.4	10.0	10.9	12.6
1978	11.6	10.8	9.7	9.0	8.8	8.6	8.7	8.9	9.4	10.0	10.8	12.5
1979	11.5	10.8	9.7	9.0	8.7	8.6	8.6	8.9	9.3	9.9	10.7	12.4
1980	11.5	10.7	9.6	8.9	8.7	8.5	8.6	8.8	9.2	9.8	10.7	12.4
1981	11.4	10.6	9.5	8.8	8.6	8.3	8.4	8.7	9.1	9.7	10.9	12.3
1982	11.3	10.6	9.5	8.7	8.4	8.3	8.4	8.6	9.0	9.6	10.8	12.2
1983	11.2	10.5	9.4	8.6	8.3	8.2	8.3	8.5	9.0	9.5	10.7	12.2
1984	11.2	10.4	9.3	8.5	8.2	8.1	8.2	8.5	8.9	9.5	10.6	12.1
1985	11.1	10.4	9.2	8.5	8.2	8.1	8.2	8.4	8.8	9.4	10.6	12.0
1986	11.0	10.3	9.2	8.4	8.1	8.0	8.1	8.3	8.7	9.3	10.5	12.0
1987	11.0	10.2	9.1	8.3	8.0	7.9	8.0	8.3	8.7	9.3	10.4	11.9
1988	10.9	10.2	9.0	8.3	7.9	7.9	7.9	8.2	8.6	9.2	10.4	11.8
1989	10.8	10.1	9.0	8.2	7.9	7.8	7.9	8.1	8.5	9.1	10.3	11.7
1990	10.8	10.0	8.9	8.1	7.8	7.7	7.8	8.1	8.5	9.1	10.2	11.7
1991	10.7	9.9	8.8	8.0	7.7	7.7	7.7	8.0	8.4	9.0	10.2	11.6
1992	10.6	9.9	8.0	7.6	7.3	7.3	7.3	7.6	8.0	8.6	10.1	11.5
1993	10.6	9.8	7.9	7.5	7.3	7.2	7.3	7.5	7.9	8.5	10.0	11.5
1994	10.5	9.7	7.9	7.5	7.2	7.1	7.2	7.5	7.9	8.4	9.9	11.4
1995	10.4	9.7	7.8	7.4	7.1	7.1	7.1	7.4	7.8	8.4	9.9	11.3
1996+	10.3	9.6	7.2	6.8	6.5	6.4	6.5	6.8	7.2	7.8	9.8	11.3

Sacramento Valley Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.8	11.1	9.9	9.3	8.9	8.8	8.9	9.2	9.6	10.2	11.3	12.7
1976	11.7	11.0	9.9	9.2	8.9	8.8	8.8	9.1	9.5	10.1	11.2	12.6
1977	11.7	10.9	9.8	9.1	8.8	8.7	8.8	9.0	9.4	10.0	11.1	12.6
1978	11.6	10.8	9.7	9.0	8.7	8.6	8.7	8.9	9.4	10.0	11.1	12.5
1979	11.5	10.8	9.7	9.0	8.7	8.5	8.6	8.9	9.3	9.9	11.0	12.4
1980	11.5	10.7	9.6	8.9	8.6	8.5	8.6	8.8	9.2	9.8	10.9	12.4
1981	11.4	10.6	9.5	8.8	8.5	8.3	8.4	8.7	9.1	9.7	10.9	12.9
1982	11.9	10.6	10.0	8.7	8.4	8.3	8.4	8.6	9.0	9.6	10.8	12.9
1983	11.9	10.5	9.9	8.7	8.3	8.2	8.3	8.5	9.0	9.5	10.7	12.8
1984	11.8	10.4	9.8	8.6	8.2	8.1	8.2	8.5	8.9	9.5	10.6	12.7
1985	11.7	10.4	9.8	8.5	8.2	8.1	8.2	8.4	8.8	9.4	10.6	12.7
1986	11.7	10.3	9.7	8.5	8.1	8.0	8.1	8.3	8.7	9.3	10.5	12.6
1987	11.6	10.2	9.6	8.4	8.0	7.9	8.0	8.3	8.7	9.3	10.4	12.5
1988	11.5	10.2	9.6	8.3	7.9	7.9	7.9	8.2	8.6	9.2	10.4	12.4
1989	11.5	10.1	9.5	8.3	7.9	7.8	7.9	8.1	8.5	9.1	10.3	12.4
1990	11.4	10.0	9.4	8.2	7.8	7.7	7.8	8.1	8.5	9.1	10.2	12.3
1991	11.3	9.9	9.4	8.1	7.7	7.7	7.7	8.0	8.4	9.0	10.2	12.2
1992	11.3	9.9	9.3	7.6	7.3	7.3	7.3	7.6	8.0	8.6	10.1	12.2
1993	11.2	9.8	9.2	7.5	7.3	7.2	7.3	7.5	7.9	8.5	10.0	12.1
1994	11.1	9.7	9.2	7.5	7.2	7.1	7.2	7.5	7.9	8.4	9.9	12.0
1995	11.0	9.7	9.1	7.4	7.1	7.1	7.1	7.4	7.8	8.4	9.9	12.0
1996+	11.0	9.6	9.0	6.8	6.5	6.4	6.5	6.8	7.2	7.8	9.8	11.9

San Joaquin Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.8	11.1	9.9	9.3	8.9	8.8	8.9	9.2	9.6	10.2	11.3	12.7
1976	11.7	11.0	9.9	9.2	8.9	8.8	8.8	9.1	9.5	10.1	11.2	12.6

1977	11.7	10.9	9.8	9.1	8.8	8.7	8.8	9.0	9.4	10.0	11.1	12.6
1978	11.6	10.8	9.7	9.0	8.7	8.6	8.7	8.9	9.4	10.0	11.1	12.5
1979	11.5	10.8	9.7	9.0	8.7	8.5	8.6	8.9	9.3	9.9	11.0	12.4
1980	11.5	10.7	9.6	8.9	8.6	8.5	8.6	8.8	9.2	9.8	10.9	12.4
1981	11.4	10.6	9.5	8.8	8.5	8.3	8.4	8.7	9.1	9.7	10.9	12.9
1982	11.9	10.6	10.0	8.7	8.4	8.3	8.4	8.6	9.0	9.6	10.8	12.9
1983	11.9	10.5	9.9	8.7	8.3	8.2	8.3	8.5	9.0	9.5	10.7	12.8
1984	11.8	10.4	9.8	8.6	8.2	8.1	8.2	8.5	8.9	9.5	10.6	12.7
1985	11.7	10.4	9.8	8.5	8.2	8.1	8.2	8.4	8.8	9.4	10.6	12.7
1986	11.7	10.3	9.7	8.5	8.1	8.0	8.1	8.3	8.7	9.3	10.5	12.6
1987	11.6	10.2	9.6	8.4	8.0	7.9	8.0	8.3	8.7	9.3	10.4	12.5
1988	11.5	10.2	9.6	8.3	7.9	7.9	7.9	8.2	8.6	9.2	10.4	12.4
1989	11.5	10.1	9.5	8.3	7.9	7.8	7.9	8.1	8.5	9.1	10.3	12.4
1990	11.4	10.0	9.4	8.2	7.8	7.7	7.8	8.1	8.5	9.1	10.2	12.3
1991	11.3	9.9	9.4	8.1	7.7	7.7	7.7	8.0	8.4	9.0	10.2	12.2
1992	11.3	9.9	9.3	7.6	7.3	7.3	7.3	7.6	8.0	8.6	10.1	12.2
1993	11.2	9.8	9.2	7.5	7.3	7.2	7.3	7.5	7.9	8.5	10.0	12.1
1994	11.1	9.7	9.2	7.5	7.2	7.1	7.2	7.5	7.9	8.4	9.9	12.0
1995	11.0	9.7	9.1	7.4	7.1	7.1	7.1	7.4	7.8	8.4	9.9	12.0
1996+	11.0	9.6	9.0	6.8	6.5	6.4	6.5	6.8	7.2	7.8	9.8	11.9

