Section 6.4 DEVELOPMENT OF AIR CONDITIONING EMISSION FACTORS

This section discusses the correction factors used to scale down emissions for air conditioner operation over a range of ambient conditions. This methodology takes into account the compressor activity, relative humidity, heat index, and fraction of vehicles with functioning air conditioning (A/C) systems.

6.4.1 Introduction

The effects of A/C are not accounted for in MVEI7G. Recent tests have shown that A/C usage can have a significant impact on vehicle emissions. Currently, a vehicle that undergoes an emissions test receives an extra 10 percent load to the road load horsepower if that vehicle is equipped with A/C. Nearly all available data on A/C effects have been collected over the Federal Test Procedure (FTP) and SC03 driving cycles, however, the Unified Cycle (UC) is more representative of current driving patterns and will be the base emissions test cycle used in EMFAC2000. The correction factors, when scaled down over the range of ambient conditions to represent partial A/C load, will more accurately represent the impact of A/C on emissions. These adjustment factors will be applied to emissions data for the fraction of the fleet with A/C_{on}. The fraction of the fleet with A/C_{on} is a function of a heat index based on the combined impact of temperature and humidity. Estimates will be provided for the fraction of vehicles equipped with A/C systems, and of those, the fraction of malfunctioning systems. This memorandum will be segregated into two major components: emissions and A/C activity.

6.4.2 Emissions

Vehicle testing was conducted on 10 vehicles (Appendix 6.4-A) at 75 degrees on the UC. The tests were conducted with the A/C_{off} but with an added 10 percent road load horsepower (RLHP) and with the A/C_{on} but without the 10 percent RLHP added. Analysis of the data shows that the emissions collected with the A/C_{on} are significantly higher than would be estimated with the 10 percent adjustment assumed in the MVEI7G model. The mean emissions with the extra 10 percent RLHP added and with the A/C_{on} are shown in Table 6.4-1. The following regression equation was used to model each pollutant for Bag 2 emissions as a function of A/C_{off} with RLHP:

$$A/C_{on} = m * (A/C_{10\%}) + C \qquad (6.4\text{-}1)$$

Since the historical UC data have been collected with $A/C_{10\%}$, this equation becomes:

$$A/C_{on} = m * (UC_{bag2}) + C \qquad (6.4\text{-}2)$$

Table 6.4-2 lists the coefficients for m and C. The emissions data and regression lines are shown in Figures 6.4-1 through 6.4-4.

Table 6.4-1. Mean Emissions.

	with 10% RLHP	with A/C_{on}
HC	0.045	0.051
CO	1.518	2.374
CO_2	391.394	430.017
NO_x	0.405	0.511

Table 6.4-2. Coefficients for Adjustment.

	m	C	R^2
HC	1.226	0	0.894
CO	1.511	0	0.753
CO_2	0.805	116.769	0.573
NO_x	1.198	0	0.820

6.4.3 A/C Activity Factors

Since "full-usage" A/C correction factors represent the emission increase during full load on the engine attributable to the A/C system, these factors must be scaled down to reflect the ambient conditions under which the model is run. The emissions factor equation should be adjusted to:

$$A/C_{adj} = (A/C_{10\%})*[1-A/C_{on}] + (A/C)*[A/C_{on}], \qquad (6.4\text{-}3)$$

where

$$[A/C_{on}] = [\text{fraction equipped with A/C}] * [\text{fraction of functional A/C systems}] * [\text{compressor activity fraction algorithm}] \qquad (6.4\text{-}4)$$

6.4.3.1 Compressor Activity Fraction

Compressor Activity

EMFAC2000 will correlate emissions with the operation of the vehicle's A/C compressor since it is the direct cause of the additional load on the engine. To model intermediate conditions which result in partial A/C load, EMFAC2000 will include a factor to model compressor time as a function of the heat index based on temperature and humidity. This correction factor will characterize overall A/C system load by reflecting the percentage of time that the compressor is actually engaged. The proposed approach will scale down the full-use emission factor by using compressor time as well as using the heat index. The compressor on fraction (COM_{fr}) may be represented as:

$$COM_{fr} = K + a*HI + b*HI^2, \qquad (6.4\text{-}5)$$

where a and b are coefficients for the heat index, and K is a constant. The scaling, or demand factor, coefficients provided by U.S. EPA for "all combined" periods of the day are shown in Table 6.4-3. Figure 6.4-5 illustrates the relationship between heat index and compressor fraction.

Table 6.4-3. Demand Factor Equation Coefficients.

Period	Constant(K)	a	b	R^2
All Combined	-3.631541	0.072465	-0.000276	0.44

Relative Humidity

Temperature and relative humidity have a significant impact on the engine load placed on the A/C system. They influence the amount of A/C usage in a vehicle. These two factors comprise the heat index and quantify the driver discomfort caused by their combined effects. Temperature matrices in which county-specific monthly, in addition to O_3- and CO-episode day, diurnal temperature profiles were developed. A sample matrix is provided in Table 6.4-4. Similarly, relative humidity matrices have been created for each county to profile average monthly humidity readings.

Heat Index

U.S. EPA has provided heat index values. The temperatures range from 50 to 100 degrees in 5 degree increments, and the relative humidity is from 0 to 100 percent in 10 percent intervals. The heat index numbers in Table 6.4-5 were used to model heat index as a function of temperature and humidity. Figure 6.4-6 illustrates the relationship between temperature, humidity, and heat index.

Table 6.4-4. Format of County-Specific Humidity Matrix.

			Hour
County ID	County	Period	H0 H1 H2 .... H21 H22 H23
1	Alameda	January	
1	Alameda	February	
1	Alameda	March	
1	Alameda	April	
1	Alameda	May	
1	Alameda	June	
1	Alameda	July	
1	Alameda	August	
1	Alameda	September	
1	Alameda	October	
1	Alameda	November	
1	Alameda	December	
1	Alameda	annual avg	
1	Alameda	ozone	
1	Alameda	co	
2	Alpine	January	
:			
:			
58	Yolo	ozone	
58	Yolo	co	

Table 6.4-5. Heat Index Values.

	0% RH	10% RH	20% RH	30% RH	40% RH	50% RH	60% RH	70% RH	80% RH	90% RH	100% RH
50°	41	41	42	43	43	44	45	46	46	47	48
55°	46	47	48	49	49	50	51	52	53	53	54
60°	51	52	53	54	55	56	57	58	59	60	60
65°	57	58	59	60	61	62	63	64	65	66	67
70°	63	64	65	66	68	69	69	70	71	72	73
75°	69	70	72	73	74	74	75	76	77	78	78
80°	76	77	78	79	79	80	82	83	84	86	89
85°	80	81	82	84	85	87	89	92	95	100	106
90°	84	86	87	89	92	95	99	104	112	125	148
95°	88	90	92	96	100	105	113	125	146	166	166
100°	92	95	98	103	109	119	135	158	166	166	166

6.4.3.2 Fraction of Vehicles Equipped with A/C

To determine the fraction of vehicles in the fleet that are equipped with A/C systems, EPA has estimated base market penetration rates by model year using Ward's Automotive Handbook for light-duty automobiles. The projection cap was 98% of vehicles and 95% of trucks would likely be equipped with A/C by the 1999 model year (Table 6.4-6).

6.4.3.3 Fraction of Functional A/C Systems

Using the annual Consumers Reports Automobile Purchase issue which surveys readers on A/C system malfunctions by vehicle age, the U.S. EPA estimates yearly increases in the absolute malfunction rate of 1.5 percent, and starting at age nine the rate is held constant at 12.5 percent. To estimate the rate of repair, the following assumptions were used: 1) all vehicles up to three years old (the standard warranty period) would be repaired; 2) after three years the majority of vehicles would still be repaired, but this percentage decreases as the vehicle becomes older; and c) vehicles before the 1993 model year (estimated cutpoint for R-134a Freon replacement on most vehicles) would have a lower rate of repair due to the cost of system recharging. The U.S. EPA estimated that 100% of the R-134a systems would be repaired during the 3-year warranty period, 90% in years four through eight, 80% in years nine through 13, 70% in years 14 through 18 and 60% in years 19 and up. The non-warranty period repair rate is reduced by a factor of 0.75 for pre-1993 system if the modeled calendar year is 1995 or later. Table 6.4-7 summarizes the malfunction rates. Therefore, the estimate of vehicles with functional A/C systems combines the base market penetration rates for that model year with the unrepaired malfunction rates for the appropriate vehicle age. Table 6.4-8 shows a sample calculation using the correction factor.

Table 6.4-6. Proposed Base Market Penetration Rates.

Model Yr	% LDVs equipped with A/C	% LDTs equipped with A/C
72	60	29
73	73	29
74	62	29
75	63	29
76	68	31
77	73	36
78	72	38
79	70	36
80	63	35
81	67	39
82	70	45
83	74	47
84	78	53
85	80	54
86	79	55
87	76	60
88	79	65
89	78	74
90	87	77
91	87	78

92	89	82
93	91	84
94	93	86
95	94	89
96	95	91
97	97	93
98	98	95
99	98	95
00+	98	95

Table 6.4-7. Proposed Rate of A/C Malfunction.

Vehicle Age (years)	Consumer Reports*	Proposed Estimates
1	< 2%	0.5 %
2	2 - 5 %	2.0 %
3	2 - 5 %	3.5 %
4	2 - 5 %	5.0 %
5	5 - 9.3 %	6.5 %
6	5 - 9.3 %	8.0 %
7	9.3 - 14.8 %	9.5 %
8	9.3 - 14.8 %	11.0 %
9+	n/a	12.5 %

* 1997 Automobile Purchase Issue

Table 6.4-8. Sample Calculation Using ACCF.

Pollutant	**$A/C_{10\%}$ (g/mi)**	**Emission Rates (g/mi)**
ROG	0.287	0.334
CO	5.131	7.019
NO_x	0.740	0.761
CO_2	308.777	349.498

*Calendar year 1998, South Coast; assuming compressor is always on, percent of fleet equipped with A/C is 90, and fraction of functional systems is 0.8

