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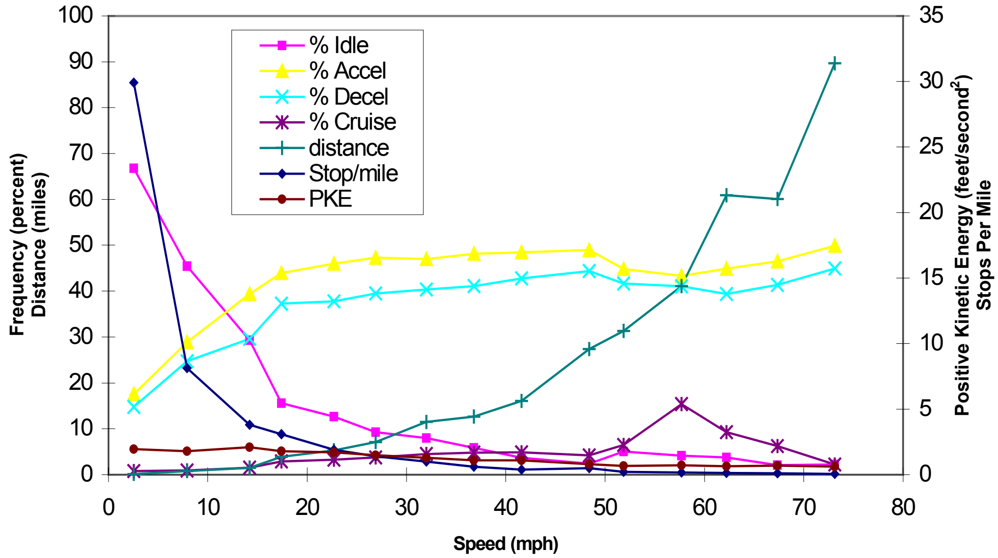
[1] T.C. Austin, F.J. DiGenova, T.R. Carlson, R.W. Joy, K.A. Gianolini, J.M. Lee, *Characterization of Driving Patterns and Emissions from Light-Duty Vehicles in California,* Final Report to the California Air Resources Board from Sierra Research, Inc., Contract No. A932-185, Sacramento, California,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

[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.

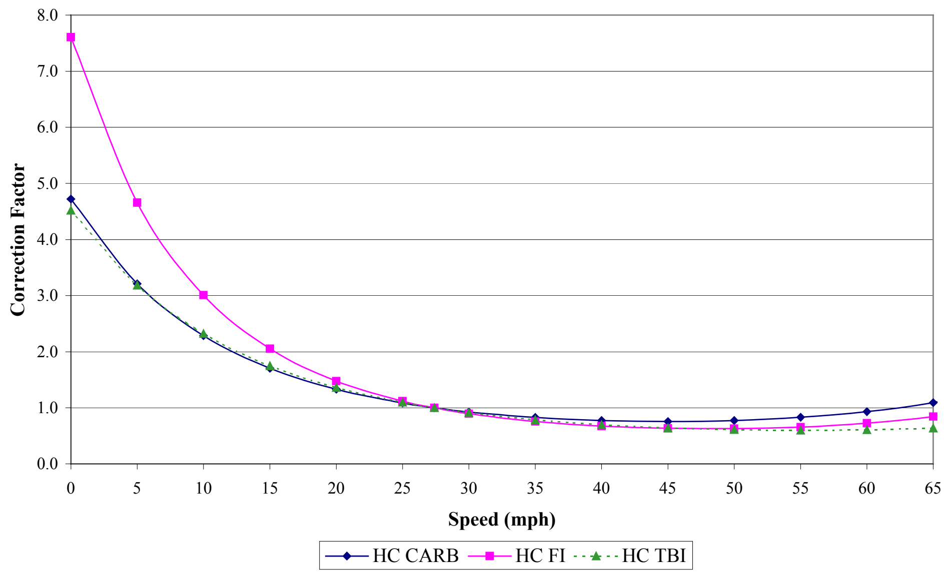


Figure 6.2-3 Carbon Monoxide Cycle Correction Factor Curves.