Mountain Counties Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.8	11.1	9.9	9.3	8.9	8.8	8.9	9.2	9.6	10.2	11.3	12.7
1976	11.7	11.0	9.9	9.2	8.9	8.8	8.8	9.1	9.5	10.1	11.2	12.6
1977	11.7	10.9	9.8	9.1	8.8	8.7	8.8	9.0	9.4	10.0	11.1	12.6
1978	11.6	10.8	9.7	9.0	8.7	8.6	8.7	8.9	9.4	10.0	11.1	12.5
1979	11.5	10.8	9.7	9.0	8.7	8.5	8.6	8.9	9.3	9.9	11.0	12.4
1980	11.5	10.7	9.6	8.9	8.6	8.5	8.6	8.8	9.2	9.8	10.9	12.4
1981	11.4	10.6	9.5	8.8	8.5	8.3	8.4	8.7	9.1	9.7	10.9	12.9
1982	11.9	10.6	10.0	8.7	8.4	8.3	8.4	8.6	9.0	9.6	10.8	12.9
1983	11.9	10.5	9.9	8.7	8.3	8.2	8.3	8.5	9.0	9.5	10.7	12.8
1984	11.8	10.4	9.8	8.6	8.2	8.1	8.2	8.5	8.9	9.5	10.6	12.7
1985	11.7	10.4	9.8	8.5	8.2	8.1	8.2	8.4	8.8	9.4	10.6	12.7
1986	11.7	10.3	9.7	8.5	8.1	8.0	8.1	8.3	8.7	9.3	10.5	12.6
1987	11.6	10.2	9.6	8.4	8.0	7.9	8.0	8.3	8.7	9.3	10.4	12.5
1988	11.5	10.2	9.6	8.3	7.9	7.9	7.9	8.2	8.6	9.2	10.4	12.4
1989	11.5	10.1	9.5	8.3	7.9	7.8	7.9	8.1	8.5	9.1	10.3	12.4
1990	11.4	10.0	9.4	8.2	7.8	7.7	7.8	8.1	8.5	9.1	10.2	12.3
1991	11.3	9.9	9.4	8.1	7.7	7.7	7.7	8.0	8.4	9.0	10.2	12.2
1992	11.3	9.9	9.3	7.6	7.3	7.3	7.3	7.6	8.0	8.6	10.1	12.2
1993	11.2	9.8	9.2	7.5	7.3	7.2	7.3	7.5	7.9	8.5	10.0	12.1
1994	11.1	9.7	9.2	7.5	7.2	7.1	7.2	7.5	7.9	8.4	9.9	12.0
1995	11.0	9.7	9.1	7.4	7.1	7.1	7.1	7.4	7.8	8.4	9.9	12.0
1996+	11.0	9.6	9.0	6.8	6.5	6.4	6.5	6.8	7.2	7.8	9.8	11.9

Lake Tahoe Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.8	11.1	9.9	9.3	8.9	8.8	8.9	9.2	9.6	10.2	11.3	12.7
1976	11.7	11.0	9.9	9.2	8.9	8.8	8.8	9.1	9.5	10.1	11.2	12.6
1977	11.7	10.9	9.8	9.1	8.8	8.7	8.8	9.0	9.4	10.0	11.1	12.6
1978	11.6	10.8	9.7	9.0	8.7	8.6	8.7	8.9	9.4	10.0	11.1	12.5
1979	11.5	10.8	9.7	9.0	8.7	8.5	8.6	8.9	9.3	9.9	11.0	12.4

1980	11.5	10.7	9.6	8.9	8.6	8.5	8.6	8.8	9.2	9.8	10.9	12.4
1981	11.4	10.6	9.5	8.8	8.5	8.3	8.4	8.7	9.1	9.7	10.9	12.9
1982	11.9	10.6	10.0	8.7	8.4	8.3	8.4	8.6	9.0	9.6	10.8	12.9
1983	11.9	10.5	9.9	8.7	8.3	8.2	8.3	8.5	9.0	9.5	10.7	12.8
1984	11.8	10.4	9.8	8.6	8.2	8.1	8.2	8.5	8.9	9.5	10.6	12.7
1985	11.7	10.4	9.8	8.5	8.2	8.1	8.2	8.4	8.8	9.4	10.6	12.7
1986	11.7	10.3	9.7	8.5	8.1	8.0	8.1	8.3	8.7	9.3	10.5	12.6
1987	11.6	10.2	9.6	8.4	8.0	7.9	8.0	8.3	8.7	9.3	10.4	12.5
1988	11.5	10.2	9.6	8.3	7.9	7.9	7.9	8.2	8.6	9.2	10.4	12.4
1989	11.5	10.1	9.5	8.3	7.9	7.8	7.9	8.1	8.5	9.1	10.3	12.4
1990	11.4	10.0	9.4	8.2	7.8	7.7	7.8	8.1	8.5	9.1	10.2	12.3
1991	11.3	9.9	9.4	8.1	7.7	7.7	7.7	8.0	8.4	9.0	10.2	12.2
1992	11.3	9.9	9.3	7.6	7.3	7.3	7.3	7.6	8.0	8.6	10.1	12.2
1993	11.2	9.8	9.2	7.5	7.3	7.2	7.3	7.5	7.9	8.5	10.0	12.1
1994	11.1	9.7	9.2	7.5	7.2	7.1	7.2	7.5	7.9	8.4	9.9	12.0
1995	11.0	9.7	9.1	7.4	7.1	7.1	7.1	7.4	7.8	8.4	9.9	12.0
1996+	11.0	9.6	9.0	6.8	6.5	6.4	6.5	6.8	7.2	7.8	9.8	11.9

North Coast
Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.8	11.1	10.5	9.5	9.0	8.9	9.0	9.3	9.7	10.3	11.3	12.7
1976	11.7	11.0	10.4	9.5	8.9	8.9	8.9	9.2	9.6	10.2	11.2	12.6
1977	11.7	10.9	10.3	9.4	8.9	8.8	8.9	9.1	9.5	10.1	11.1	12.6
1978	11.6	10.8	10.3	9.3	8.8	8.7	8.8	9.0	9.5	10.0	11.1	12.5
1979	11.5	10.8	10.2	9.2	8.7	8.6	8.7	9.0	9.4	10.0	11.0	12.4
1980	11.5	10.7	10.1	9.2	8.7	8.6	8.7	8.9	9.3	9.9	10.9	12.4
1981	11.4	10.6	10.1	9.1	8.6	8.3	8.4	8.7	9.1	9.8	10.9	12.9
1982	11.9	10.6	10.0	8.7	8.4	8.3	8.4	8.6	9.0	9.7	10.8	12.9
1983	11.9	10.5	9.9	8.7	8.4	8.2	8.3	8.5	9.0	9.6	10.7	12.8
1984	11.8	10.4	9.8	8.6	8.3	8.1	8.2	8.5	8.9	9.6	10.6	12.7
1985	11.7	10.4	9.8	8.5	8.2	8.1	8.2	8.4	8.8	9.5	10.6	12.7
1986	11.7	10.3	9.7	8.5	8.1	8.0	8.1	8.3	8.7	9.4	10.5	12.6
1987	11.6	10.2	9.6	8.4	8.1	7.9	8.0	8.3	8.7	9.3	10.4	12.5
1988	11.5	10.2	9.6	8.3	8.0	7.9	7.9	8.2	8.6	9.3	10.4	12.4
1989	11.5	10.1	9.5	8.3	7.9	7.8	7.9	8.1	8.5	9.2	10.3	12.4
1990	11.4	10.0	9.4	8.2	7.9	7.7	7.8	8.1	8.5	9.1	10.2	12.3
1991	11.3	9.9	9.4	8.1	7.8	7.7	7.7	8.0	8.4	9.1	10.2	12.2
1992	11.3	9.9	9.3	8.0	7.3	7.3	7.3	7.6	8.0	9.0	10.1	12.2
1993	11.2	9.8	9.2	8.0	7.3	7.2	7.3	7.5	7.9	8.9	10.0	12.1
1994	11.1	9.7	9.2	7.9	7.2	7.1	7.2	7.5	7.9	8.9	9.9	12.0
1995	11.0	9.7	9.1	7.8	7.1	7.1	7.1	7.4	7.8	8.8	9.9	12.0
1996+	11.0	9.6	9.0	7.8	6.5	6.4	6.5	6.8	7.2	8.7	9.8	11.9