FIGURE 6.4-1

COMPARISON OF HC EMISSIONS WITH 10% RLHP TO AC_{ON} FOR UC CYCLE

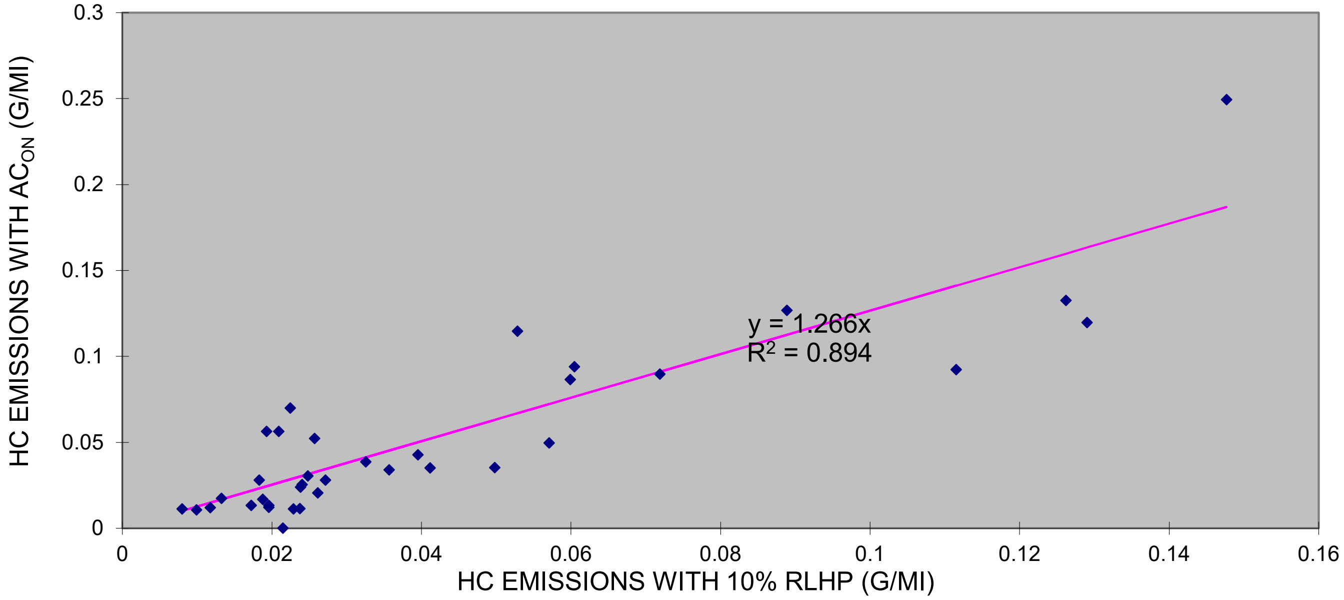


FIGURE 6.4-2

COMPARISON OF CO EMISSIONS WITH 10% RLHP TO AC_{ON} FOR UC CYCLE

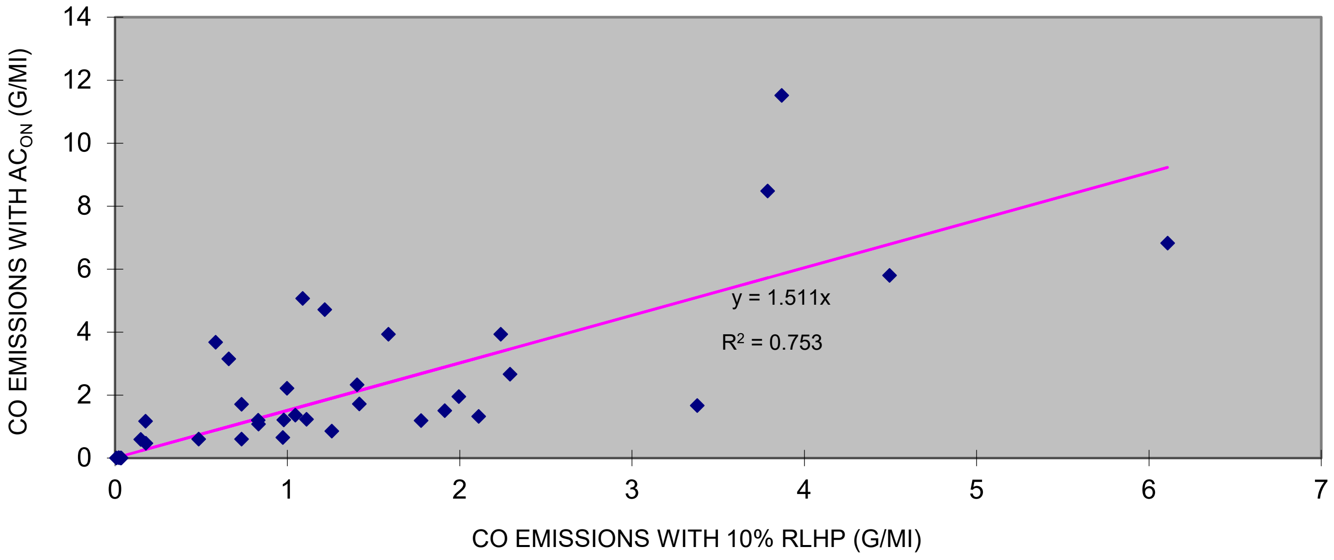


FIGURE 6.4-3

COMPARISON OF CO_2 EMISSIONS WITH 10% RLHP TO AC_{ON} FOR UC CYCLE

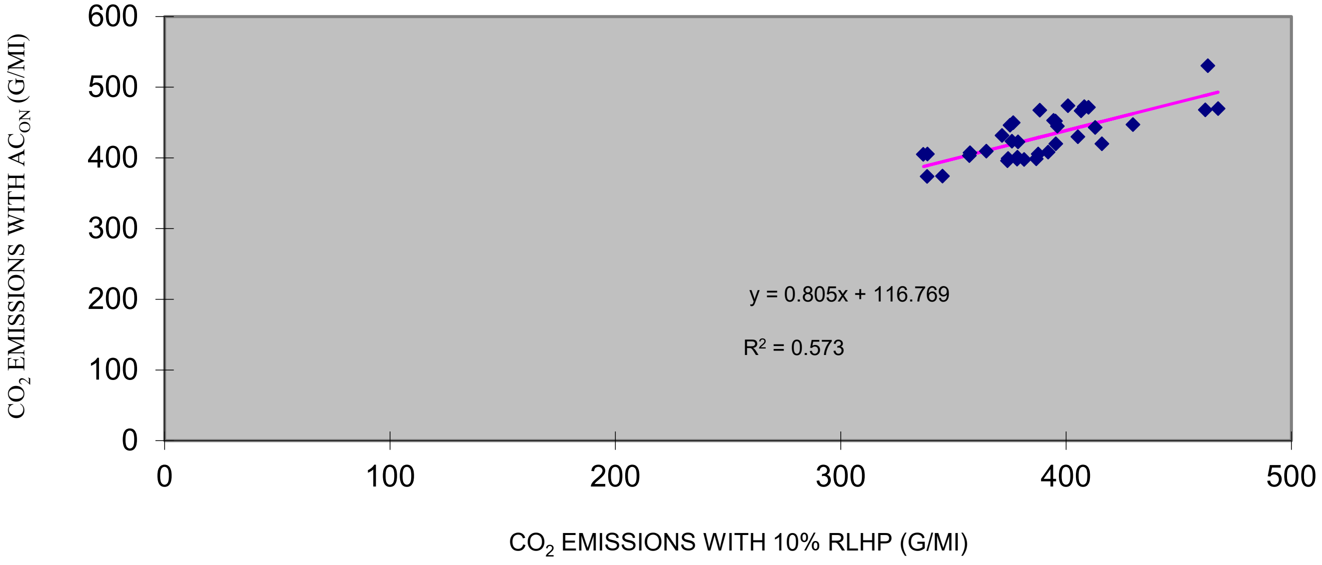


FIGURE 6.4-4

COMPARISON OF NO_x EMISSIONS WITH 10% RLHP TO AC_{ON} FOR UC CYCLE

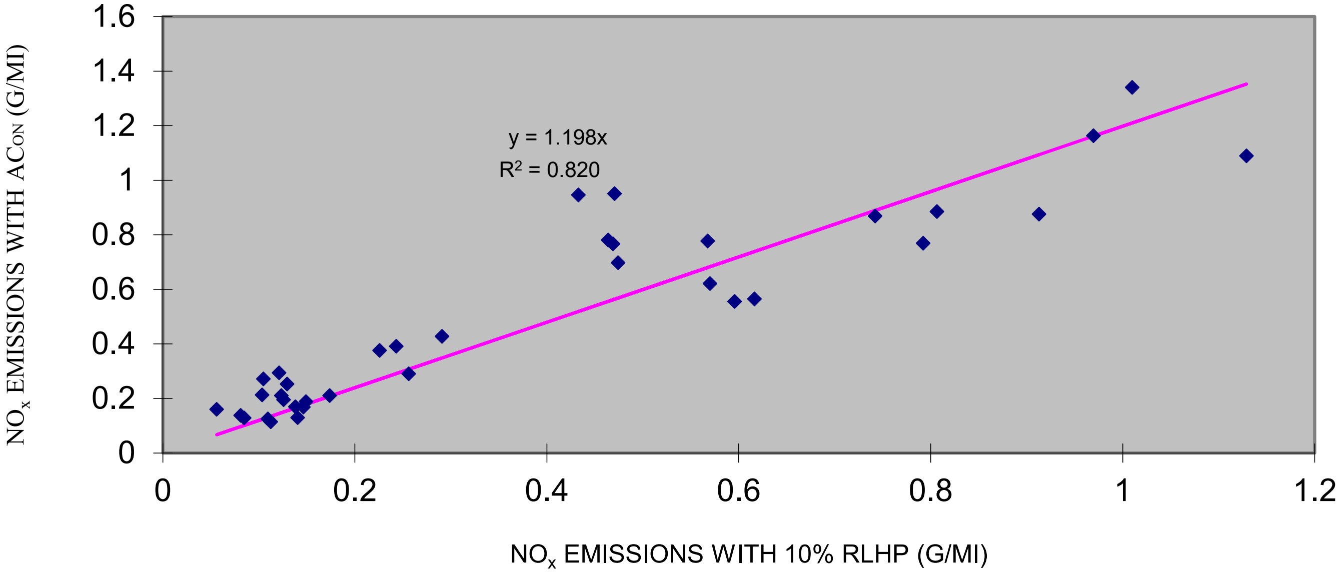


FIGURE 6.4-5
Compressor Fraction vs Heat Index

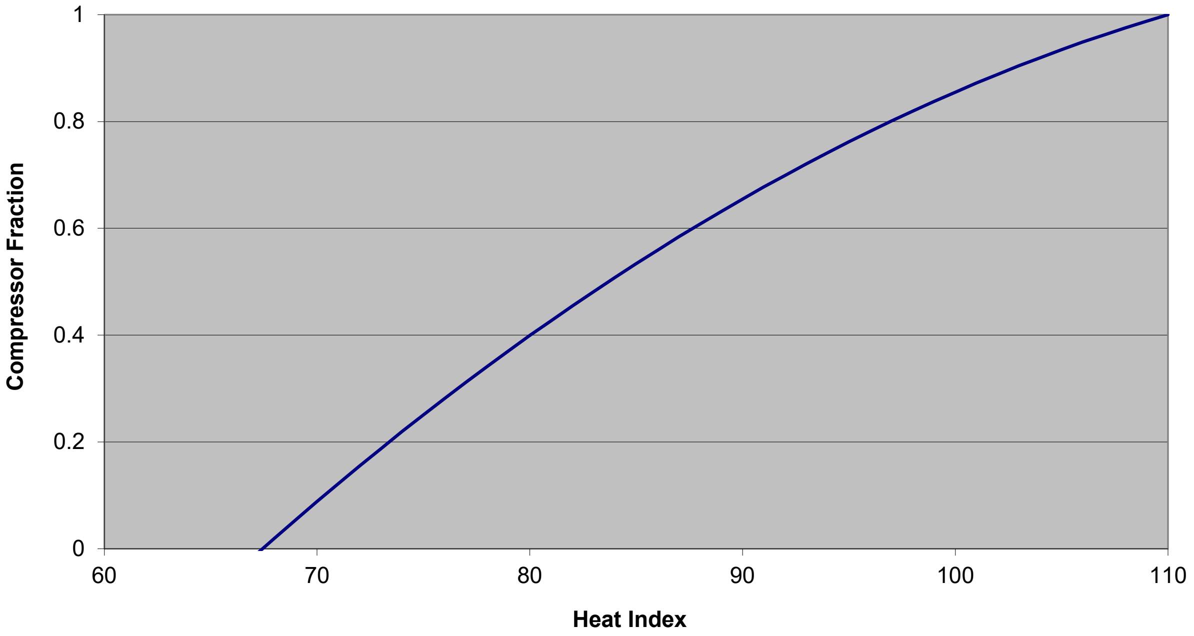
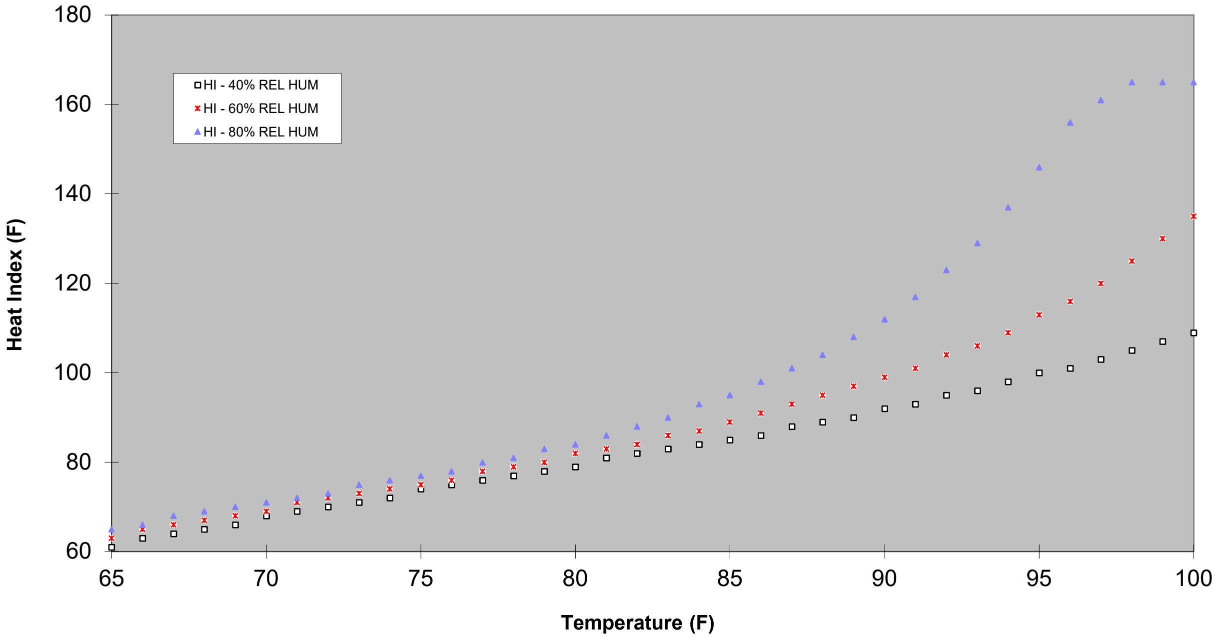


FIGURE 6.4-6
Heat Index



Appendix 6.4-A. Description of Test Vehicles.

Model Year	Manufacturer	Division	Model
91	GM	Chevrolet	Lumina
91	Ford	Ford	Taurus
92	GM	Chevrolet	Astrovan
92	Ford	Ford	Tempo
94	Ford	Ford	Taurus
96	Honda	Honda	Accord
94	Ford	Ford	Taurus
92	GM	Pontiac	Grand Am
95	GM	Oldsmobile	Cutlass
97	GM	Oldsmobile	Achieva

Section 6.6 ALTITUDE CORRECTION FACTORS

This section details the altitude correction factors (ACF) used in EMFAC2000.

6.6.1 Introduction

The basic exhaust emission rates are based on FTP or UC tests performed at CARB's Haagen-Smit Laboratory (HSL). The HSL is at an altitude of 300 feet. Emission rates developed from testing at HSL are representative of emissions from vehicles operating at sea level. These emission rates are then assigned to all vehicles operating in California. However, some older technology vehicles emit more hydrocarbon (HC) and carbon monoxide (CO) emissions and have lower oxides of nitrogen (NOx) emissions when operated at high altitudes. This is especially a concern for older technology vehicles operating in the Lake Tahoe Air Basin, which is at an altitude of more than 5,000 feet. At higher altitudes the air pressure and air density is lower than that at sea level. Older technology vehicles, designed for operation at sea level, were not equipped with adaptive fuel controls to reduce the fuel flow for operation at high altitudes. Hence older technology vehicles tended to run rich at higher altitudes. This increased HC and CO emissions but suppressed NOx formation due to the quenching effect of the excess fuel.

6.6.2 Methodology

In MVEI7G, altitude correction factors of 1.3 (HC), 1.9 (CO) and 0.6 (NOx) were applied to the running exhaust and continuous starting emissions in the Lake Tahoe Air Basin. These factors were applied to all vehicle classes including diesel-fueled vehicles. The ACF have remained the same since EMFAC7D. In EMFAC2000, the ACF were revisited with the intentions of updating them, and verifying the magnitude of emissions increase. Staff contacted USEPA to obtain any new or old test data, which were used in developing the ACF. The historical data are no longer available; however, both CARB and USEPA staff recollect that the ACF are only applicable to older technology gasoline fueled vehicles. Newer technology vehicles have adaptive fuel controls that compensate for higher altitudes. In EMFAC2000, the ACF are only applied to the following technology groups (Table 6.6-1) operating in the Lake Tahoe Air Basin.

