



Basic Exhaust Emission Rates of Open Loop Vehicles for MOBILE6:

Exhaust Emissions at High and
Low Altitudes for Engine
Starts and Running
Emissions for Motorcycles,
Light-Duty Diesel Vehicles and
Trucks and Pre-1981 Model
Year Light-Duty Gasoline
Vehicles and Trucks

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Vehicles and Trucks and Pre-1981 Model Year Light-Duty Gasoline
Vehicles and Trucks

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1.0 INTRODUCTION

“Open loop” is a term that refers to vehicles which do not use electronic feedback systems to control the delivery of fuel to the engine cylinders. Most current light-duty vehicles make use of feedback systems. However, motorcycles, older light-duty vehicles and most diesel vehicles are open-loop. This report discusses how the basic rates for both engine starts and exhaust running emissions for these open loop vehicles will be estimated for MOBILE6. The MOBILE6 basic exhaust emission rates for heavy duty trucks and 1981 and newer model year gasoline fueled passenger cars and light-duty trucks are discussed in separate reports.

2.0 DATA SOURCES

In order to calculate the exhaust running emissions and the effect of engine start on exhaust emissions it is necessary to know the emissions from vehicles measured with and without the effect of an engine start. This can be estimated using the individual bag results from Federal Test Procedure (FTP) testing. However, the data from each individual bag of the FTP were not always saved, since only the composite results are usually needed. Since individual bag data is not available, it is not possible to use all of the data used to develop the basic emission rates used in MOBILE5 to develop the factors needed to determine the exhaust running emissions and the effect of engine start on exhaust emissions separately.

2.1 Motorcycles

The most recent available FTP test data on motorcycles was used in this report. These data were obtained from a series of tests performed on 25 motorcycles from various manufacturers in 1996 and 1997 for the California Air Resources Board (CARB) by Northern California Diagnostic Laboratories and California Environmental Engineering. The tests included motorcycles from model years 1992 through 1995. The tested motorcycles had an average mileage of slightly less than 12,000 miles, with a mileage range from 981 to 47,594 miles.

None of the motorcycle testing information used to develop the basic emission rates used in MOBILE5 included the emission rates by FTP bag. As a result, only the results from the recent California testing were available to be used to determine the split between exhaust running versus engine start emissions.

2.2 Diesels

A total of forty Light Duty Diesel Vehicles (LDDV) were tested using the FTP at two sites in two different time periods. Twenty 1967-1975 Diesel LDVS were tested in Phoenix by Auto Testing Laboratories (ATL) in November and December of 1977 and twenty 1980 models were tested in Ann Arbor at the EPA's National Vehicle Fuel and Emissions Laboratory

(NVFEL) during July, August and September of 1983. The Phoenix vehicles had an average mileage of 86,300 miles with a range from 14,000 to 369,000 miles; the Ann Arbor vehicles had an average mileage of 70,000 with a range from 40,600 to 119,000 miles. These same data were used to develop the basic emission rates used in MOBILE5.

2.3 Pre-1981 Model Year Light Duty Gasoline Vehicles and Trucks

More than 12,000 vehicle tests from the EPA Emission Factor program for pre-1981 model year light-duty gasoline fueled passenger cars and light-duty gasoline fueled trucks which included individual bag-by-bag FTP results were used for this analysis. However, the sample size was small for some model year groupings, especially for high altitude areas. These same data were used to develop the basic emission rates used in MOBILE5. Sample sizes for these vehicles are shown in the tables.

3.0 METHODOLOGY

In addition to the FTP data described in Section 2.0, additional FTP test results, which do not have individual bag-by-bag breakouts of emissions, were used to develop the basic emission factor rates found in the MOBILE5 model. In order to include all of the available data, a methodology which begins with the basic emission factor emission rates in MOBILE5 was chosen as the basis for the composite emission rates estimated for MOBILE6 for motorcycles, light-duty diesel vehicles and pre-1981 model year gasoline passenger cars and light-duty trucks. The specific bag-by-bag data were used to estimate the allocation of the basic emission rate into the portion that represents the effect of engine start and the exhaust running emissions. These allocations were then applied to the existing MOBILE5 emission factor estimates.

This section of the report describes the methodology used to develop the factors used to transform the “zero mile level” (ZML) emissions and “deterioration rates” (DET) used in the basic exhaust emission factors in MOBILE5 to rates applicable to MOBILE6. All of the MOBILE5 emission rates for the vehicle classes and model years covered in this analysis are simple linear estimates versus mileage. The emission rates for both engine start and running emissions for the vehicle classes and model years covered in this analysis are also assumed to be linear. The model year groupings used in the analysis (and shown in the tables) are taken directly from the groupings used for the basic emission rates in MOBILE5. These are based on changes in technology (i.e., introduction of catalysts) and changes in the exhaust emission standards. The model year grouping will sometimes vary depending on the pollutant.