Lake County
Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.8	11.1	10.5	9.5	9.0	8.9	9.0	9.3	9.7	10.3	11.3	12.7
1976	11.7	11.0	10.4	9.5	8.9	8.9	8.9	9.2	9.6	10.2	11.2	12.6
1977	11.7	10.9	10.3	9.4	8.9	8.8	8.9	9.1	9.5	10.1	11.1	12.6
1978	11.6	10.8	10.3	9.3	8.8	8.7	8.8	9.0	9.5	10.0	11.1	12.5
1979	11.5	10.8	10.2	9.2	8.7	8.6	8.7	9.0	9.4	10.0	11.0	12.4
1980	11.5	10.7	10.1	9.2	8.7	8.6	8.7	8.9	9.3	9.9	10.9	12.4
1981	11.4	10.6	10.1	9.1	8.6	8.3	8.4	8.7	9.1	9.8	10.9	12.9
1982	11.9	10.6	10.0	8.7	8.4	8.3	8.4	8.6	9.0	9.7	10.8	12.9

1983	11.9	10.5	9.9	8.7	8.4	8.2	8.3	8.5	9.0	9.6	10.7	12.8
1984	11.8	10.4	9.8	8.6	8.3	8.1	8.2	8.5	8.9	9.6	10.6	12.7
1985	11.7	10.4	9.8	8.5	8.2	8.1	8.2	8.4	8.8	9.5	10.6	12.7
1986	11.7	10.3	9.7	8.5	8.1	8.0	8.1	8.3	8.7	9.4	10.5	12.6
1987	11.6	10.2	9.6	8.4	8.1	7.9	8.0	8.3	8.7	9.3	10.4	12.5
1988	11.5	10.2	9.6	8.3	8.0	7.9	7.9	8.2	8.6	9.3	10.4	12.4
1989	11.5	10.1	9.5	8.3	7.9	7.8	7.9	8.1	8.5	9.2	10.3	12.4
1990	11.4	10.0	9.4	8.2	7.9	7.7	7.8	8.1	8.5	9.1	10.2	12.3
1991	11.3	9.9	9.4	8.1	7.8	7.7	7.7	8.0	8.4	9.1	10.2	12.2
1992	11.3	9.9	9.3	8.0	7.3	7.3	7.3	7.6	8.0	9.0	10.1	12.2
1993	11.2	9.8	9.2	8.0	7.3	7.2	7.3	7.5	7.9	8.9	10.0	12.1
1994	11.1	9.7	9.2	7.9	7.2	7.1	7.2	7.5	7.9	8.9	9.9	12.0
1995	11.0	9.7	9.1	7.8	7.1	7.1	7.1	7.4	7.8	8.8	9.9	12.0
1996+	11.0	9.6	9.0	7.8	6.5	6.4	6.5	6.8	7.2	8.7	9.8	11.9

North East Plateau Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.8	11.1	9.9	9.3	8.9	8.8	8.9	9.2	9.6	10.2	11.3	12.7
1976	11.7	11.0	9.9	9.2	8.9	8.8	8.8	9.1	9.5	10.1	11.2	12.6
1977	11.7	10.9	9.8	9.1	8.8	8.7	8.8	9.0	9.4	10.0	11.1	12.6
1978	11.6	10.8	9.7	9.0	8.7	8.6	8.7	8.9	9.4	10.0	11.1	12.5
1979	11.5	10.8	9.7	9.0	8.7	8.5	8.6	8.9	9.3	9.9	11.0	12.4
1980	11.5	10.7	9.6	8.9	8.6	8.5	8.6	8.8	9.2	9.8	10.9	12.4
1981	11.4	10.6	9.5	8.8	8.5	8.3	8.4	8.7	9.1	9.8	10.9	12.9
1982	11.9	10.6	10.0	8.7	8.4	8.3	8.4	8.6	9.1	9.7	10.8	12.9
1983	11.9	10.5	9.9	8.7	8.4	8.2	8.3	8.5	9.0	9.6	10.7	12.8
1984	11.8	10.4	9.8	8.6	8.3	8.1	8.2	8.5	8.9	9.6	10.6	12.7
1985	11.7	10.4	9.8	8.5	8.2	8.1	8.2	8.4	8.8	9.5	10.6	12.7
1986	11.7	10.3	9.7	8.5	8.1	8.0	8.1	8.3	8.8	9.4	10.5	12.6
1987	11.6	10.2	9.6	8.4	8.1	7.9	8.0	8.3	8.7	9.3	10.4	12.5
1988	11.5	10.2	9.6	8.3	8.0	7.9	7.9	8.2	8.6	9.3	10.4	12.4
1989	11.5	10.1	9.5	8.3	7.9	7.8	7.9	8.1	8.6	9.2	10.3	12.4
1990	11.4	10.0	9.4	8.2	7.9	7.7	7.8	8.1	8.5	9.1	10.2	12.3
1991	11.3	9.9	9.4	8.1	7.8	7.7	7.7	8.0	8.4	9.1	10.2	12.2
1992	11.3	9.9	9.3	8.0	7.3	7.3	7.3	7.6	8.0	9.0	10.1	12.2
1993	11.2	9.8	9.2	8.0	7.3	7.2	7.3	7.5	7.9	8.9	10.0	12.1
1994	11.1	9.7	9.2	7.9	7.2	7.1	7.2	7.5	7.9	8.9	9.9	12.0
1995	11.0	9.7	9.1	7.8	7.1	7.1	7.1	7.4	7.8	8.8	9.9	12.0
1996+	11.0	9.6	9.0	7.8	6.5	6.4	6.5	6.8	7.2	8.7	9.8	11.9

North Central Coast Air Basin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	11.8	11.1	10.5	9.5	9.0	8.9	9.0	9.3	9.7	10.3	11.3	12.7
1976	11.7	11.0	10.4	9.5	8.9	8.9	8.9	9.2	9.6	10.2	11.2	12.6
1977	11.7	10.9	10.3	9.4	8.9	8.8	8.9	9.1	9.5	10.1	11.1	12.6
1978	11.6	10.8	10.3	9.3	8.8	8.7	8.8	9.0	9.5	10.0	11.1	12.5
1979	11.5	10.8	10.2	9.2	8.7	8.6	8.7	9.0	9.4	10.0	11.0	12.4
1980	11.5	10.7	10.1	9.2	8.7	8.6	8.7	8.9	9.3	9.9	10.9	12.4
1981	11.4	10.6	10.1	9.1	8.6	8.3	8.4	8.7	9.1	9.7	10.9	12.9
1982	11.9	10.6	10.0	8.7	8.4	8.3	8.4	8.6	9.0	9.6	10.8	12.9
1983	11.9	10.5	9.9	8.7	8.4	8.2	8.3	8.5	9.0	9.5	10.7	12.8
1984	11.8	10.4	9.8	8.6	8.3	8.1	8.2	8.5	8.9	9.5	10.6	12.7
1985	11.7	10.4	9.8	8.5	8.2	8.1	8.2	8.4	8.8	9.4	10.6	12.7

1986	11.7	10.3	9.7	8.5	8.1	8.0	8.1	8.3	8.7	9.3	10.5	12.6
1987	11.6	10.2	9.6	8.4	8.1	7.9	8.0	8.3	8.7	9.3	10.4	12.5
1988	11.5	10.2	9.6	8.3	8.0	7.9	7.9	8.2	8.6	9.2	10.4	12.4
1989	11.5	10.1	9.5	8.3	7.9	7.8	7.9	8.1	8.5	9.1	10.3	12.4
1990	11.4	10.0	9.4	8.2	7.9	7.7	7.8	8.1	8.5	9.1	10.2	12.3
1991	11.3	9.9	9.4	8.1	7.8	7.7	7.7	8.0	8.4	9.0	10.2	12.2
1992	11.3	9.9	9.3	8.0	7.3	7.3	7.3	7.6	8.0	8.6	10.1	12.2
1993	11.2	9.8	9.2	8.0	7.3	7.2	7.3	7.5	7.9	8.5	10.0	12.1
1994	11.1	9.7	9.2	7.9	7.2	7.1	7.2	7.5	7.9	8.4	9.9	12.0
1995	11.0	9.7	9.1	7.8	7.1	7.1	7.1	7.4	7.8	8.4	9.9	12.0
1996+	11.0	9.6	9.0	7.8	6.5	6.4	6.5	6.8	7.2	7.8	9.8	11.9

Section 7.8 COUNTY-SPECIFIC DIURNAL TEMPERATURE PROFILES

This section describes how the average monthly and episodic hourly county specific diurnal temperature profiles were developed for EMFAC2000.