Table 6.6-1 Technology Groups With ACF

Tech Group	Model Years	Technology Group Descriptions
1	Pre-1975	With Secondary Air
2	Pre-1975	Without Secondary Air
3	1975 & Later	No Catalyst
4	1975-1976	Oxidation catalyst with secondary air
5	1975-1979	Oxidation catalyst without secondary air
6	1980 & Later	Oxidation catalyst without secondary air
7	1977 & Later	Oxidation catalyst with secondary air

Section 6.3 Fuel Correction Factors for Cleaner-Burning Gasoline

This section discusses the Fuel Correction Factors related to cleaner-burning gasoline for all gasoline vehicles in EMFAC2000.

6.3.1 Introduction

As a part of overall program to reduce emissions from motor vehicles, State of California requires that all gasoline sold in the state must be California cleaner-burning gasoline. Cleaner-burning fuels were introduced in two phases: Phase I in 1992; and Phase II in 1996.

6.3.2 Methodology & Results

The change in emissions attributed to clean burning fuel, in the form of correction factors, are included in EMFAC2000. The fuel correction factors (FCF) are multiplied by the base emission rate, for each pollutant, in order to determine the effect of the fuel on emissions. FCF for phase I are same as in the previous version of the emissions inventory model (MVEI7G). Compared to MVEI7G, in EMFAC2000 FCF for phase II fuel in 1996 are revised to reflect the reductions estimated by stationary source division of the ARB. Stationary source division, lead division on fuels regulations, conducted several motor vehicle test programs to evaluate different fuels and estimated an overall reduction of 11% in HC, CO and NOx emissions. Table 6.3.1 shows FCF used in EMFAC2000.

Table 6.3.1 Fuel Correction Factors (FCF) for Cleaner-Burning Gasoline

Cleaner-Burning Fuel	CY	MY	HC	CO	NOx
Phase I	1992-1995 Summertime	All	0.988	0.994	0.997
	1992-1995 Wintertime	All	0.963	0.895	0.997
Phase II	1996+ Summertime	All	0.890	0.890	0.890
	1996+ Summertime	All	0.890	0.890	0.890

Section 3.2 HIGH EMITTER CORRECTION FACTORS

3.2.1.1 Introduction

In the previous emissions inventory model, MVEI7G, a high emitter correction factor (HECF) was used to adjust the estimated model year specific emission rates such that they matched the model year specific emission rates observed in an independent data set. The HECF is not used in EMFAC2000 since the estimated model year specific emission rates closely match those observed in another independent data set. This section gives a brief background of the HECF, why it was used in MVEI7G, and why it became redundant in EMFAC2000.

3.2.1.2 Background

Prior to MVEI7G, it was often stated that the "the mobile source emissions inventory is underestimated by a factor of 2," and that "a minority of "high emitting" vehicles are responsible for majority of the emissions." The basic argument was that the CALIMFAC[1] model underrepresented the amount of high emitters that were present in the fleet at any given time. People speculated that CARB's low vehicle capture rate in surveillance programs resulted in a data set that contained fewer high emitting vehicles than those observed in remote sensing studies. It was theorized that a bias data set resulted from the reluctance of owners of tampered vehicles to participate in a state-operated vehicle-testing program. This data set, which was used in CALIMFAC for determining the average emission rate by regime and the population of vehicles in each regime, was responsible for an underestimation of the population of high emitting vehicles. In 1994, CARB conducted a Pilot IM program with the goal of assessing the relative merits of conducting vehicle inspections using either the IM240 or ASM tests. The program was designed such that participation was mandatory. This resulted in a 60% capture rate; the highest ever achieved by CARB for a testing program. During the development of the MVEI7G model, data from the IM Pilot program were compared the modeled rates for HC, CO and NOx from the CALIMFAC model. This analysis, detailed in a document entitled "Development of High Emitter Correction Factors[2]" indicated that the CALIMFAC model tended to under-predict the emissions of older model year vehicles, and slightly overestimate the emissions from newer vehicles. To rectify this, the MVEI7G model included a multiplicative high emitter correction factor, which was applied to both starting and running emission rates. The effect of this factor was to increase HC, CO and NOx emissions by 37%, 52% and 21%, respectively, for passenger cars in calendar year 1995.

In EMFAC2000, the HECF was made redundant because of fundamental improvements in the amount of data used in developing basic emission rates, and how this data was used in characterizing the vehicle fleet. The EMFAC2000 emission rates are based on testing more than 5,200 vehicles, which is more than double the number used in developing the MVEI7G emission

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[1] The CALIMFAC model estimates basic emission rates for with and without IM. These rates were then input into the EMFAC model for adjustment with other correction factors.

[2] This is part of a compendium of documents for the MVEI7G document entitled "Derivation of Emission and Correction Factors for EMFAC7G."

rates. Sections 4.0 through 4.6 detail the steps taken in developing the basic emission rates for passenger cars, light-, and medium-duty trucks. These steps include adding data from: recent surveillance programs where increased monetary incentives have resulted in a higher vehicle capture rate, special high mileage surveillance programs, USEPA's testing from Hammond, Indiana, and from IM evaluation programs (including the IM Pilot program). In addition to adding more data, checks were made to ensure that the vehicle malperformance rate observed in random roadside inspections matched those from surveillance programs. Further, the regime populations predicted by the model were also compared to those observed in surveillance programs, and steps were taken to address any deficiencies. The goal of these steps was to ensure that a representative data set was used in developing the basic emission rates. To validate this data set and verify staff's assumption that an external HECF was no longer necessary, the model year specific emission rates, as modeled by EMFAC2000, were compared to those observed from testing a random sample of vehicles. This is a useful technique for determining whether the emission reduction trends are modeled correctly and in identifying anomalous model year(s) where the modeled emission rates differ significantly from the observed rates. These comparisons only provide a validation of the model year specific gram per mile emission estimates and not the entire inventory, which includes vehicle activity and provides tons per day emission estimates. In addition, this methodology can only be used to compare emission rates, in this case exhaust emission rates, from light-duty vehicles since these vehicles were tested in the independent data set.

3.2.2 Methodology

The CARB routinely conducts surveillance test projects in an ongoing effort to improve the motor vehicle emissions inventory. During these projects, vehicles are randomly selected from the Department of Motor Vehicles' (DMV) vehicle registration database. Those vehicles registered within a 25-mile radius of CARB's Haagen-Smit laboratory (HSL) are procured and tested in an "as-received" condition. Vehicles are given a battery of tests, which include the FTP and UC dynamometer tests. The EMFAC2000 light-duty vehicle emission rates are based on data collected from vehicle surveillance projects. These include:

1. Data collected from light-duty vehicle surveillance projects 1 through 12.
2. Data from Inspection and Maintenance (I&M) evaluation projects.
3. Special high mileage test programs.
4. USEPA data from Hammond, Indiana and Ann Arbor, Michigan.

The database contains model year specific emission rates for vehicles tested at various ages since in every project; a cross section of the vehicle fleet is tested. The EMFAC2000 light-duty vehicle emission rates are based on approximately 5,200 vehicles covering 1968 to 1993 model years.

The EMFAC2000 estimated model year specific UC based emission rates were compared to the measured UC rates in the light-duty vehicle surveillance 13 project. In surveillance 13, 263 passenger cars were tested over the UC test cycle. Since the EMFAC2000 UC rates are adjusted for ambient temperature, relative humidity, the effect of air conditioning usage and speed; the model was modified to generate emission rates comparable to testing conditions at the HSL. The following changes were made to the EMFAC2000 model:

1. The modeled rates were indicative of vehicles in the South Coast Air Basin (SCAB) since light-duty vehicle surveillance 13 vehicles were procured from this area. In addition, it was assumed that these vehicles have undergone the same inspection and maintenance programs as modeled for the SCAB region.
2. The speed correction factors were disabled such that the modeled rates were comparable to the bag 2 rates of the UC test.
3. The temperature and relative humidity corrections were disabled. In the model, these correction factors account for the fact that vehicles are driven under ambient conditions that differ significantly from the standardized ambient conditions used in vehicle testing.
4. The correction factors for air conditioning usage were disabled.
5. Only passenger car emission rates were compared since this was the predominant vehicle class tested in surveillance 13.

3.2.3 Results

Figure 3.2-1 shows the comparison of the modeled HC rates from EMFAC2000 versus the average measured HC rates from passenger cars tested in surveillance 13. The average HC rate is highly influenced by the emission rates of outliers. Outliers are those vehicles with either significantly higher or lower emissions than the remaining vehicles in the model year group. Depending on the number of vehicles in the model year group, outliers can strongly influence the average emission rate. Therefore, Figure 3.2-1 also shows the minimum and maximum model year specific HC rates observed in surveillance 13 program. Figure 3.2-1 also shows the number of vehicles tested in each model year. Similarly, Figures 3.2-2 and 3.2-3 show the comparison of the modeled EMFAC2000 CO and NOx rates versus the observed CO and NOx rates from surveillance 13 project, respectively.

Figure 3.2-1 Comparison of the Modeled EMFAC2000 HC Rates Versus the Observed HC Rates from Surveillance 13 Project

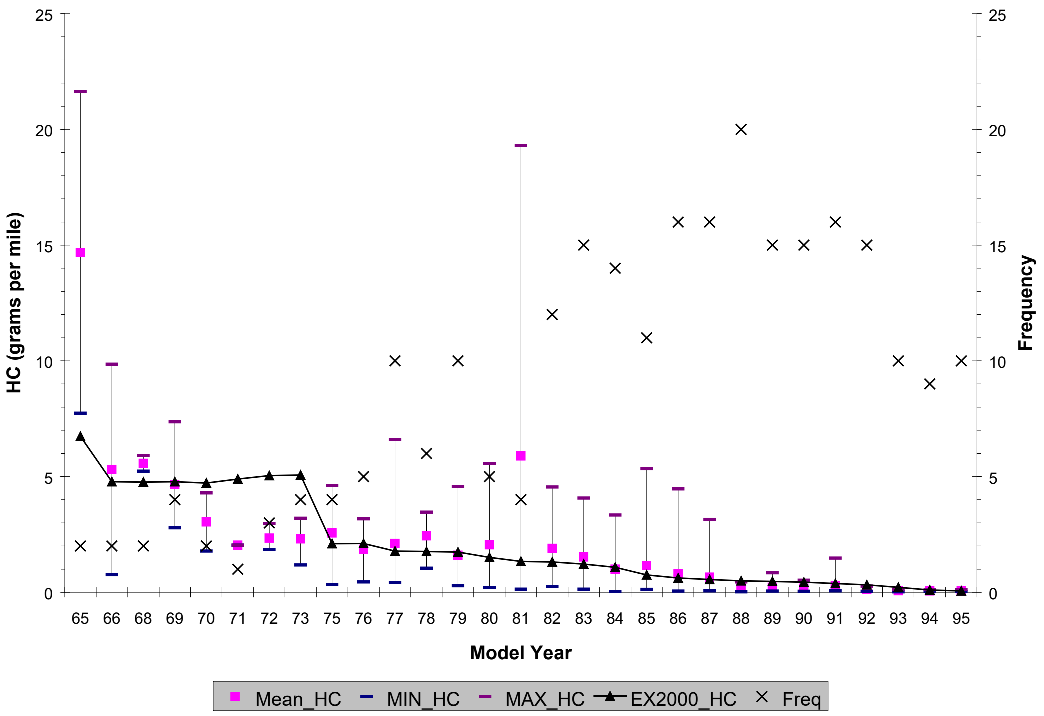


Figure 3.2-2 Comparison of the Modeled EMFAC2000 CO Rates Versus the Observed CO Rates from Surveillance 13 Project

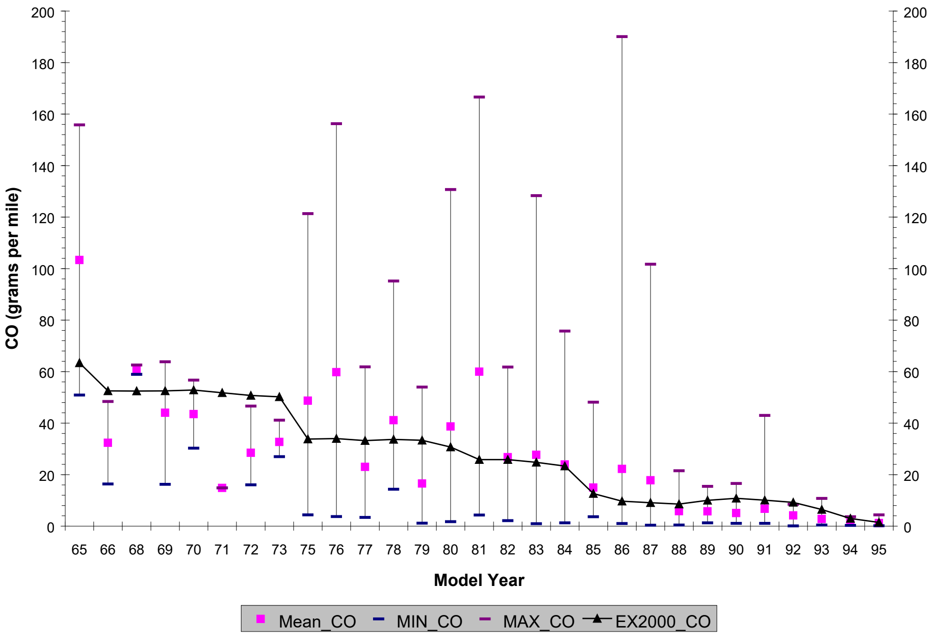
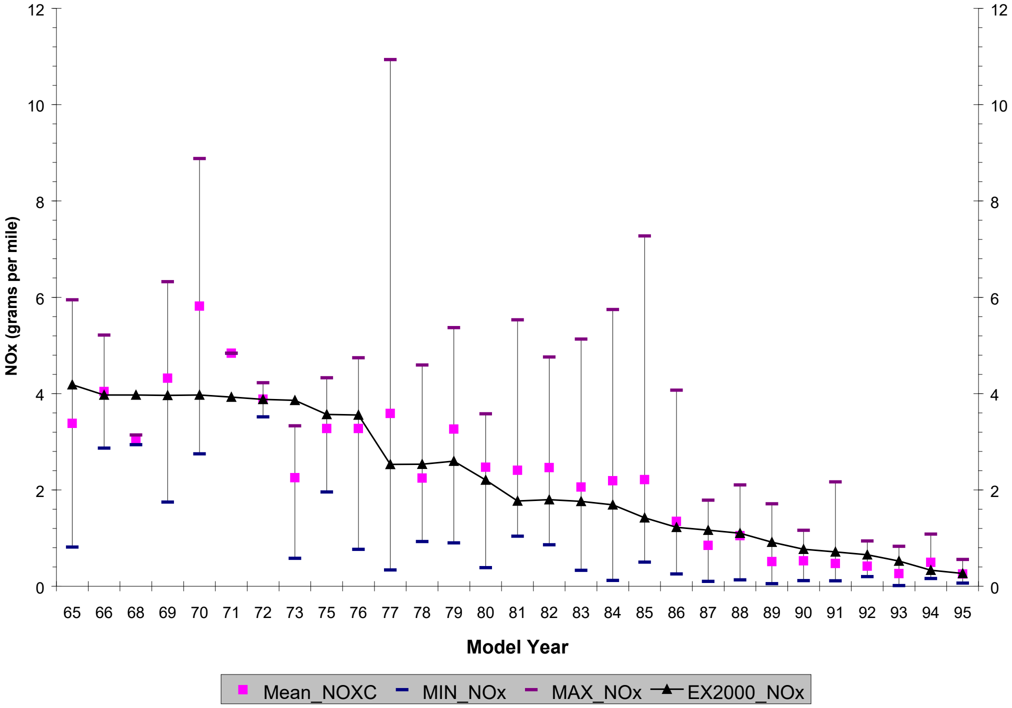