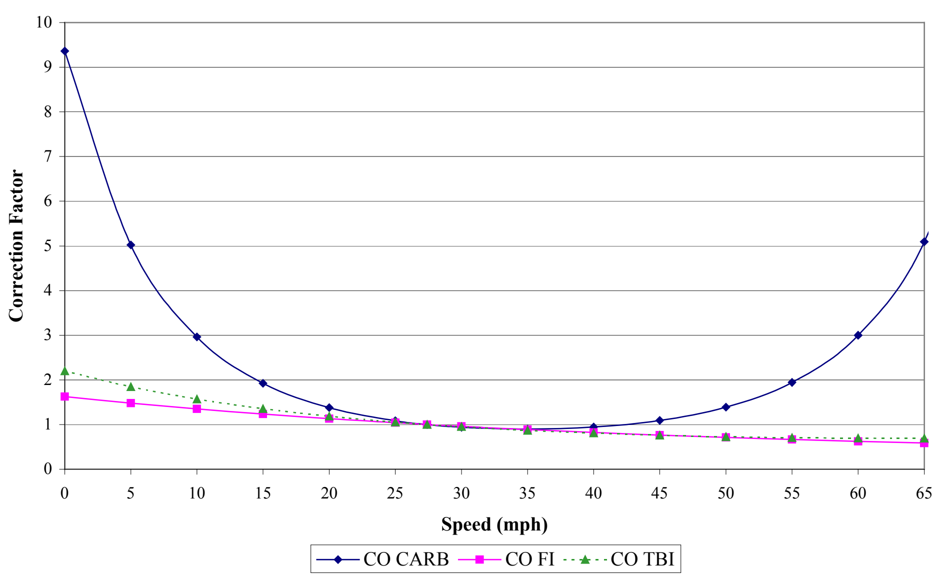


Figure 6.2-4. Oxides of Nitrogen Cycle Correction Factor Curves.

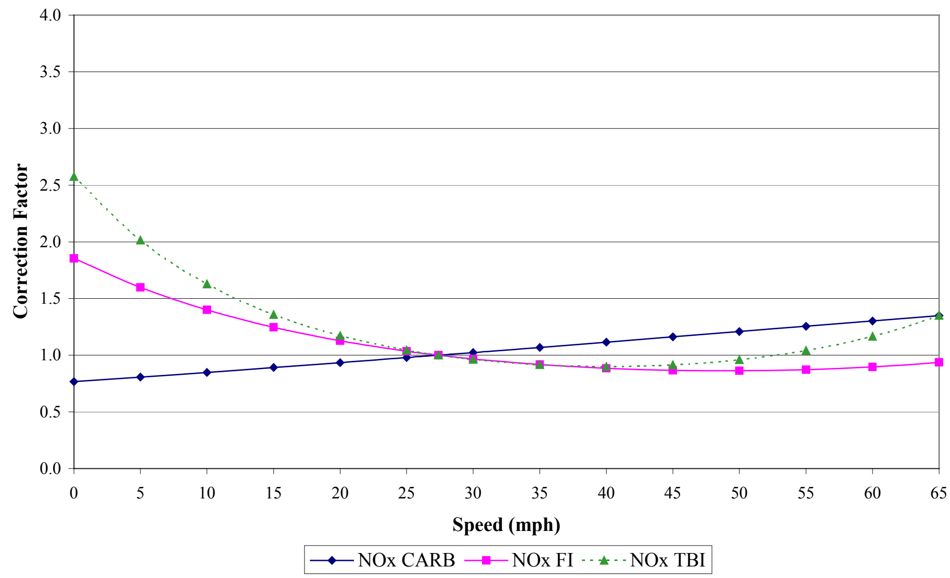


Figure 6.2-5. Carbon Dioxide Cycle Correction Factor Curves.