7.8.1 Introduction

Diurnal, resting loss and hot soak emission factors used in the Motor Vehicle Emission Inventory (MVEI) model require county-specific, diurnal temperature profiles. The previous model (MVEI7G) averaged hourly ambient temperature data for monitoring stations in the State to produce county-specific summer or winter temperature profiles, aggregated into six time periods (0000-0600, 0600-0900, 0900-1200, 1200-1500, 1500-1800, 1800-2400 hours). Hourly temperature data used in development of these profiles were obtained for the period 1987-1989 from the following sources: ARB and District monitoring stations, the National Weather Service (NWS), the California Irrigation Management Information System (CIMIS), and the California Data Exchange Center (CDEC). By averaging temperature data for either the ten highest ozone (O_3) or carbon monoxide (CO) days, the summer and winter temperature profiles were supposed to reflect temperature conditions during O_3- and CO-episodes, respectively. Slightly different methodologies were used in developing county-specific summer and winter temperature profiles. Summer temperature profiles were calculated by averaging all the hourly temperature data within an air basin and then assigning that profile to all counties or portions of counties within that air basin. In contrast, county-specific winter temperature profiles were based solely on data from stations within each county. For those counties containing no temperature monitoring stations, temperature profiles from neighboring counties within the same air basin were assigned.

There were a number of possible flaws in the previous methodology for calculating county-specific temperature profiles. First, the previous temperature profiles reflect O_3- or CO-episode temperature conditions rather than average summer or winter temperatures. This may leaded to inaccurate estimation of evaporative emissions for inventory purposes. Second, the previous methodology calculates county-specific temperatures by taking a simple arithmetic average of all the station data within a given county, without regard for the spatial distribution of monitoring stations. For counties with no monitoring stations, temperature profiles were assigned the temperature profile of an adjacent county with monitoring stations. County-specific temperature profiles developed in this manner reflect the temperatures in the immediate vicinity of the monitoring station, not necessarily the ambient temperatures experienced by the vehicle fleet in a given county. Third, aggregating the hourly temperature data into six periods reduced the temporal resolution inherent in the original database. This increased the difficulty of accurately defining the breakpoint between diurnal and resting loss portions of the diurnal profile. In addition, performing multi-day diurnal evaporative emissions tests requires hourly diurnal temperature profiles, as opposed to the previous aggregated diurnal profiles. Fourth, the previous summer and winter temperature profiles were not representative of either spring or fall temperature conditions, thus yielding inaccurate evaporative emissions estimates for these seasons.

7.8.2 <u>Methodology</u>

This section describes a revised methodology for producing spatially- and temporally-resolved average monthly, as well as O_3- and CO-episode day, diurnal temperature profiles for California. Implementation of this methodology required the use of ARC/INFO, a geographic information system (GIS) software package used for spatial data analysis and modeling, and SAS, a statistical software package.

7.8.3 <u>Development of Average Monthly Diurnal Temperature Profiles</u>

Specific steps involved in development of average monthly diurnal temperature profiles are described below and illustrated in Figure 7.8-1.

1. Hourly temperature data from a total of 323 meteorological stations were compiled as the basis for the spatially- and temporally-resolved temperature profiles. The following data sources were used: 1) 94 CIMIS agricultural stations for the period 1988-1993; 2) 195 California Department of Forestry (CDF) meteorological stations for the period 1992-1993; 3) 17 NWS weather buoys for the period 1992-1993; and 4) 16 National Climatic Data Center (NCDC) meteorological stations for various years between 1949 and 1970. In addition, for those few boundary areas where no actual stations existed, 2 boundary condition or "pseudo" stations were established, using temperature data from the nearest CIMIS or NCDC station, such that spatial interpolation beyond the boundaries of California could be completed.

2. For each station, all available days of hourly temperature data were averaged by hour and month using SAS to produce station-specific monthly diurnal temperature profiles.

   Of the 323 stations used, the majority were located below 1000 ft (330 m) elevation, however, the mean elevation for the State is 2900 ft (880 m). As temperature generally decreases with increasing elevation, a simple spatial interpolation using the reported average station temperatures would result in an overestimation of interpolated temperature in mountainous portions of California. Therefore, prior to spatial interpolation of the temperature data, the averaged station temperatures were corrected to sea-