Figure 3.2-3 Comparison of the Modeled EMFAC2000 NOx Rates Versus the Observed NOx Rates from Surveillance 13 Project



Figures 3.2-1 to 3.2-3 graphically show how the estimated model year specific emission rates compare to the measured rates for passenger cars tested in the surveillance 13 project. While these figures show that the modeled rates are comparable to the measured rates they do not indicate what the impact is on the average fleet emission rate as a result of slight variations in the model year specific emission rates. To determine the impact on the average emission rate the modeled and observed model year specific emission rates were weighted by the vehicle miles traveled (VMT) in each model year. Table 3.2-1 shows the VMT weighted emission rate from EMFAC2000 and the surveillance 13 project. This table also shows the ratios of EMFAC2000/surveillance_13 emission estimates by pollutant.

Table 3.2-1 Average Fleet Emission Rates from EMFAC2000 and Surveillance 13

VMT Weighted Grams Per Mile Emission Estimates			
	HC	CO	NOx
EX2000	0.81	13.95	1.19
Surveillance_13	0.95	14.54	1.20
Ratio (*)	0.85	0.96	0.99
Ratio (*) = (Modeled EMFAC2000) / (Observed in Surv 13)			

3.2.4 Discussion

At first glance, Figures 3.2-1 and 3.2-2 suggests that the modeled HC and CO rates for model years 1969 to 1973 are much higher than the observed HC and CO rates, respectively. This may be true, however, the observed rates are based on the average of two to four vehicles in each model year as indicated by the frequency of vehicles tested. The limited sample size prevents any meaningful comparisons of the average emission rate for vehicles in these model years. It could be that the observed rates are lower than the modeled rates by the mere fact that people who own older cars have maintained them and hence there a decline the deterioration rates beyond a certain age. To answer this question, one should test a representative sample of vehicles in each model year and then compare the measured rates to the modeled rates. However, in a surveillance project, vehicles are tested to represent a snap shot of the vehicle fleet in that calendar year, hence, it is dominated by newer vehicles. The data from newer vehicles are used in updating emission rates of newer technology vehicles, which will dominate future calendar year forecasts. This issue will be revisited if similar trends are observed in future surveillance projects.

Figure 3.2-2 indicates that the modeled CO rates for model years 1988-1995 are higher than the observed CO rates. For these vehicles sample size is not an issue since the observed rates are based on testing a minimum of nine vehicles in each model year group. Unlike the differences in older model year emission rates, slight differences in the emission rates of newer model years can result in larger differences on the average fleet emission rate because the majority of the VMT comes from newer vehicles. One should evaluate additional data sets to verify this difference in CO emission rates for newer vehicles. This analysis will also point to the causes for the over-prediction in the emission rates for CO. The reasons may be:

1. Regime growth rates. The modeled CO emissions may be deteriorating at a faster rate than what is observed.
2. Regime specific emission rates. The regime specific emission rates may be slightly higher than what is observed.
3. The inspection and maintenance program may be more effective at lowering CO emissions than currently modeled.
4. Any combination of above reasons may cause the modeled CO emission rates to be higher than the measured CO rates.

Despite these differences, Table 3.2-1 indicates that the modeled HC, CO and NOx emissions are comparable to the observed emission estimates. The ratio of the modeled versus observed rates is below 1 for all three pollutants suggesting an underestimation of 1 to 15 percent.

3.2.5 Recommendations

1. Staff believes that the HECF should not be used in EMFAC2000 since there is little difference between the modeled and observed rates. However, similar analyses should be performed using additional data sources. These analyses can be used to either confirm or repudiate some of the observations noted from comparing the modeled EMFAC2000

emission rates to the measured emission rates. These analyses will highlight those model years where more data is needed or where the modeled rates need to be changed.

2. These comparisons should be done for all other vehicle classes and fuel types. While this is data and resource intensive, one will be able to gauge how close the modeled rates are to the measured rates. These comparisons will also identify data sources, which can be used in future, model updates.
3. The modeled rates should be compared to Bureau of Automotive Repair's (BAR) smog check test data from their two-percent audit sample. The BAR sends two percent of randomly selected vehicles to test-only centers. These vehicles should also be tested over a transient cycle, which measures emissions in grams per mile. These measurements, after conversion to an UC basis, can be compared to the modeled UC rates by vehicle class. This methodology has its own limitations; however, it may be a good technique for identifying anomalies in the model year specific emission rates.

Section 6.5 NO_X EMISSION RATES AND HUMIDITY

This section reviews the NO_x humidity correction factor and specifies the methodology to apply this factor to county specific ambient conditions.

6.5.1 Introduction

In general the moisture content of the air affects combustion. This is particularly important for NO_x emissions and has been well documented. With high moisture content in the air, the combustion processes losses some energy to water, reducing the energy available to produce NO_x. When the air is dryer, the combustion process has more energy available to produce nitrogen oxides. When vehicles are tested in the laboratory, their emissions are corrected to a standard temperature. The impact of this standardization depends on the particular ambient conditions. In MVEI7G there was no correction of NO_x emissions due to ambient conditions. In EMFAC2000, a NO_x humidity correction factor is applied to reflect county specific ambient conditions.

The NO_x humidity correction factor used in the Federal Test Procedure (FTP) was developed in the early 1970s using non-catalyst equipped vehicles tested over the 7-mode cycle. The methodology employed is described in the SAE publication 720124 by Manos et al.[1] The findings were incorporated in 40 CFR 86-144.[2] This correction factor adjusts the NO_x emission rates to an absolute humidity of 75 grains of water per pound of dry air (gr/lb). Since the vehicles used to develop the current correction factor used older emission control technology there was a need to review the soundness of the factor for the different vehicle technologies in the current California fleet. Additionally, the emission rates adjusted to 75 gr/lb did not represent the varied ambient conditions in space and time that California vehicles experience while on the road.

6.5.2 Review of the NO_x Humidity Correction Factor

The ARB reviewed the NO_x humidity correction factor using information contained in its Motor Vehicle Data Acquisition System (MVDAS). This system stores information on passenger cars and light- and medium-duty vehicle tested by the ARB for exhaust emissions. The system has the capability to store all of the relevant test parameters such vehicle model year, fuel delivery system, presence and type of catalyst, odometer reading, vehicle class and ambient test conditions. Ambient conditions such as temperature, dew point temperature, relative humidity and absolute (specific) humidity are collected and stored for each test.

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[1] Manos, M.J.; J.W. Bozek and T.A. Huls “Effect of Laboratory Conditions on Exhaust Emissions,” SAE 720124 (1972).

[2] Code of Federal Regulations, Protection of Environment, 40 86.144 (Revised as of July 1, 1995).

The data used for this review were the baseline FTP bag emissions (as received) performed at ARB from 1989 through 1995. The retrieved data included 885 light-duty trucks, 116 medium-duty vehicles and 3447 passenger cars ranging in model year from 1962 to 1995. Ambient temperatures ranged from 50 to 90 ºF and absolute humidity varied from 6 to 112 gr/lb during the tests.

6.5.3 Original Methodology

The article by Manos et al. describes the effects of temperature (T) and humidity (H) on NO_x emissions (E in g/mile) for a set of vehicles. The ambient conditions tested included roughly a temperature range of 60 to 95ºF and a humidity range of 20 to 180 gr/lb. The results were based on 5 American made vehicles. Manos et al. developed a linear regression equation to standardize to mean conditions (denoted by the hat) as:

$$E = \bar{E} + a_1(T - \bar{T}) + a_2(H - \bar{H}) \tag{6.5-1}$$

Later they recalculated the equation for standard conditions of 78 ºF (T_s) and 75 gr/lb (H_s),

$$E = [\bar{E} + a_1(T_s - \bar{T}) + a_2(H_s - \bar{H})] + a_1(T - T_s) + a_2(H - H_s) \tag{6.5-1a}$$

equivalent to (since the terms within the brackets are constant):

$$E = \bar{E}_s + a_1(T - T_s) + a_2(H - H_s) \tag{6.5-1b}$$

Since the temperature effect was considered to be much smaller than the humidity effect it was dropped from the correction factor to standard conditions. The correction factor was then defined as:

$$K_H = \frac{\bar{E}_s}{\bar{E}_s + a_2(H - H_s)} \tag{6.5-2}$$

Or

$$K_H = \frac{1}{1 + a_2/\bar{E}_s(H - H_s)} = \frac{1}{1 + m(H - H_s)} \tag{6.5-2a}$$

where

$$m = a_2/\bar{E}_s \tag{6.5-3}$$

The constant m was found to have a value of –0.0047, and will later be referred to as m_{manos}.

6.5.4 ARB Methodology

The analysis presented here relies on a large number of data points collected over varying ambient test conditions, rather than the original methodology which relied upon a few vehicles under well controlled targeted conditions. Once the 4448 vehicle records were retrieved, linear regression models were fit to humidity and temperatures. The analysis, stratified by bag, was performed to verify the validity of the original correction factor. The final model includes only the test humidity (H_T) as the independent variable and raw (uncorrected) NO_x emission rates as the dependent variable per bag and vehicle class:

$$E_{class} = \overline{E}_{s\_class} + a_{class}(H_T - H_s) \qquad (6.5-4)$$

and the *m* parameter by class was calculated as:

$$m_{class} = a_{class} / \overline{E}_{s\_class} \qquad (6.5-5)$$

The overall result confirmed the original value of -0.0047 for the parameter *m*. Carbureted vehicles presented a Bag-2 *m* parameter of -0.0050 for non-catalyst vehicles, -0.0055 for oxidation catalyst and -0.0053 for three way catalyst vehicles. The multi-point fuel-injected models presented an *m* parameter of -0.0036. Using these categories it was apparent that newer technologies tend to be less affected by humidity than the older technologies. These results were encouraging and, when pulled for all classes, were close to the older vehicle K_H. Although the slopes and constant values of the regression model were statistically different than zero, it was not possible to prove that they were different from each other. The original value of the *m* parameter, –0.0047, was retained for each category. Table 6.5-1 presents the results for the evaluated dataset.

6.5.5 Ambient Conditions

In this section it is assumed that the m_{class} parameters are different than the original *m* parameter calculated by Manos et al. in case future tests have better statistical resolution and sensitivity.

To return the standard conditions NOx emission rates (E_s) to test conditions (E_T), the inverse of K_H will be calculated using the *m* reported in Manos et al. and the average absolute humidity encountered during testing (H_T) for each vehicle class reported in Table 6.5-1.

$$E_T = E_s(1 + m_{manos}(H_T - H_s)) \qquad (6.5-6)$$

Then the emission rate is adjusted to the standard conditions (E_{new_s}) using the new class specific m_{class} parameter.

Table 6.5-1 Parameters to evaluate the NOx humidity correction factor using simple linear regression.

Finj/Cat	Bag	$\overline{MY}$	$\overline{H}_T$	n	R^2	$\overline{E}_{s\_class}$	a_{class}	m_{class*}
All	1	81.8	58.0	4447	0.014	2.16	-0.0103	-0.0048
All	2	81.8	58.2	4448	0.009	1.35	-0.0064	-0.0048
All	3	81.8	58.0	4446	0.009	1.96	-0.0086	-0.0044
MPF	1	85.6	57.5	1165	0.008	1.67	-0.0059	-0.0035
MPF	2	85.7	57.7	1166	0.004	0.85	-0.0031	-0.0036
MPF*	3	85.7	57.6	1166	0.002	1.30	-0.0026	-0.0020
C-TWC	1	84.5	58.2	1733	0.010	1.97	-0.0082	-0.0042
C-TWC	2	84.5	58.3	1731	0.009	1.19	-0.0064	-0.0053
C-TWC	3	84.5	58.1	1730	0.010	1.61	-0.0082	-0.0051
C-OXY	1	78.6	57.7	934	0.033	2.46	-0.0164	-0.0066
C-OXY	2	78.6	58.0	935	0.020	1.72	-0.0094	-0.0055
C-OXY	3	78.6	57.8	934	0.021	2.47	-0.0133	-0.0054
C-NON	1	71.5	58.9	612	0.032	3.13	-0.0174	-0.0055
C-NON	2	71.5	59.1	614	0.023	2.13	-0.0107	-0.0050
C-NON	3	71.5	59.0	613	0.033	3.35	-0.0180	-0.0054

(From previous page table) MPF, multi-point fuel-injection: C-TWC, carbureted three way catalyst: C-OXY, carburted oxidation catalyst; C-NON, carbureted non-catalyst. Note that the MPF bag 3 coefficient *a* was not statistically significant. The m_{class} parameters were not statistically significantly different from each other.