An FTP estimate can be made by summing the exhaust running emission rate (in grams per mile) with a weighted engine start emission estimate (converted to grams per mile). A composite FTP value contains a portion (43%) of the emissions from an engine start after a 12-hour soak and a portion (57%) of the emissions from an engine start after a 10 minute soak. The basic exhaust emission rate from an engine start in MOBILE6 represents only emissions from a

12-hour soak. The emissions from a 10 minute soak must be calculated from the 12 hour soak and the two results appropriately weighted. Then, the results (in grams) must be divided by 7.49 miles (the length of the LA4 trip) to be converted to grams per mile.

3.1 Engine Start Emissions Fraction

Recent testing by EPA has included the measurement of emissions on fully warmed vehicles over the first 505 seconds of the FTP driving cycle without the inclusion of an engine start (a "Hot Running 505"). These results can be directly compared to Bag 1 and Bag 3 of the FTP (which contain the effects of an engine start) to determine the emission impact of engine start on the emissions of a trip. These data have been used to develop a relationship between the emission impact of engine starts and the measured FTP emissions. This relationship is described in the report, "The Determination of Hot Running Emissions From FTP Bag Emissions," (M6.STE.002). Older model years of light-duty vehicles, diesel vehicles or motorcycles were not included in recent testing. However, the same technique can be used to help estimate the effect of engine starts for these other vehicle classes as well.

The Federal Test Procedure is basically a single LA4 cycle trip containing a mix of engine start emissions. The engine start portion of the FTP (the first 505 seconds of the LA4 or the "505") makes up about 48% of the miles traveled during the LA4 (3.59 miles in the 505, divided by the total 7.49 miles in the LA4). Both Bag 1 and Bag 3 of the FTP use the same driving cycle (505) and contain an engine start. The FTP assumes that 43% of the trips start with an engine off soak time of at least 12 hours (a "cold" start), which is represented by Bag 1, and the remaining starts are represented by Bag 3 (a "hot" start after a 10 minute soak). So, any emissions from Bag 1 (in grams per mile) must be weighted by the fraction of travel represented by the 505 (48%) and the fraction of trips that begin after a 12 hour soak period (43%), or 20.6% (48% times 43%). Those familiar with the MOBILE model may recognize this fraction as the default VMT normally assigned to the "cold" start operating mode.

The calculation of Start Emissions is based on the assumption that, on average, the effect on emissions that is attributable to an engine start can be represented by a simple fraction of total FTP emissions, which includes the effects of engine starts. The basic engine start emission rate in MOBILE6 is meant to represent the effect on exhaust emissions from the first engine start in the FTP, after a 12 hour soak period. The effect of engine start on emissions is defined to be that fraction of the total emissions collected during the FTP represented by the portion of the Bag 1 emissions that remains when emissions measured over the same driving cycle, on a fully warm engine without an engine start, are subtracted from it.

The formula used to obtain the engine start emission fraction is therefore:

$$(1) \quad \text{Engine Start Emissions Fraction} = ((\text{Bag1} - \text{HR505}) * 0.479) / \text{FTP}$$

Bag 1 is the emissions measured in the first 505 seconds of the FTP, HR505 is the emissions measured for the Hot Running 505 (a driving cycle containing no engine starts), 0.479 is the proportion of the FTP VMT attributable to Bag 1 (0.206) and Bag 3 (0.273), and FTP is the composite Federal Test Procedure emissions. All emissions are in grams per mile.

Using coefficients described in the report, “The Determination of Hot Running Emissions From FTP Bag Emissions,” (M6.STE.002), the HR505 results were estimated using the average FTP bag information from the available vehicle samples. Using this HR505 estimate and the average FTP bag information, the Engine Start Emission Fraction for motorcycles, light-duty diesel vehicles and pre-1981 model year gasoline passenger cars and light-duty trucks could be calculated. The fraction represents the fraction of total grams measured in a full FTP which are the grams added to the first bag of the FTP from an engine cold start.

Table 1 shows the results of the calculation of the Engine Start Emissions Fraction for light-duty diesel vehicles, motorcycles and the older (pre-1981 model year) gasoline passenger cars and light-duty trucks.

The Engine Start Emissions Fraction and the Exhaust Running Emissions Fraction (discussed below) will not sum to one. The reason is that a simple addition of cold start emissions and LA4 running emissions will not equal the composite FTP results. The FTP includes two engine starts, one after a 12 hour period without the engine running (12-hour soak) and one after a 10 minute soak. The MOBILE6 model will have explicit emission rates for the 12 hour soak engine start emission effects and the exhaust running emission rate. The effect of engine starts with soak times of less than 12 hours are calculated from the 12-hour soak estimate using correction factors within MOBILE6. These correction factors are discussed in the report, “The Determination of Start Emissions as a Function of Mileage and Soak Time for 1981-1993 Model Year Light-Duty Vehicles,” (M6.STE.003). In this way, a variety of soak times can be modeled using MOBILE6.