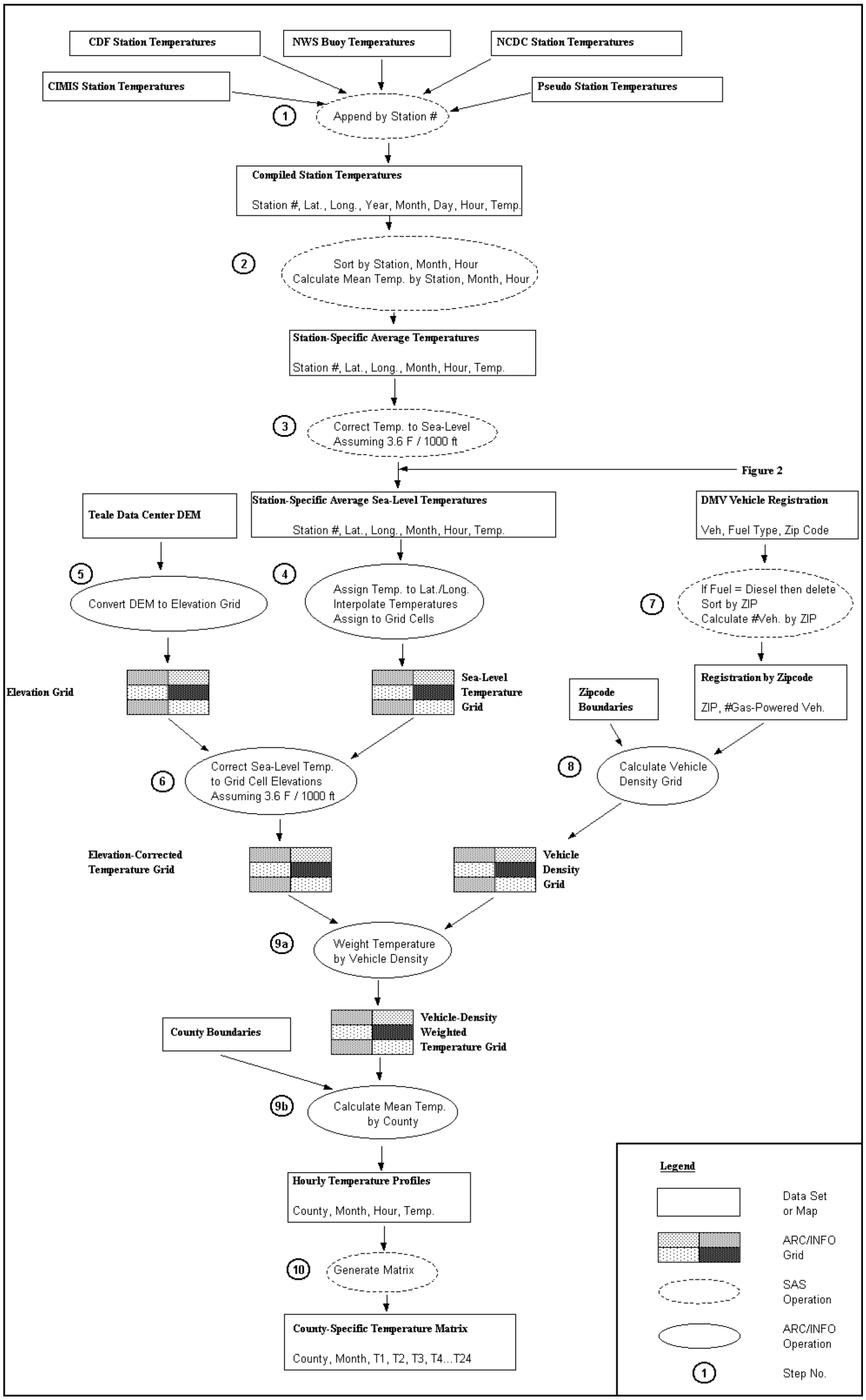


Figure 7.8-1 Flowchart showing methodology used in developing hourly, county-specific diurnal temperature profiles, corrected for elevation effects and vehicle density.

level, using the known elevations of the stations and calculated monthly temperature lapse rates.

The temperature lapse rates used were empirically derived based on the hourly CDF dataset. This dataset was used because the large number of stations included (195) were located at a wide range of elevations and the data were collected for the same time period. Average monthly lapse rates were calculated by averaging all available days of hourly temperature data by station and then a linear regression model was used to estimate change in temperature with elevation. The average monthly temperature lapse rates used in this analysis are shown in Table 7.8-1.

Table 7.8-1 Monthly and O3- and CO-episode temperature lapse rates estimated from hourly CDF temperature data for the period 1992-1993.

		degrees F/1000 feet
Monthly	January	2.2
	February	3.3
	March	3.0
	April	2.5
	May	2.1
	June	2.2
	July	1.7
	August	1.6
	September	1.7
	October	2.4
	November	2.8
	December	2.8
Episodic	O_3	2.1
	CO	2.6

3. For each hour of each month, the following procedure was repeated using ARC/INFO:

   a. The station-specific, averaged sea-level temperatures were assigned to the geographic location of each station.

   b. Using an inverse-distance weighted algorithm, the sea-level temperatures were interpolated between stations, producing a gridded sea-level temperature map with a 500 m resolution and approximately 1,635,000 grid cells total.

5. Based on a digital elevation model (DEM) of California obtained from the Teale Data Center (TDC), a gridded elevation map with a 72 m resolution was produced.

6. For each hour of each month, the following procedure was repeated:

    a. Applying empirically-derived temperature lapse rate (Table 7.8-1) used in the correction of the average station temperatures to sea-level , the sea-level temperature map was overlayed over the elevation map to produce a gridded elevation-corrected temperature map.

7. Using a July 1995 Department of Motor Vehicles (DMV) database, the number of gasoline-powered vehicles (with current and lapsed registration) in each of the 1551 ZIP codes in the State was calculated.

8. Based on the zipcode-specific vehicle registrations and a map of ZIP code boundaries, a gridded vehicle-density map of California with a 500 m resolution was produced.

9. For each hour of each month, the following procedure was repeated:

    a. The vehicle-density map was overlaid over the elevation-corrected temperature map and the temperature of each grid cell was weighted by the number of vehicles in that grid cell.

    b. A map of county boundaries was overlaid over the elevation-corrected, vehicle-density weighted temperature map, and the mean temperature of all grid cells falling within the boundaries of each county was calculated. The resultant county-specific temperature is an area-weighted average of all the grid cells within a given county, taking into account the effects of elevation on temperature, as well as the density distribution of vehicles in the county.

10. The results were compiled to produce a matrix of hourly average ambient temperature, grouped by month and county.

7.8.4 Development of O_3- and CO-episode Day Diurnal Temperature Profiles

County-specific diurnal temperature profiles for O_3- and CO-episode days were calculated by selecting from the compiled temperature dataset those days of temperature data coinciding with documented O_3- and CO-episode days. The specific steps involved in developing O_3- and CO-episode day diurnal temperature profiles are described below and shown in Figure 7.8-2.

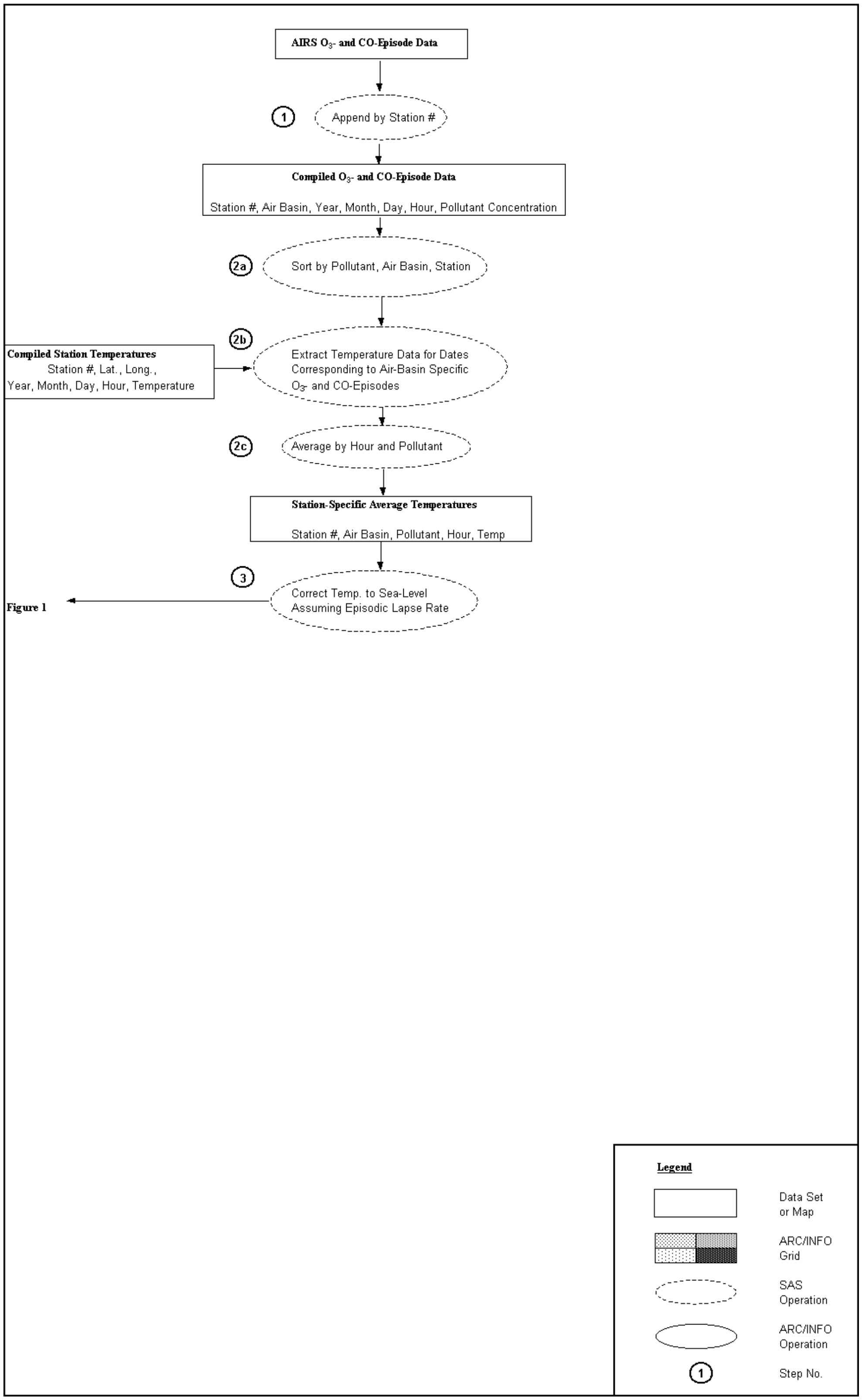


Figure 7.8-2 Flowchart showing methodology used in extracting temperature data for use in developing episodic, county-specific diurnal temperature profiles.