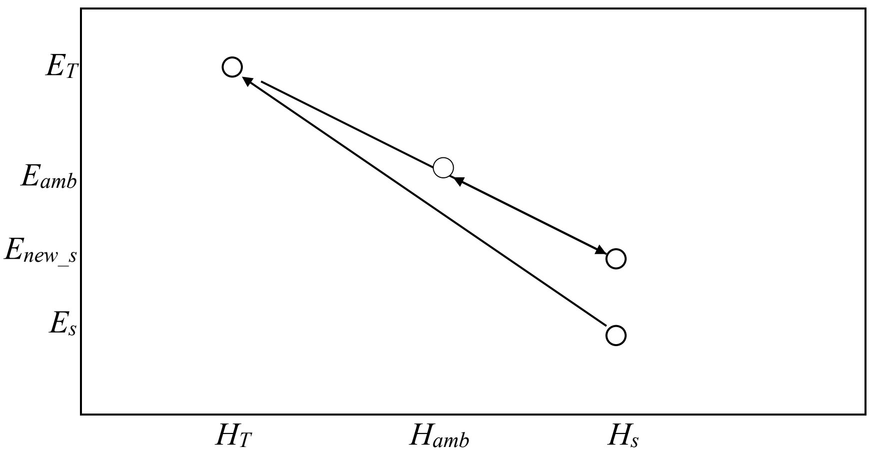
$$E_{new\_s} = E_T \frac{1}{1 + m_{class}(H_T - H_s)} = E_s \frac{1 + m_{manos}(H_T - H_s)}{1 + m_{class}(H_T - H_s)} \qquad (6.5-7)$$

To finally adjust the emission rate (E_{amb}) to the spatial-time-specific ambient humidity (H_{amb}) conditions the inverse of the correction factor with the proposed parameter is used.

$$E_{amb} = E_{new\_s}(1 + m_{class}(H_{amb} - H_s)) = E_s \frac{(1 + m_{manos}(H_T - H_s))(1 + m_{class}(H_{amb} - H_s))}{1 + m_{class}(H_T - H_s)} \qquad (6.5-8)$$

A graphical representation of the procedure is presented in Figure 6.5-1 that includes the adjustments from E_s to E_{amb} including the intermediate E_T and E_{new_s}.

Figure 6.5-1 Adjustment of emission rates from reviewed NO_x humidity correction factors and adjustment to ambient conditions.



6.5.6 Time-Space Resolved Absolute and Relative Humidity

At sea level pressure, for a given absolute humidity and temperature, all other psychrometric parameters are fixed, such as relative humidity. Similarly, knowing temperature and relative humidity it is possible to estimate absolute humidity. The temperature matrices are explained in Section 8.8. The format of the county-specific monthly, O_3 and CO episodic days, and annual diurnal distributions of relative humidity are show in Table 6.5-2.

To estimate absolute humidity (H) values within a temperature (T) range of 40 to 120 °F and relative humidity (RH) range of 0 to 100 percent, an equation was developed using values estimated from the psychrometric charts in Perry's Chemical Engineers' Handbook[3] and the ACGIH Industrial Ventilation Recommended Practice Handbook[4] as follow:

$$H = RH(a + bT + cT^2 + dT^3) \qquad (6.5-9)$$

where

$a = -0.09132$
$b = 0.01594$
$c = -0.00029$
$d = 4.37\text{x}10^{-06}$

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[3] Sierra Research, "Additional Study of Preconditioning Effects and Other IM240 Testing Issues" prepared for USEPA by Sierra Research (1998).

[4] American Conference of Governmental Industrial Hygienist (ACGIH) Industrial Ventilation Recommended Practice Handbook, Chapter 5, 20th Edition (1988).

For values below 40 °F the corresponding absolute humidities may be assumed from the relative humidities at this temperature.

If $T < 40$, then:

$$H = RH\,(a + b40 + c40^2 + d40^3) = RH\,(0.362) \qquad (6.5-9a)$$

An absolute humidity cap of 200 gr/lb was established for the very high temperatures and high relative humidities (conditions, unlikely to occur on average diurnal distributions in California).

$$200 \leq RH\,(a + bT + cT^2 + dT^3) \qquad (6.5-9c)$$

When

then

$$H = 200 \qquad (6.5\text{-}9d)$$

Table 6.5-2 Format of county-specific relative humidity matrix.

			Hour
Cnty ID	County	Period	RH_0 RH_1 RH_2 ….. RH_{21} RH_{22} RH_{23}
1	Alameda	January	
1	Alameda	February	
1	Alameda	March	
1	Alameda	April	
1	Alameda	May	
1	Alameda	June	
1	Alameda	July	
1	Alameda	August	
1	Alameda	September	
1	Alameda	October	
1	Alameda	November	
1	Alameda	December	
1	Alameda	Ozone	
1	Alameda	CO	
1	Alameda	annual avg	
2	Alpine	January	
:			
:			
58	Yolo	CO	
58	Yolo	annual avg	

These ranges and the pertinent adjustments were decided based upon the test range in the Manos et al. report, available ARB data, and a report prepared for the USEPA by Sierra Research (1998).[5]

6.5.7 County Specific NO_x Emissions Adjustments

The adjustment of the standard emissions to the county-month-hour (denoted by $_{c,m,h}$) specific ambient humidity conditions is defined as follow.

$$E_{amb\_c,m,h} = E_{s\_c,m,h} \frac{(1+m_{manos}(\overline{H}_T - H_s))(1+m_{class}(H_{c,m,h} - H_s))}{1+m_{class}(\overline{H}_T - H_s)} \qquad (6.5-10)$$

or

$$HCF = \frac{E_{amb\_c,m,h}}{E_{s\_c,m,h}} = \frac{(1+m_{manos}(\overline{H}_T - H_s))(1+m_{class}(H_{c,m,h} - H_s))}{1+m_{class}(\overline{H}_T - H_s)} \qquad (6.5-11)$$

HCF is the humidity correction factor applied to Bag-2 of the Unified Cycle.

The Bag-2 average test absolute humidity per class ($\overline{H}_T$) is defined in Table 6.5-1 as well as the specific parameter m_{class}. The standardizing absolute humidity (H_s) is 75 gr/lb and the original m_{manos} parameter has a value of –0.0047.

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[5] Sierra Research, "Additional Study of Preconditioning Effects and Other IM240 Testing Issues" prepared for USEPA by Sierra Research (1998).

Section 6.7 START CORRECTION FACTORS

This section discusses the development of revised Start Correction Factors for all Light- and Medium-Duty vehicles in EMFAC2000.

6.7.1 Introduction

Start Correction Factors (StCF) in the current emissions inventory model (MVEI7G1.0c) are used to adjust the basic FTP based bag 1 emission rates to model start emissions for real-world driving conditions. While the FTP cycle had been historically used to represent in-use driving patterns, recent studies have instead established that the Unified Cycle (UC) represents a more contemporary account of typical driving events, including higher speeds and acceleration/deceleration rates than the FTP cycle. For this reason, the basic emission rates in the new model, EMFAC2000, will be based on the UC. The Start Correction Factors therefore need to be updated accordingly to coincide with this change.

Another purpose of the StCF is to adjust the basic emission rate to model start emissions that are independent of running emissions. This is accomplished by focusing strictly on the emissions produced by the start-up procedure, defined as the emissions produced in the first 100 seconds. Numerically, the Start Correction Factor is defined as follows:

$$\text{StCF} = \frac{\text{CE}_{100}\ \text{UC bag 1 (g)}}{\text{UC bag 1 (g/mi)}} \qquad (6.7\text{-}1)$$

where StCF = Start Correction Factor (mi per 100 sec),
CE_{100} UC bag 1 = cumulative emissions within the first 100 seconds of bag 1 of the Unified Cycle (g),
UC bag 1 = bag 1 emission rate of the Unified Cycle (g/mi).

6.7.2 Data Analysis

Modal (second-by-second) data were gathered from the Light- and Medium-Duty Vehicle Surveillance Programs conducted at the Haagen-Smit Laboratory facilities of the Air Resources Board. A total of 238 automobiles and trucks were tested over the Unified Cycle. After a comprehensive statistical data analysis, the Start Correction Factors were calculated and grouped by technology. Table 6.7-1 contains the resulting correction factors that are applied to the basic emission rate of bag 1 of the UC to yield start emissions for trips that are taken after an overnight soak. These factors are applicable to all light- and medium-duty vehicles and are applied using the following equation.

$$BER_C = BER\ (g/mi) * StCF\ (mi) \qquad (6.7\text{-}2)$$

where BER_C = corrected emission rate (g/100 sec for the overnight soak),
BER = basic emission rate of UC bag 1 (g/mi),
StCF = Start Correction Factor (mi per 100 sec).

Table 6.7-1. Start Correction Factors

	Non-Catalyst	**Oxidation Catalyst**	**Three-Way Catalyst**	
			Carb/TBI	**MPFI**
HC	0.4565	0.6010	0.6472	0.7897
CO	0.4283	0.5838	0.6087	0.8168
NOx	0.2235	0.2306	0.3448	0.4948
CO_2	0.3632	0.3584	0.3546	0.3365

* CARB - Carbureted
TBI – Throttle-Body Fuel Injection
MPFI – Multipoint Fuel Injection

6.7.3 Application of Correction Factors in Start Methodology

Once the overnight start emissions are calculated, soak factors are applied to estimate the emissions of those trips that begin after shorter soak periods. The soak factors are calculated using the following polynomial equation.

$$\text{Normalized Start Emissions of HC, CO, NOx, and } CO_2 = a_0 + a_1 * t + a_2 * t^2 \qquad (6.7\text{-}3)$$

where t = soak time (minutes),
a_i = coefficients of the curves,
Normalized start emissions = grams per soak time *i* divided by grams per overnight soak.

The corresponding coefficients and soak time intervals for each technology group are given in Table 6.7-2. By using the above continuous functions in conjunction with the start emissions produced following a cold soak, it is possible to estimate the amount of start emissions produced after any soak time.

Table 6.7-2. Coefficients by Technology Group for All Light- and Medium-Duty Vehicles

(a) Non-catalyst vehicles

	HC curve 1	**HC curve 2**	**CO curve 1**	**CO curve 2**	**NOx curve 1**	**NOx curve 2**	**CO2 curve 1**	**CO2 curve 2**
a0	0.3806708	0.4362844	0.4380312	-0.085415	1.31568216	2.48061071	0.36302129	0.99064304
a1	-0.001638	0.0007826	-0.00998	0.0030314	0.0275196	-0.0001841	0.00697116	1.2996E-05
a2	6.642E-05		7.019E-05	-2.12E-06	-0.0001531	-2.6E-06	-1.335E-05	
domain (min)	0-52	53-720	0-119	120-720	0-119	120-720	0-115	116-720

(b) Catalyst-equipped vehicles

	HC curve 1	**HC curve 2**	**CO curve 1**	**CO curve 2**	**NOx curve 1**	**NOx curve 2**	**CO2 curve 1**	**CO2 curve 2**
a0	0	0.5713026	0	0.7064116	0.11796024	1.12983289	0	0.25889542
a1	0.012723	0.0007196	0.0119476	0.0003344	0.02966956	2.2138E-05	0.00433672	0.0014848
a2	-6.3E-05	-1.76E-07	-4.76E-05	1.001E-07	-0.000215	-3.04E-07	-2.393E-06	-6.364E-07
domain (min)	0-89	90-720	0-116	117-720	0-61	62-720	0-96	97-720

(c) Advanced catalyst equipped vehicle

	HC curve 1	**HC curve 2**	**CO curve 1**	**CO curve 2**	**NOx curve 1**	**NOx curve 2**	**CO2 curve 1**	**CO2 curve 2**
a0	0	0.5064134	0	0.4473331	1.05016953	1.37178406	0.0537617	0.31251366
a1	0.0056083	0.0006855	0.0070714	0.0016176	0.00361983	0.00026788	0.00114395	0.00095484
a2	-5.09E-06		-1.33E-05	-1.18E-06	-5.575E-06	-1.089E-06	1.6526E-05	
domain (min)	0-117	118-720	0-107	108-720	0-113	114-720	0-119	120-720

While StCF are allocated into four technology groups, the Soak Factors that allocate the emissions associated with different soak periods are defined by three groups: Non-catalyst, Catalyst-equipped, and Advanced Catalyst vehicles (formerly referred to as Electrically-Heated Catalyst). In order to accommodate the different technology groups for the StCF and Soak Factors, it is suggested that the matrix shown in either Table 6.7-3a or 6.7-3b be used. These tables contain the same information; they are both given here for further clarification.

Table 6.7-3a. Application of Correction Factors by Technology Group

Technology Groups of Basic Emission Rates	**Corresponding Correction Factors**	
	Start Correction Factor	**Soak Factor**
1-3, 40, 50-51, 70-71, 90-91,150-151	I	A
4-7, 41	II	B
8-10, 14, 16-17, 19, 27, 42	III	B
11-13, 15, 18, 20, 26, 43, 52-55, 72-75, 92, 152	IV	B
21-24, 28-30	IV	C

KEY

Start Correction Factors

I = Non-Catalyst
II = Oxidation Catalyst
III = Three-Way Catalyst Carbureted/Throttle-Body Fuel Injection
IV = Three-Way Catalyst/Multipoint Fuel Injection

Soak Factors

A = Non-Catalyst
B = Catalyst-Equipped
C = Advanced Catalyst

Table 6.7-3b. Application of Correction Factors by Technology Group

Technology Groups	Correction Factors (CF)	
	Start CF	Soak CF
1	I	A
2	I	A
3	I	A
4	II	B
5	II	B
6	II	B
7	II	B
8	III	B
9	III	B
10	III	B
11	IV	B
12	IV	B
13	IV	B
14	III	B
15	IV	B
16	III	B
17	III	B
18	IV	B
19	III	B
20	IV	B
21	IV	C
22	IV	C
23	IV	C
24	IV	C
26	IV	B
27	III	B
28	IV	C
29	IV	C
30	IV	C
40	I	A
41	II	B
42	III	B
43	IV	B
50	I	A
51	I	A
52	IV	B
53	IV	B
54	IV	B
55	IV	B
70	I	A
71	I	A
72	IV	B
73	IV	B
74	IV	B
75	IV	B
90	I	A
91	1	A
92	IV	B
150	I	A
151	I	A
152	IV	B

SECTION 6.2 CYCLE CORRECTION FACTORS

This section discusses the development of cycle correction factors (CCF's) for use in EMFAC2000. The CCF's will be used to correct the basic emission rates to account for county specific speed distributions.

6.2.1 Introduction

In prior versions of EMFAC, the FTP was used as the base cycle for developing basic emission rates, and the basic emission rates were corrected using speed correction factors (SCF's) to account for driving at different speeds. In the early 1990's, chase car and instrumented vehicle data collection efforts revealed that the FTP does not sufficiently represent contemporary driving[1,2,3]. With EMFAC2000 and subsequent versions, the Unified Cycle (UC) will be used for developing basic emission rates. However, EMFAC2000 will still need to account for county specific speed distributions through a speed correction methodology since the UC is based on driving that occurred during the 1992 calendar year. As driving behavior changes, the base UC emission rates will be corrected in EMFAC2000 through a set of CCF's. The CCF's will be developed from a set of 12 cycles referred to as Unified Correction Cycles (UCC's).

The 12 new UCC's were designed to be representative of an average trip for a given speed. The mean speeds of the UCC's range from approximately 2.4 mph to 59.1 mph at approximately 5 mph increments. The cycles were synthesized using ARB chase car data and ARB and EPA instrumented vehicle data. Prior to developing the cycles, the chase car and instrumented vehicle data were analyzed for several variables including mean speed, speed-acceleration frequency distribution, positive kinetic energy (PKE), load, maximum acceleration, maximum deceleration, percent idle, percent acceleration, distance, etc., and binned by trip mean speed. Analysis of the data indicated that there is a substantial difference in the noted driving characteristics on a per trip basis as shown in Figure 6.2-1.

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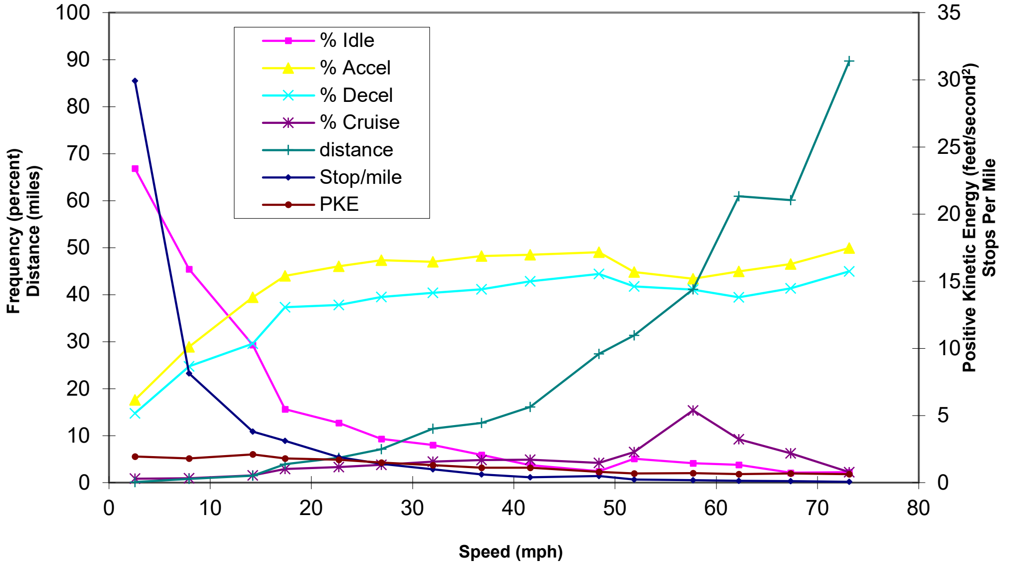
[1] T.C. Austin, F.J. DiGenova, T.R. Carlson, R.W. Joy, K.A. Gianolini, J.M. Lee, *Characterization of Driving Patterns and Emissions from Light-Duty Vehicles in California,* Final Report to the California Air Resources Board from Sierra Research, Inc., Contract No. A932-185, Sacramento, California, November 12, 1993.

[2] T.H. DeFries, S. Kishan, *Light-Duty Vehicle Driving Behavior: Private Vehicle Instrumentation*, Final Report to the U.S. Environmental Protection Agency from Radian Corporation, DCN 92-254-036-90-04, Austin, Texas, August 24,1992.

[3] S. Magbuhat and J.R. Long, *Using Instrumented Vehicles to Improve Activity Estimates for the California Emissions Inventory Model*, VIP-45, The Emission Inventory: Applications and Improvement, Air and Waste Management Association, 1995.

Figure 6.2-1. Driving Characteristics on a Per Trip Basis.



The UCC's were developed in two phases. The first set of UCC's were developed using the ARB chase car data, and ranged in speeds from 15 to 45 mph[4]. Since the ARB chase car data did not contain trips of less than 15 mph or greater than 50 mph, the ARB and EPA instrumented vehicle data was used to evaluate and develop cycles on the high and low ends of the speed range.

6.2.2 Data Analysis

The vehicles used in this analysis were selected from surveillance projects 2S95C1, 2S97C1 and research projects 2R9513 and 2R9811. Technology and model year groups consistent with the EMFAC2000 technology group designations were used in this analysis. The vehicles chosen from surveillance project 2S95C1 were randomly selected for exhaust emission testing from a group of vehicles that were representative of the California fleet. For the remaining test projects, vehicles were selected to represent specific technology and model year groups.

The CCF equations were developed using exhaust emission test data from the UC and the UCC's. The UCC's were developed in two phases. The first phase of cycles (UCC15 to UCC45) were developed using chase car data. The second phase of cycles (UCC5, UCC10, and UCC55-UCC65) were developed using instrumented vehicle data. Since the UCC's were developed in two phases, there is an imbalance in the exhaust emission test data. Ten vehicles have been tested on the full range of UCC's, while over 130 vehicles have been tested on the UCC15 to UCC45. The CCF equations were fitted to the mean of the UCC divided by the mean of the UC for each individual speed bin. The CCF

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[4] R. Gammariello and J.R. Long, Development of Unified Correction Cycles, Sixth CRC On-Road Vehicle Emissions Workshop, San Diego, California, March 18, 1996.

equations were developed using a methodology that curve fits the ratio of the mean data as opposed to the raw data.

Table 6.2-1 contains the coefficients for the CCF equations by emission category and technology group. The equations are second order for each emission category and technology group and are normalized to the Bag 2 UC mean speed (27.4 mph) emission rates. An example of the general equation for CCF's for any given emission category and technology grouping is shown in Equation 6.2-1.

$$CCF(S)_{s,p,t,my} = EXP(A(S-27.4) + B(S-27.4)^2) \qquad (6.2\text{-}1)$$

Where:

$CCF_{s,p,t,my}$ = Cycle Correction Factor for a given speed "s", pollutant "p", technology group "t", and model year "my".
S = Trip mean speed from 2.5 to 65 miles per hour.
A,B = coefficients.

The CCF equations are bounded by the 2.5 mph and 65 mph speed ranges.

Table 6.2-1

Cycle Correction Factor Coefficients by Emission Category and Technology Group				
Emission Category	Technology Group	CCF Technology Group Mapping	A Coefficient	B Coefficient
CO	CARB	1	-0.028971	0.001922
CO	FI	2	-0.016288	0.000054
CO	TB	3	-0.020787	0.000292
CO2	CARB	4	-0.025952	0.000309
CO2	FI	5	-0.026423	0.000744
CO2	TB	6	-0.023750	0.001056
HC	CARB	7	-0.031762	0.000908
HC	FI	8	-0.044726	0.001070
HC	TB	9	-0.036860	0.000664
NOX	CARB	10	0.008967	-0.000027
NOX	FI	11	-0.013763	0.000320
NOX	TB	12	-0.016610	0.000654

Table 6.2-1 also contains the CCF technology group mapping number for each CCF equation. Since there are fewer CCF technology group equations than are contained in the technology group designation for EMFAC2000, the CCF equations need to be mapped to the corresponding EMFAC2000 designation. The technology group designations for EMFAC2000 are shown in Table 6.2-2 along with the assigned CCF technology group mapping number. There are four CCF technology group mapping numbers applied to each technology group designation that correspond to the four mapped emission regimes (HC, CO, NO_X, and CO_2).

The CCF equations are shown graphically in Figure 6.2-2 through Figure 6.2-5 for HC, CO, NO_X and CO_2, respectively. The individual technology groups are shown on each graph for the respective emission type. Currently, there are no exhaust emission test data for the throttle body technology group at speeds greater than 50 mph. The equations for the throttle body technology group were modeled using the existing data up to 50 mph. If the throttle body technology group equations are extrapolated beyond 50 mph there is an increase in NO_X and CO_2 emission as shown in Figure 6.2-4 and Figure 6.2-5, respectively. This artificial increase in emissions for the throttle body technology group will be included in the model.

Table 6.2-2

Cycle Correction Factor
Equation Mapping to EMFAC2000
Technology Groups

Technology Group	CCF Equation Mapping	Model Years	Emission Control Technology
1	1,4,7,10	Pre-75	LDV no AIR
2	1,4,7,10	Pre-76	LDV with AIR
3	1,4,7,10	1975+	LDV noncatalyst
4	1,4,7,10	1975-76	LDV OxCat with AIR
5	1,4,7,10	1975-79	LDV OxCat no AIR
6	1,4,7,10	1980+	LDV OxCat no AIR
7	1,4,7,10	1977+	LDV OxCat with AIR
8	3,6,9,12	1977-79	LDV TWC TBI/CARB
9	3,6,9,12	1981-84	LDV TWC TBI/CARB 0.7 NOx
10	3,6,9,12	1985+	LDV TWC TBI/CARB 0.7 NOx
11	2,5,8,11	1977-80	LDV TWC MPFI
12	2,5,8,11	1981-85	LDV TWC MPFI 0.7 NOx
13	2,5,8,11	1986+	LDV TWC MPFI 0.7 NOx
14	3,6,9,12	1981+	LDV TWC TBI/CARB 0.4 NOx
15	2,5,8,11	1981+	LDV TWC MPFI 0.4 NOx
16	3,6,9,12	1980	LDV TWC TBI/CARB
17	3,6,9,12	1993+	LDV TWC TBI/CARB .25 HC
18	2,5,8,11	1993+	LDV TWC MPFI .25 HC
19	3,6,9,12	1996+	LDV TWC TBI/CRB .25 OBD2
20	2,5,8,11	1996+	LDV TWC MPFI .25HC OBD2
21	2,5,8,11	1994-95	LDV TLEV MPFI .25HC
22	2,5,8,11	1996+	LDV TLEV OBD2 GCL
23	2,5,8,11	1996+	LDV LEV OBD2 GCL CARBC AFC
24	2,5,8,11	1996+	LDV ULEV OBD2 GCL CARBC AFC
25		ALL	ZEV
26	2,5,8,11	1996+	LDT TWC MPFI OBD2 .7NOx
27	3,6,9,12	1996+	LDV TWC TBI/CARB OBD2
28	2,5,8,11	2004+	LDV LEV II
29	2,5,8,11	2004+	LDV ULEV II
30	2,5,8,11	2004+	LDV SULEV II
40	1,4,7,10	Mex	LDV NoCat / NoAir
41	1,4,7,10	Mex	LDV OxCat with Air
42	3,6,9,12	Mex	LDV TWC TBI / CARB 0.7 NOx
43	2,5,8,11	Mex	LDV TWC MPFI 0.7 NOx

Figure 6.2-2 Hydrocarbon Cycle Correction Factor Curves.

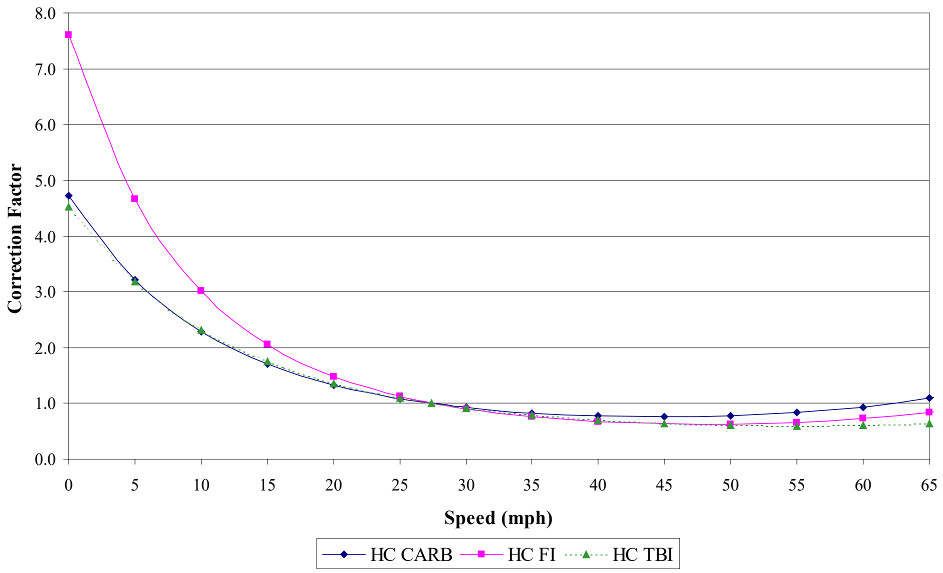


Figure 6.2-3 Carbon Monoxide Cycle Correction Factor Curves.