1. Aerometric Information Retrieval System (AIRS) Yearly Maximum Values reports for the period 1988 through 1992 were obtained from the United States Environmental Protection Agency (USEPA). The Yearly Maximum Values reports requested include the dates and pollutant concentrations for the ten worst O_3- and CO-episode days for each of the 241 ambient air monitoring stations in California.

    a. The compiled air quality data were sorted by pollutant, air basin, and station.

    b. For each air basin, hourly temperature data for those dates corresponding to the documented O_3- and CO-episode days were extracted from the temperature dataset compiled for development of monthly diurnal temperature profiles.

    c. For each meteorological station, the extracted hourly temperature data were averaged by hour and pollutant to produce station-specific O_3- and CO-episode day diurnal temperature profiles.

2. The averaged station temperatures were corrected to sea-level, using the known elevations of the stations and O_3- and CO-episode temperature lapse rates.

    The O_3- and CO-episode temperature lapse rates were calculated based on the monthly temperature lapse rates, weighted by the number of O_3- and CO-episodes occurring in each month. The O_3- and CO-episode lapse rates used in this analysis are shown in Table 7.8-1.

The remaining steps involved in developing county-specific, O_3- and CO-episode day diurnal temperature profiles were the same as described previously in steps 4 through 10 for development of monthly temperature profiles.

7.8.5 Results

County-specific monthly, as well as O_3- and CO-episode day, diurnal temperature profiles were developed into a matrix format. For each of the 58 counties in California, the matrices provide average temperature by time of day aspresented in Table 7.8-2.

Table 7.8-2. Format of county-specific temperature matrices.

	Hour						
County	T0	T1	T2	………..	T21	T22	T23
1	46.7	46.0	45.6	………..	48.3	47.7	47.2
2	55.5	53.8	52.5	………..	61.2	59.1	57.3
3	53.5	51.6	50.0	………..	60.1	57.7	55.6
:	:	:	:	:	:	:	:
56	57.0	56.8	56.6	………..	58.6	57.9	57.5
57	57.3	56.9	56.7	………..	59.0	58.3	57.8
58	62.5	62.0	61.2	………..	64.8	64.3	63.6

Figure 7.8-3 contrasts statewide average O_3- and CO-episode day diurnal temperature profiles developed for EMFAC2000 with the methodology described here to the temperature profiles previously assumed in MVEI7G. This figure suggests the existing temperature profile for CO-episode days approximates reasonably well the temperature profile developed in this analysis. However, the previous temperature profile for O_3-episode days appears to overestimate the temperature experienced by vehicles in the State by approximately 5-10° F. The magnitude of the offset in the existing and proposed episodic temperature profiles are consistent from county to county throughout the State. Work is currently being performed to identify whether the offset is due to the use of different hourly temperature data or specific methodological differences.

The methodology described here is a significant improvement over the previous method for developing diurnal temperature profiles. Specifically, by using a GIS, it is possible to produce gridded temperature maps which take into account station location, elevation effects, and vehicle distribution within a county. The county-specific temperatures calculated based on these gridded temperature maps reflect the average of all the grid cells within a county rather than the average of a relatively small number of monitoring stations. Therefore, the temperature profiles developed using this methodology more accurately reflect the temperatures experienced by vehicles within a county.

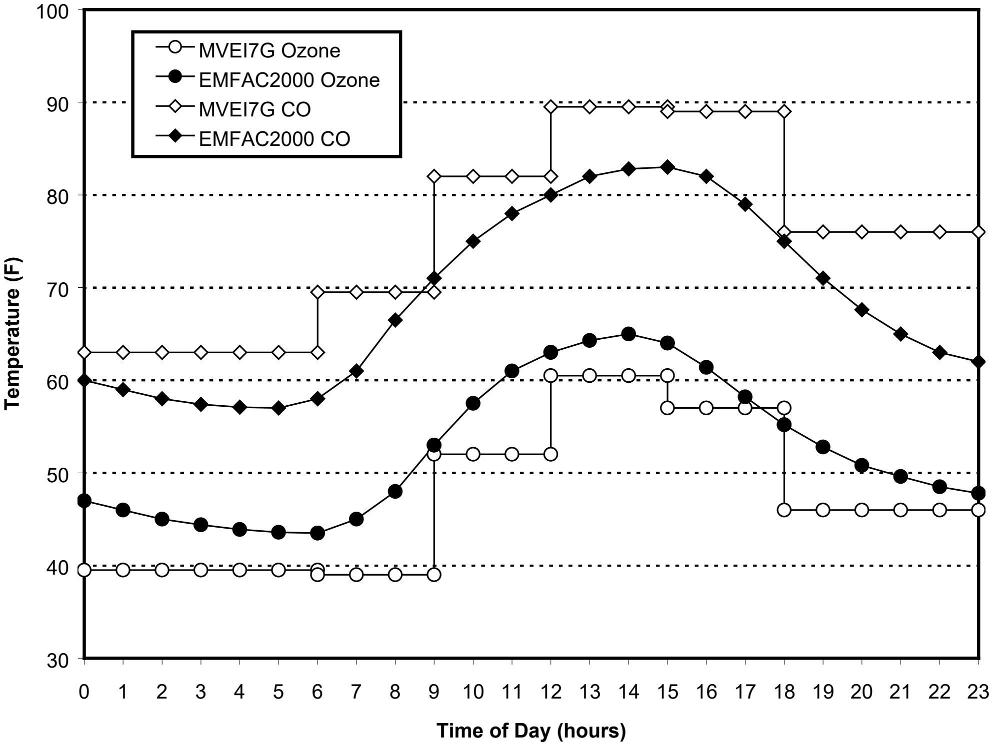


Figure 7.8-3 Comparison of MVEI7G and EMFAC2000 statewide average episodic temperature profiles.

Section 4.12 TOTAL PARTICULATE MATTER EMISSION FACTORS

This section discusses the development of particulate matter (PM) exhaust emission factors from gasoline-powered vehicles for EMFAC2000. It also outlines the methodology for calculating tire-wear and brake-wear emission factors for all vehicles.

4.12.1 Introduction

When MVEI7G was released, there were very little PM exhaust emissions data available from gasoline-fueled vehicles. For this reason, the gasoline PM exhaust emission factors in MVEI7G were taken from U.S. EPA's PART5 model, which is the PM portion of MOBILE5.

PM emissions from gasoline-powered vehicles have become a greater concern as a result of U.S. EPA's decision to regulate PM2.5. It is believed that most of the PM from gasoline-powered vehicles is in the PM2.5 micron diameter range. For this reason, several test projects were conducted to gain more knowledge about the characteristics of PM from these vehicles. Data sources from the following studies were considered when determining PM emission factors for EMFAC2000.

The ARB contracted with the College of Engineering-Center for Environmental Research and Technology (CE-CERT) to characterize PM emissions from gasoline-powered vehicle exhaust. The resulting report is titled, "Characterization of Particulate Emissions from Gasoline-Fueled Vehicles", dated May 1998. In Phase 1 of the project, three passenger vehicles - one without a catalyst, one with an oxidation catalyst, and one with a three-way catalyst, were tested on both the Unified Cycle (UC) and the Federal Test Procedure (FTP). These tests were conducted using California's Phase 1 fuel as well as cleaner burning gasoline. In Phase 2 of the project, 24 passenger vehicles of various technology types were tested on the UC using California's cleaner burning gasoline.

A test program conducted by Southwest Research Institute (SwRI), included PM data from 39 passenger vehicles, 14 light duty trucks and seven visibly smoking vehicles. The test procedures and data analysis are summarized in a report titled, "Measurement of Primary Exhaust Particulate Matter Emissions From Light-Duty Motor Vehicles," dated November 1998. All of the vehicles in this program were tested only on the FTP, and the smoking vehicles were identified as those vehicles that emitted visible smoke in nearly every operating condition.