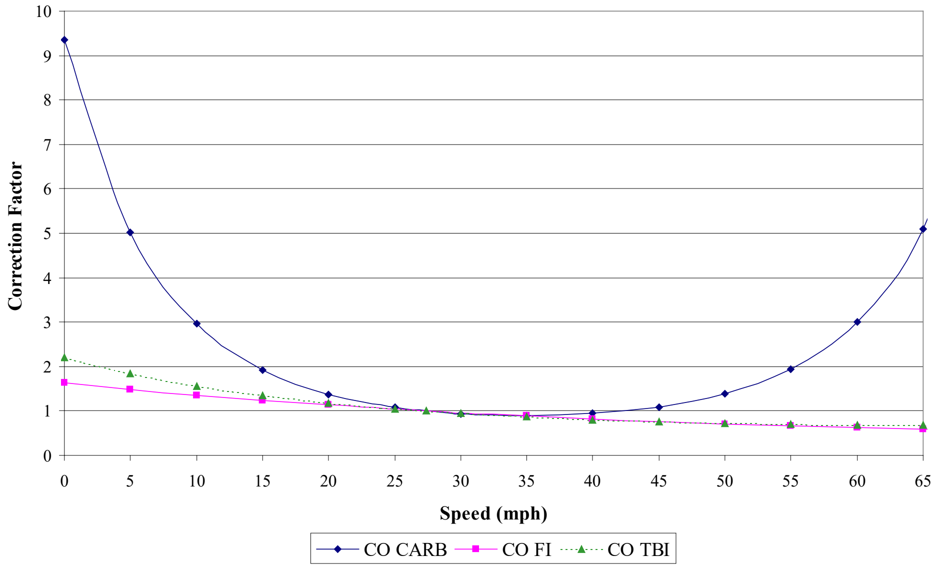


Figure 6.2-4. Oxides of Nitrogen Cycle Correction Factor Curves.

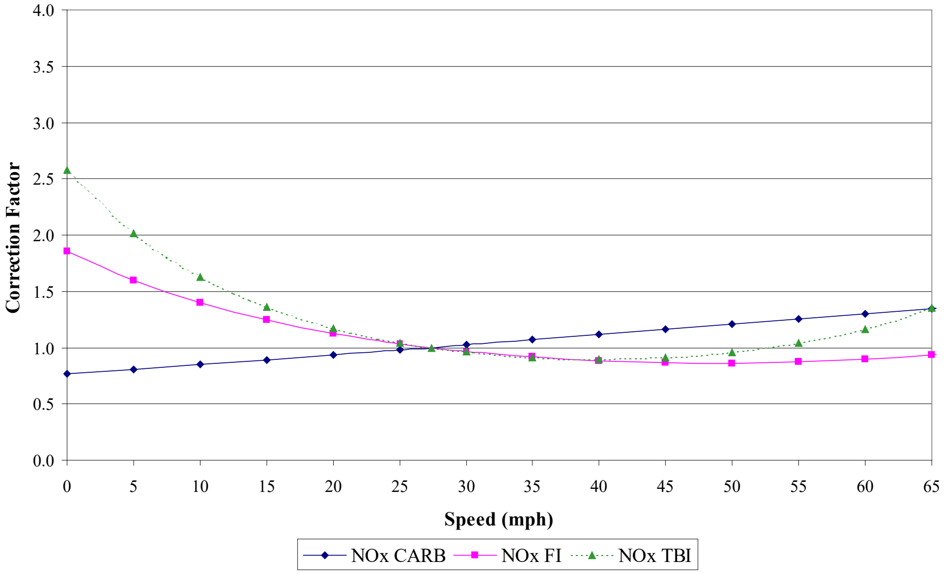
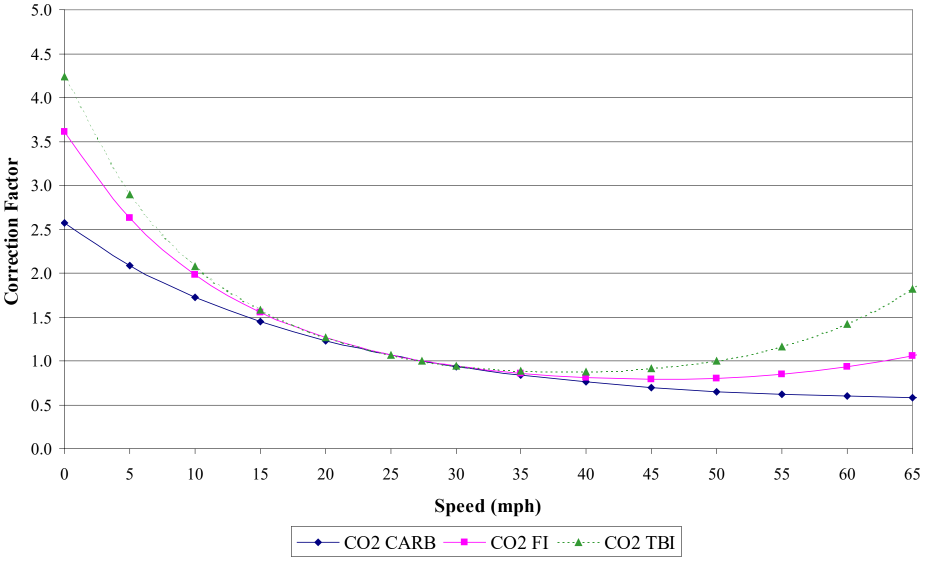


Figure 6.2-5. Carbon Dioxide Cycle Correction Factor Curves.



Section 6.7 START CORRECTION FACTORS

This section discusses the development of revised Start Correction Factors for all Light- and Medium-Duty vehicles in EMFAC2000.

6.7.1 Introduction

Start Correction Factors (StCF) in the current emissions inventory model (MVEI7G1.0c) are used to adjust the basic FTP based bag 1 emission rates to model start emissions for real-world driving conditions. While the FTP cycle had been historically used to represent in-use driving patterns, recent studies have instead established that the Unified Cycle (UC) represents a more contemporary account of typical driving events, including higher speeds and acceleration/deceleration rates than the FTP cycle. For this reason, the basic emission rates in the new model, EMFAC2000, will be based on the UC. The Start Correction Factors therefore need to be updated accordingly to coincide with this change.

Another purpose of the StCF is to adjust the basic emission rate to model start emissions that are independent of running emissions. This is accomplished by focusing strictly on the emissions produced by the start-up procedure, defined as the emissions produced in the first 100 seconds. Numerically, the Start Correction Factor is defined as follows:

$$\text{StCF} \quad = \quad \frac{\text{CE}_{100}\ \text{UC bag 1 (g)}}{\text{UC bag 1 (g/mi)}} \qquad (6.7\text{-}1)$$

where StCF = Start Correction Factor (mi per 100 sec),
CE_{100} UC bag 1 = cumulative emissions within the first 100 seconds of bag 1 of the Unified Cycle (g),
UC bag 1 = bag 1 emission rate of the Unified Cycle (g/mi).

6.7.2 Data Analysis

Modal (second-by-second) data were gathered from the Light- and Medium-Duty Vehicle Surveillance Programs conducted at the Haagen-Smit Laboratory facilities of the Air Resources Board. A total of 238 automobiles and trucks were tested over the Unified Cycle. After a comprehensive statistical data analysis, the Start Correction Factors were calculated and grouped by technology. Table 6.7-1 contains the resulting correction factors that are applied to the basic emission rate of bag 1 of the UC to yield start emissions for trips that are taken after an overnight soak. These factors are applicable to all light- and medium-duty vehicles and are applied using the following equation.

$$BER_C = BER\ (g/mi) * StCF\ (mi) \qquad (6.7\text{-}2)$$

where BER_C = corrected emission rate (g/100 sec for the overnight soak),
BER = basic emission rate of UC bag 1 (g/mi),
StCF = Start Correction Factor (mi per 100 sec).

Table 6.7-1. Start Correction Factors

	Non-Catalyst	Oxidation Catalyst	Three-Way Catalyst	
			Carb/TBI	MPFI
HC	0.4565	0.6010	0.6472	0.7897
CO	0.4283	0.5838	0.6087	0.8168
NOx	0.2235	0.2306	0.3448	0.4948
CO_2	0.3632	0.3584	0.3546	0.3365

* CARB - Carbureted
TBI – Throttle-Body Fuel Injection
MPFI – Multipoint Fuel Injection

6.7.3 Application of Correction Factors in Start Methodology

Once the overnight start emissions are calculated, soak factors are applied to estimate the emissions of those trips that begin after shorter soak periods. The soak factors are calculated using the following polynomial equation.

$$\text{Normalized Start Emissions of HC, CO, NOx, and } CO_2 = a_0 + a_1 * t + a_2 * t^2 \qquad (6.7\text{-}3)$$

where t = soak time (minutes),
a_i = coefficients of the curves,
Normalized start emissions = grams per soak time *i* divided by grams per overnight soak.

The corresponding coefficients and soak time intervals for each technology group are given in Table 6.7-2. By using the above continuous functions in conjunction with the start emissions produced following a cold soak, it is possible to estimate the amount of start emissions produced after any soak time.

Table 6.7-2. Coefficients by Technology Group for All Light- and Medium-Duty Vehicles

(a) Non-catalyst vehicles

	HC curve 1	HC curve 2	CO curve 1	CO curve 2	NOx curve 1	NOx curve 2	CO2 curve 1	CO2 curve 2
a0	0.3806708	0.4362844	0.4380312	-0.085415	1.31568216	2.48061071	0.36302129	0.99064304
a1	-0.001638	0.0007826	-0.00998	0.0030314	0.0275196	-0.0001841	0.00697116	1.2996E-05
a2	6.642E-05		7.019E-05	-2.12E-06	-0.0001531	-2.6E-06	-1.335E-05	
domain (min)	0-52	53-720	0-119	120-720	0-119	120-720	0-115	116-720

(b) Catalyst-equipped vehicles

	HC curve 1	HC curve 2	CO curve 1	CO curve 2	NOx curve 1	NOx curve 2	CO2 curve 1	CO2 curve 2
a0	0	0.5713026	0	0.7064116	0.11796024	1.12983289	0	0.25889542
a1	0.012723	0.0007196	0.0119476	0.0003344	0.02966956	2.2138E-05	0.00433672	0.0014848
a2	-6.3E-05	-1.76E-07	-4.76E-05	1.001E-07	-0.000215	-3.04E-07	-2.393E-06	-6.364E-07
domain (min)	0-89	90-720	0-116	117-720	0-61	62-720	0-96	97-720

(c) Advanced catalyst equipped vehicle

	HC curve 1	HC curve 2	CO curve 1	CO curve 2	NOx curve 1	NOx curve 2	CO2 curve 1	CO2 curve 2
a0	0	0.5064134	0	0.4473331	1.05016953	1.37178406	0.0537617	0.31251366
a1	0.0056083	0.0006855	0.0070714	0.0016176	0.00361983	0.00026788	0.00114395	0.00095484
a2	-5.09E-06		-1.33E-05	-1.18E-06	-5.575E-06	-1.089E-06	1.6526E-05	
domain (min)	0-117	118-720	0-107	108-720	0-113	114-720	0-119	120-720

While StCF are allocated into four technology groups, the Soak Factors that allocate the emissions associated with different soak periods are defined by three groups: Non-catalyst, Catalyst-equipped, and Advanced Catalyst vehicles (formerly referred to as Electrically-Heated Catalyst). In order to accommodate the different technology groups for the StCF and Soak Factors, it is suggested that the matrix shown in either Table 6.7-3a or 6.7-3b be used. These tables contain the same information; they are both given here for further clarification.

Table 6.7-3a. Application of Correction Factors by Technology Group

Technology Groups of Basic Emission Rates	**Corresponding Correction Factors**	
	Start Correction Factor	**Soak Factor**
1-3, 40, 50-51, 70-71, 90-91,150-151	I	A
4-7, 41	II	B
8-10, 14, 16-17, 19, 27, 42	III	B
11-13, 15, 18, 20, 26, 43, 52-55, 72-75, 92, 152	IV	B
21-24, 28-30	IV	C

KEY

Start Correction Factors

I = Non-Catalyst
II = Oxidation Catalyst
III = Three-Way Catalyst Carbureted/Throttle-Body Fuel Injection
IV = Three-Way Catalyst/Multipoint Fuel Injection

Soak Factors

A = Non-Catalyst
B = Catalyst-Equipped
C = Advanced Catalyst

Table 6.7-3b. Application of Correction Factors by Technology Group

Technology Groups	Correction Factors (CF) Start CF	Soak CF
1	I	A
2	I	A
3	I	A
4	II	B
5	II	B
6	II	B
7	II	B
8	III	B
9	III	B
10	III	B
11	IV	B
12	IV	B
13	IV	B
14	III	B
15	IV	B
16	III	B
17	III	B
18	IV	B
19	III	B
20	IV	B
21	IV	C
22	IV	C
23	IV	C
24	IV	C
26	IV	B
27	III	B
28	IV	C
29	IV	C
30	IV	C
40	I	A
41	II	B
42	III	B
43	IV	B
50	I	A
51	I	A
52	IV	B
53	IV	B
54	IV	B
55	IV	B
70	I	A
71	I	A
72	IV	B
73	IV	B
74	IV	B
75	IV	B
90	I	A
91	1	A
92	IV	B
150	I	A
151	I	A
152	IV	B

Section 6.0 CORRECTION FACTORS

Correction factors are used to correct emissions from non-standard conditions. In a general sense, emissions can be described as:

ER = BER*CF1*CF2*CF3….etc.

For a given technology group. In EMFAC2000, the following correction factors are addressed:

Temperature correction factors (TCF) adjust exhaust emissions for temperatures other than 75F. Section 6.1 largely adjusts the MVEI7G TCFs to be consistent EMFAC2000 technology groups. Speed correction factors (SCF) adjust the UC-based BERs for other trip speeds, and are detailed in section 6.2. Section 6.3 details the methodologies employed to adjust for gasoline fuel characteristics (FCF). Section 6.4 details a newly modeled correction factor, air conditioning correction factors (ACCF). Similarly, section 6.5 describes a new methodology to adjust NOx emissions for humidity. Finally, section 6.6 describes how emissions are adjusted for high altitude areas (namely, Lake Tahoe).

Section 6.1 TECHNOLOGY SPECIFIC TEMPERATURE CORRECTION FACTORS

This section details the temperature correction factors (TCFs) used in EMFAC2000. The TCFs are based on a memorandum entitled "Temp/RVP Exhaust Correction Factors" dated November 22, 1991, which details the exhaust TCF used in EMFAC7F.

6.1.1 Introduction

The basic exhaust emission rates are based on FTP or UC tests that were performed between 68-86°F (nominally 75°F), the standard temperature specifications for the FTP test. Various research projects were conducted, as detailed in the above memorandum, in which the FTP tests were performed at non-standard temperatures. This data was then used to develop TCFs, which adjust the basic emission rates for non-FTP temperature conditions.

6.1.2 Methodology

In EMFAC7F, the technology specific TCFs were weighted with the model year specific technology fractions to calculate a weighted model year specific TCF. The weighted model year TCFs were determined for passenger cars, light-, and medium- duty trucks. Equation 6.1-1 shows the general form of the TCFs, where the regression coefficients A, B and C have been weighted with respect to the technology fractions.

$$\mathrm{TCF}_{(9\ \mathrm{RVP})} = A * (T-75) + B*(T-75)^2 + C*(T-75)^3 + 1 \qquad \textbf{(6.1-1)}$$

In EMFAC2000, the TCFs are applied at a technology specific level. Since the TCF memorandum contains technology specific TCF coefficients (A, B and C) that have been weighted with respect to technology fraction to arrive at model year specific weighted TCF coefficients, staff determined the technology specific TCF by applying the inverse of the model year technology fractions. This process was necessary to determine the technology specific TCF coefficients.

Table 6.1-1 shows the model year specific technology fractions applied to passenger cars in EMFAC7F. The technology specific TCF coefficients were determined using linear matrix algebra, where matrix A contains technology fractions for three model years, matrix B represents the unknown technology specific coefficients and matrix C contains the resulting weighted TCF coefficients. Therefore, A*B=C and matrix B=A^{-1} *C, where A^{-1} is an inverse matrix.

Table 6.1-1 Technology Fractions Used In EMFAC7F

M Year	Carb-OL	Carb-CL	FI	CARB	MPFI	TBI
1980	1.000					
1981	0.350	0.436	0.214			
1982	0.318	0.436	0.246			
1983				0.644	0.216	0.140
1984				0.543	0.297	0.160
1985				0.399	0.359	0.242
1986				0.358	0.467	0.175
1987				0.314	0.501	0.185
1988				0.234	0.596	0.170
1989				0.119	0.663	0.218
1990				0.048	0.718	0.234
1991				0.048	0.718	0.234
1992				0.048	0.718	0.234
1993				0.000	0.900	0.100
1994+				0.000	0.900	0.100

Where:
CARB-OL represents carbureted open loop vehicles
CARB-CL represents carbureted closed loop vehicles
FI represents fuel-injected vehicles
MPFI represents multi-point fuel-injected vehicles
TBI represents throttle body injected vehicles

Table 6.1-2 shows the technology specific TCF coefficients used in EMFAC7F. These coefficients were weighted with respect to the technology fractions to determine model year weighted TCF coefficients. These weighted coefficients were then compared with those shown in the EMFAC7F TCF memorandum to ensure that correct technology coefficients were calculated. Table 6.1-2 contains a column labeled “TCF groups” which shows the numbers assigned to technology specific TCFs. This numbering scheme was used to map these TCF coefficients to the EMFAC2000 technology groups. Table 6.1-3 shows the EMFAC2000 technology groups. The column labeled “MAP_GRP” shows, which set of TCF coefficients (from Table 6.1-2) are applied to the EMFAC2000 technology groups. For example, the non-cat TCF are used in adjusting the basic emission rates for technology groups 1, 2, 3 and 40.

Table 6.1-2 Technology Specific Temperature Correction Factors

TCF Groups		BAG1_HC			BAG2_HC			BAG3_HC		
		A	B	C	A	B	C	A	B	C
1	NON_CAT	-0.029798	0.004427	0	-0.011131	0.0048358	0	-0.0090264	0.0074688	0
2	CARB-OL	-0.0454000000	0.0016360000	0.0000152100	0.0061870000	0.0008449000	0.0000095940	0.0053680000	0.0009159000	0.0000118100
3	CARB-CL	-0.0191200000	0.0008523000	0.0000057879	0.0028450000	0.0000443897	0.0000005637	-0.0026460000	-0.0000427500	-0.0000006094
4	FI	-0.0191200000	0.0008523000	0.0000057881	0.0028450000	0.0000443906	0.0000005627	-0.0026460000	-0.0000427500	-0.0000006056
5	CARB	-0.0454000000	0.0016360000	0.0000152101	0.0061870000	0.0008448999	0.0000095940	0.0053680000	0.0009159007	0.0000118102
6	MPFI	-0.0191200000	0.0008523000	0.0000057866	0.0028450000	0.0000443900	0.0000005632	-0.0026460000	-0.0000427500	-0.0000006079
7	TBI	-0.0191200000	0.0008523000	0.0000057900	0.0028450000	0.0000443902	0.0000005636	-0.0026460000	-0.0000427502	-0.0000006085
8	Diesel	0	0	0	0	0	0	0	0	0
		BAG1_CO			BAG2_CO			BAG3_CO		
		A	B	C	A	B	C	A	B	C
1	NON_CAT	0	0.0062182	0	-0.014584	0.014943	0	-0.011371	0.014923	0
2	CARB-OL	-0.0516300000	0.0012250000	0.0000166800	0.0045770000	0.0004151000	0.0000017830	0.0066080000	0.0010680000	0.0000120200
3	CARB-CL	-0.0328200000	0.0011260000	0.0000160800	0.0027370000	0.0001239000	0.0000007077	-0.0007422000	0.0003014000	0.0000036847
4	FI	-0.0328200000	0.0011260000	0.0000160800	0.0027370000	0.0001239000	0.0000007080	-0.0007422000	0.0003014000	0.0000036825
5	CARB	-0.0516300000	0.0012250000	0.0000166800	0.0045770000	0.0004151000	0.0000017829	0.0066079949	0.0010680000	0.0000120206
6	MPFI	-0.0328200000	0.0011260000	0.0000160800	0.0027370000	0.0001239000	0.0000007076	-0.0007422005	0.0003014000	0.0000036840
7	TBI	-0.0328200000	0.0011260000	0.0000160800	0.0027370000	0.0001239000	0.0000007082	-0.0007421958	0.0003014000	0.0000036836
8	Diesel	0	0	0	0	0	0	0	0	0
		BAG1_NOx			BAG2_NOx			BAG3_NOx		
		A	B	C	A	B	C	A	B	C
1	NON_CAT	-0.007684	0	0	-0.005859	0	0	-0.009088	0	0
2	CARB-OL	-0.0061420000	0.0002478000	0.0000044870	-0.0063320000	0.0003164000	0.0000046260	-0.0070410000	0.0002937000	0.0000045590
3	CARB-CL	-0.0059370000	0.0001700000	0.0000034930	-0.0042800000	0.0002846000	0.0000041804	-0.0066990000	0.0003721000	0.0000063487
4	FI	-0.0059370000	0.0001700000	0.0000034901	-0.0042800000	0.0002846000	0.0000041791	-0.0066990000	0.0003721000	0.0000063496
5	CARB	-0.0061420000	0.0002478000	0.0000044871	-0.0063320000	0.0003164000	0.0000046259	-0.0070410000	0.0002937000	0.0000045589
6	MPFI	-0.0059370000	0.0001700000	0.0000034921	-0.0042800000	0.0002846000	0.0000041805	-0.0066990000	0.0003721000	0.0000063490
7	TBI	-0.0059370000	0.0001700000	0.0000034918	-0.0042800000	0.0002846000	0.0000041797	-0.0066990000	0.0003721000	0.0000063492
8	Diesel	0	0	0	0	0	0	0	0	0

Table 6.1-3 EMFAC2000 Technology Groups

Technology	Description of Gas Fueled Technology Group		Map_Grp
Group	Model Years	Emission Control Technology	TCF
1	Pre-75	LDV no AIR	1
2	Pre-76	LDV with AIR	1
3	1975+	LDV noncatalyst	1
4	1975-76	LDV OxCat with AIR	2
5	1975-79	LDV OxCat no AIR	2
6	1980+	LDV OxCat no AIR	2
7	1977+	LDV OxCat with AIR	2
8	1977-79	LDV TWC TBI/CARB	3
9	1981-84	LDV TWC TBI/CARB 0.7 NOx	3
10	1985+	LDV TWC TBI/CARB 0.7 NOx	3
11	1977-80	LDV TWC MPFI	4
12	1981-85	LDV TWC MPFI 0.7 NOx	4
13	1986+	LDV TWC MPFI 0.7 NOx	4
14	1981+	LDV TWC TBI/CARB 0.4 NOx	3
15	1981+	LDV TWC MPFI 0.4 NOx	4
16	1980	LDV TWC TBI/CARB	3
17	1993+	LDV TWC TBI/CARB .25 HC	7
18	1993+	LDV TWC MPFI .25 HC	6
19	1996+	LDV TWC TBI/CRB .25 OBD2	7
20	1996+	LDV TWC MPFI .25HC OBD2	6
21	1994-95	LDV TLEV MPFI .25HC	6
22	1996+	LDV TLEV OBD2 GCL	6
23	1996+	LDV LEV OBD2 GCL CBC AFC	6
24	1996+	LDV ULEV OBD2 GCL CBC AFC	6
25	ALL	ZEV	
26	1996+	LDT TWC MPFI OBD2 .7NOx	6
27	1996+	LDV TWC TBI/CARB OBD2	7
28	2004+	LDV LEV II	6
29	2004+	LDV ULEV II	6
30	2004+	LDV SULEV II	6
40	Mex	LDV NoCat/NoAir	40
41	Mex	LDV OxCat with AIR	2
42	Mex	LDV TWC TBI/CARB 0.7 NOx	3
43	Mex	LDV TWC MPFI 0.7 NOx	4
170	1965-74	LDA dsl	8
171	1975-79	LDA dsl	8
172	1980	LDA dsl	8
173	1981-83	LDA dsl	8
174	1984-85	LDA dsl	8
175	1986	LDA dsl	8
176	1987-95	LDA dsl	8
177	1996+	LDA dsl	8
178	1965-78	LDT dsl	8
179	1979-80	LDT dsl	8
180	1981-83	LDT dsl	8
181	1984-85	LDT dsl	8
182	1986	LDT dsl	8
183	1987-93	LDT dsl	8
184	1994-96	LDT dsl	8
185	1997+	LDT dsl	8
186	1965-78	MDT dsl <8500LBS	8
187	1979-80	MDT dsl <8500LBS	8
188	1981-82	MDT dsl <8500LBS	8
189	1983-84	MDT dsl <8500LBS	8
190	1985-86	MDT dsl <8500LBS	8
191	1987-90	MDT dsl <8500LBS	8
192	1991-93	MDT dsl <8500LBS	8

6.1.3 Application of TCF Coefficients

The application of bag 1, 2 or 3 TCF is dependent on the exhaust emissions process under consideration. For example, running exhaust emissions are temperature corrected using bag 2 TCF coefficients. In both EMFAC7F and MVEI7G, the starting emissions were temperature corrected using bag 1 TCF coefficients. This methodology is valid for vehicle starts, which occur after an overnight (8 hour) soak. However, this is not true for starts following short soak durations. The incremental starting emissions methodology indicates that starting emissions are dependent on the amount of soak time. One of the findings of the incremental starts methodology is that starting emissions produced after soak times greater than 60 minutes are not the same as those produced after an overnight soak. This suggests that the catalyst is not completely cold even after 60 minutes. For vehicles that have been sitting for short time intervals, the starting emissions are temperature corrected using bag 3 TCF coefficients. Table 6.1-4 shows the logic used in EMFAC2000 for temperature correcting starting emissions. For non-catalyst vehicles, with soak times less than 60 minutes, the starting emissions are temperature corrected using bag 3 TCF coefficients. For catalyst equipped vehicles, with a soak of less than 90 minutes, the starting emissions are temperature corrected using bag 3 TCF coefficients. For low emission vehicles, with soak times less than 120 minutes, starting emissions are temperature corrected using bag 3 TCF coefficients. The breakpoints (Time-Off) correspond approximately to the inflexion point in the starts emission rate equations.

Table 6.1-4

Technology	Time-Off	Logic
Non-Catalyst	<60 min.	If time-off is less than 60 minutes then use bag 3 TCF, else use bag 1 TCF coefficients.
Catalyst	<90 min.	If time-off is less than 90 minutes then use bag 3 TCF, else use bag 1 TCF coefficients.
Low Emission Vehicles	<120 min.	If time-off is less than 120 minutes then use bag 3 TCF, else use bag 1 TCF coefficients.

6.1.4 Discussion

The temperature correction factors used in EMFAC2000 are the same as those used in both EMFAC7F and MVEI7G. The only substantive changes involve the development of technology specific TCF coefficients, and how these are applied to vehicles with short soak periods. This methodology will reduce the starting emissions slightly.