In the National Cooperative Highway Research Program (NCHRP) study, "Measurement of Primary Particulate Matter Emissions from Light-Duty Motor Vehicles," dated December 1998, 67 passenger vehicles and 62 light duty trucks were tested on the FTP. Thirty-nine of the vehicles were deemed high gaseous emitters. A Tier 0 vehicle was defined as a high gaseous emitter if the HC or CO emissions were two times the certification standard, or the NOx emissions were four times the standard. A Tier 1 vehicle was considered a high gaseous emitter if the HC, CO or NOx emissions were one and a half times the certification standard.

The last available study that collected PM emissions data was conducted by the Coordinating Research Council (CRC). Its report is titled, "In-Use Light-Duty Gasoline Vehicle

Particulate Matter Emissions on the FTP, REP05, and UC Cycles," dated June 1999. This test project included 24 properly functioning vehicles and 6 high CO emitters. The vehicles were tested at 35°F using the FTP, UC, and REP05 driving cycles. Sixteen of the vehicles were passenger cars and 8 were light duty trucks. A vehicle was considered a high CO emitter if the emission rate was at least 30 g/mi.

4.12.2 Data Analysis

The test fleets for both the SwRI and NCHRP studies were biased towards smoking or high gaseous emitter vehicles. SwRI defined a vehicle as a "smoker" if it was visibly smoking during most operating conditions, and NCHRP defined a high emitter based on the vehicle's gaseous emissions relative to its standards. Neither study, though, provided a clear indication of how to identify high particulate matter emitters. An attempt was made to find a relationship between PM and CO emissions from both of these studies; however, the correlation was insignificant. As more data becomes available in the future, this method of determining PM emissions may become more feasible.

CE-CERT's PM emission database included 20 vehicles tested on the UC and three vehicles tested on both the FTP and UC. While this provides some PM emissions data performed on the UC, FTP data from all of the other projects would not be able to be included if this data set were used. The CRC study was also a source of both FTP and UC data; but it involved only 30 vehicles tested on only the hot start UC, at a temperature of 35°F. Upon review of all available PM emissions data, staff determined that it would be best to use the larger sources of FTP data rather than the smaller source of UC data. As a result, the FTP data from the SwRI and NCHRP studies were used to estimate PM emissions from gasoline vehicles.

A comprehensive statistical analysis was performed on all PM emissions to establish the effects of vehicle class and technology type. The analysis showed that there was a significant difference in PM emissions with respect to vehicles with and without catalysts. However, there was no significant difference between passenger cars, light-duty trucks and medium-duty trucks. For this reason, all vehicles were grouped together to obtain bag specific PM emission rates.

In order to accurately estimate PM emissions from gasoline vehicles, it is important to incorporate the contribution of smoking vehicles. The study conducted by SwRI defined vehicles as smokers by those that exhibited visible smoke during nearly every operating mode. By looking at the minimum PM emissions levels of these seven smoking vehicles, the cutpoints between normal PM emitters and smoking (high) PM emitters was determined to be the following: 0.20 g/mile for bag 1 and 0.15 g/mile for bag 2.

These cutpoints were used to distinguish smokers from non-smokers (normals) for all vehicles in the combined SwRI and NCHRP database. Any vehicle having a bag specific PM emission rate higher than the cutpoint for either bag was assumed to be a smoking vehicle. All vehicles are thus split into the following categories for further analyses: non-catalyst smokers, non-catalyst normals, catalyst-equipped smokers, and catalyst-equipped normals.

For all catalyst-equipped non-smoking vehicles, bag specific PM emissions were fit with second-order polynomial functions characterizing emissions as a function of age. The bag specific smoking emission rates for catalyst-equipped vehicles were calculated by taking the simple average of those vehicles. This resulted in catalyst-equipped smoking PM emission rates of 0.58 g/mi for bag 1 and 0.27 g/mi for bag 2. In order to accurately weight the non-smoking and smoking emission rates, the population distribution of smoking vehicles is needed.

In a study performed by CE-CERT titled, “Measurement of Primary Particulate Matter Emissions from Light-Duty Motor Vehicles”, it was determined that at any given time, 2% of all vehicles in California are smoking vehicles. While this study quantifies the number of smoking vehicles overall, it does not assess how this 2% is distributed throughout the fleet. One would assume that there would be fewer smoking vehicles among the newer model years, and subsequently more smokers within the older vehicles.

Without actual data, the challenge then is to identify a relationship that reflects this concept. Staff determined the most appropriate way of modeling this distribution would be to use the inverse relationship of the registration distribution. The registration distribution from 1997 and its inverse are illustrated in Figure 4.12-1. The distribution of smokers was then normalized and curve fit to obtain the smoking vehicle population distribution in Table 4.12-1. For weighting purposes, the values in Table 4.12-1 were then multiplied by the overall smoking population of 2%.

Figure 4.12-1. Population Distribution of PM Smoking Vehicles

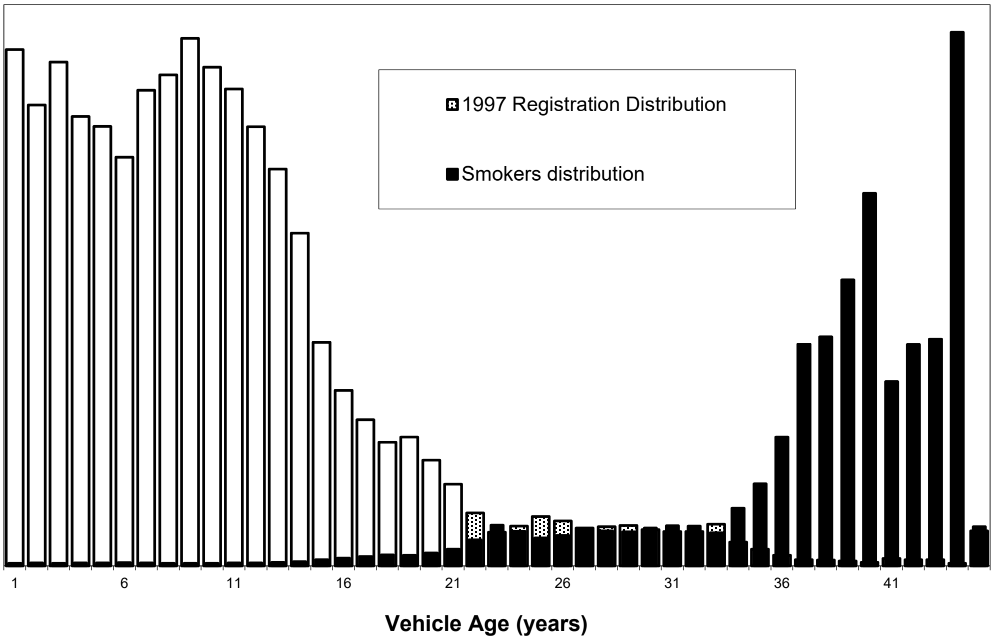
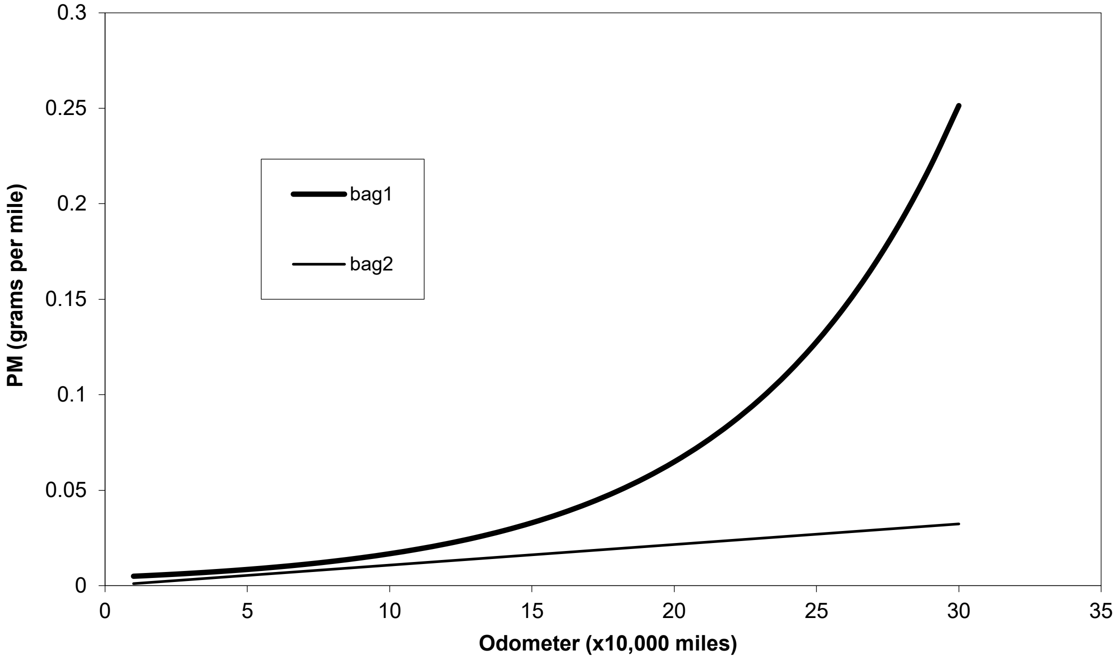


Table 4.12-1. Population Distribution of Smoking Catalyst Vehicles

AGE (yrs)	Distribution of Smokers
1	0.0006
2	0.0007
3	0.0008
4	0.0008
5	0.0010
6	0.0011
7	0.0012
8	0.0014
9	0.0015
10	0.0017
11	0.0020
12	0.0022
13	0.0025
14	0.0028
15	0.0031
16	0.0035
17	0.0040
18	0.0045
19	0.0051
20	0.0057
21	0.0064
22	0.0073
23	0.0082
24	0.0092
25	0.0104
26	0.0117
27	0.0132
28	0.0149
29	0.0167
30	0.0189
31	0.0213
32	0.0239
33	0.0270
34	0.0304
35	0.0343
36	0.0386
37	0.0435
38	0.0490
39	0.0552
40	0.0622
41	0.0701
42	0.0790
43	0.0890
44	0.1003
45	0.1131

To calculate the final particulate emissions by age for catalyst equipped vehicles, the emissions of non-smoking vehicles by age were then weighted together with the emissions of smoking vehicles based on the smoking population distribution. To accommodate the EMFAC2000 model, emissions by age were converted to emissions by cumulative mileage. The resulting curve fit gives bag specific composite catalyst PM emission rates in grams per mile. This is illustrated in Figure 4.12-2.

Figure 4.12-2. Composite Catalyst PM Emission Rates



For the non-catalyst vehicles, there was not enough data to establish any emissions correlation with respect to age. For this reason, the composite PM emission factor was calculated simply by weighting the average smoking emission rate and the average non-smoking emission rate by its assumed population split of 2%:98%. PM emission factors for all gasoline-fueled vehicles are given in Table 4.12-2.

TABLE 4.12-2. PM Emission Factors for Gasoline Vehicles
For LDA, LDT, MDT, LHDT, MHDT, and Buses

	CATALYST				NON CAT	
	bag1		bag2		bag1	bag2
zero mile (g/mi)	0.0043204		0		0.06335	0.03582
DR coefficients (per 10,000 mi)	*exponential* y = a*exp(b*x)		*linear* y = m*x		*non cat DR = 0*	
	a	0.0043204	m	0.0010781		
	b	0.1354566				

*Note: If catalyst equipped vehicle emission rates exceed the emission rates of vehicles without catalyst, the non-catalyst emission rate is used.

Start Correction Factors

Start Correction Factors (StCF) for HC, CO, and NOx are currently calculated using modal emissions gathered from tests performed on the Unified Cycle. The purpose of the start correction factor is to adjust the bag 1 gram per mile emission rates to a gram per start value for the first 100 seconds of the start event. In the studies evaluated here, however, there were no second-by-second PM emissions data available. Therefore, the start correction factor is represented here by the number of miles within the first 100 seconds of the FTP. This value is given in Table 4.12-3 and applies to both non-catalyst and catalyst-equipped vehicles.

TABLE 4.12-3. PM Start Correction Factor

	StCF
PM	0.506

* Note: StCF applies to all vehicles regardless of catalyst type.

Tire-Wear and Brake-Wear Emissions

The tire-wear emission factors are based on the methodology included in U.S. EPA's PART5 model and are calculated as follows:

$$EFTW = 0.002 * WHLAVG * PSTIRE, \tag{4.12-1}$$

where EFTW is the tire-wear emission factor in g/mi,
0.002 g/mi/wheel is the emission rate of airborne particulates from tire-wear,
WHLAVG is the average number of wheels a type of vehicle has, and
PSTIRE is the fraction of particles less than or equal to the particle size cutoff.
PSTIRE values are obtained from PART5.

In this case, PSTIRE is equal to one since Part5 assumes that all of the airborne particulates from tire-wear are less than 10 microns. Based on the average number of wheels and the equation shown above, tire-wear emission factors by vehicle class are shown in Table 4.12-4.

Table 4.12-4. Tire-wear PM Emission Rates

Vehicle Class (gasoline & diesel)	Average Number of Wheels	Tire-Wear Emission Factors
LDA	4	0.008
LDT	4	0.008
MDT	4	0.008
LHGT, LHDT	6	0.012
MHGT, MHDT	6	0.012
HHDT	18	0.036
UBD	6	0.012
SCHOOL BUS	6	0.012
MOTOR HOME	6	0.012
MCY	2	0.004

PM emission factors from brake-wear were also obtained from U.S. EPA's PART5 model. The PM emission factor for total brake-wear is 0.0128 g/mi for all vehicles.

PM Size Fractions

PART5 included fractions for various particle sizes including 10.0 μm; however, it did not provide the PM 2.5 value for some of the particle components. In these instances, a linear relationship was determined between the particle size and the fraction of particles less than that size. Similar to Part 5, the linear interpolation was performed on the two nearest points to the PM 2.5 fraction. The resulting fraction which correlates with the 2.5 μm size was then determined from this two-point interpolation. The sizes and corresponding fractions are given in Table 4.12-5.

Table 4.12-5. PM Size Fractions

Particulate Component	Percent Less Than 10 µm	Percent Less Than 2.5 µm
Gasoline vehicles' exhaust w/catalyst, using unleaded fuel	0.97	0.90
Gasoline vehicles' exhaust w/out catalyst, using unleaded fuel	0.90	0.68
Diesel vehicles	1.00	0.92
Brake-wear	0.98	0.42
Tire-wear	1.00	0.25

4.12.3 Conclusion

Table 4.12-6 contains a comparison of the statewide exhaust PM emissions for gasoline-fueled vehicles. The tons per day estimates from MVEI7G contain the PM emission factors based on PART5. The EMFAC2000 emissions are calculated using the emission factors from Table 4.12-2.

Table 4.12-6. Statewide Total PM Exhaust Emissions for Gasoline-Fueled Vehicles in Tons per Day

Vehicle Type	2000 MVEI7G	2000 EMFAC2000	2010 MVEI7G	2010 EMFAC2000
LDA				
Non-Catalyst	0.26	0.73	0.01	0.18
Catalyst	2.45	7.78	2.58	10.01
LDT				
Non-Catalyst	0.02	0.31	0.00	0.09
Catalyst	1.12	5.34	1.20	7.85
MDT				
Non-Catalyst	0.00	0.24	0.00	0.07
Catalyst	0.17	1.47	0.25	2.64
LHDT				
Non-Catalyst	0.15	1.80	0.02	0.84
Catalyst	1.05	0.11	1.37	0.18
MHDT				
Non-Catalyst	0.05	0.79	0.01	0.34
Catalyst	0.13	0.04	0.18	0.05