3.2 Exhaust Running Emissions Fraction

The calculation of Exhaust Running Emissions for motorcycles, light-duty diesel vehicles and pre-1981 model year gasoline passenger cars and light-duty trucks is based on the assumption that, on average, the basic exhaust running emissions rate can be represented by the total FTP emissions less the fraction of emission attributable to the effects of engine starts (both cold and hot starts). The previous section describes how the fraction of emissions attributable to the effects of engine start are estimated.

The effect of engine start on emissions is found in both Bag 1 and Bag 3 of the FTP (Federal Test Procedure). Both the FTP Bag 1 and Bag 3 driving cycle is the first 505 seconds of the LA4 driving cycle. Emissions measured over the same driving cycle (the 505), on a fully warm engine without an engine start, is referred to as a Hot Running 505 (HR505). If a HR505

is substituted for both Bag 1 and Bag 3 in the calculation of FTP emissions, the resulting exhaust emission rate represents a LA4 trip without the effect of engine starts. This Hot Running LA4 will be used as the basic exhaust running emission rate in MOBILE6.

The driving cycle used for Bag 2 of the FTP makes up about 52.1% of the miles traveled during the LA4 (3.91 miles in the Bag 2 cycle, divided by the total 7.49 miles in the LA4). Both Bag 1 and Bag 3 can be replaced by the HR505 (without engine starts), and weighted by the remaining VMT in the FTP, or 47.9%, to give the Hot Running LA4 basic exhaust running emission rate.

The formula used to obtain the exhaust running emission fraction is therefore:

$$(2) \quad \text{Exhaust Running Emission Fraction} = (\text{HR505} * 0.479) + (\text{Bag2} * 0.521) / \text{FTP}$$

HR505 is the emissions measured for the Hot Running 505, 0.479 is the proportion of the FTP VMT attributable to the Bag 1 and Bag 3, Bag 2 is the emissions measured during the second bag of the FTP, 0.521 is the proportion of the FTP VMT attributable to the Bag 2 and FTP is the Federal Test Procedure emissions. All emissions are in grams per mile.

As was done for engine starts, using the coefficients developed from actual measured HR505 values, the HR505 results can be estimated using FTP bag information. This relationship is described in the report, "The Determination of Hot Running Emissions From FTP Bag Emissions," (M6.STE.002). Using this HR505 estimate and the available FTP bag information, the Exhaust Running Emission Fraction was calculated for motorcycles, light-duty diesel vehicles and pre-1981 model year gasoline passenger cars and light-duty trucks.

Table 2 shows the results of the calculation of the Exhaust Running Emission Fraction for motorcycles, light-duty diesel vehicles and pre-1981 model year gasoline passenger cars and light-duty trucks.

3.3 Calculating Zero Mile Level and Deterioration Rates for MOBILE6

The linear coefficients, zero mile level (ZML) and deterioration (DET) basic emission rates, in MOBILE6 for light-duty diesel vehicles, motorcycles and the older (pre-1981 model year) gasoline passenger cars and light-duty trucks are determined using the fractions developed in the previous sections. The linear basic emission rates (emission factors) in MOBILE5 (ZML's and DET's) predict the FTP emissions of these vehicles versus mileage. Using the fractions developed in the previous sections, the proportion of FTP emissions that are the effect of engine start and exhaust running emissions were calculated from the MOBILE5 basic emission rates. The equations calculate exhaust emission engine start and running emissions from the MOBILE5 emission factor coefficients would be:

- (3) $\text{MOBILE6 ZML}_S (\text{grams}) = \text{MOBILE5 ZML} (\text{g/mi}) * X * 7.49 \text{ miles}$
 (4) $\text{MOBILE6 DET}_S (\text{grams}/10\text{k-mi}) = \text{MOBILE5 DET} (\text{g/mi}/10\text{k-mi}) * X * 7.49 \text{ miles}$

and

- (5) $\text{MOBILE6 ZML}_R (\text{g/mi}) = \text{MOBILE5 ZML} (\text{g/mi}) * Y$
 (6) $\text{MOBILE6 DET}_R (\text{g/mi}/10\text{k-mi}) = \text{MOBILE5 DET} (\text{g/mi}/10\text{k-mi}) * Y$

where:

X = Engine Start Emissions Fraction

Y = Exhaust Running Emission Fraction

MOBILE5 ZML = MOBILE5 emission factor zero mile intercept coefficient (g/mi)

MOBILE5 DET = MOBILE5 emission factor deterioration coefficient (g/mi/10k mi)

MOBILE6 ZML_S = MOBILE6 engine start emission zero mile intercept coefficient (grams)

MOBILE6 DET_S = MOBILE6 engine start emission deterioration coefficient (grams/10k mi)

MOBILE6 ZML_R = MOBILE6 exhaust running emission zero mile intercept coefficient (g/mi)

MOBILE6 DET_R = MOBILE6 exhaust running emission deterioration coefficient (g/mi/10k mi)

The 7.49 miles is the miles in the LA4 driving schedule of the FTP. This multiplication is necessary to convert the grams per mile of the FTP to grams. The effect of engine start on emissions in MOBILE6 is expressed in grams.

For some model years there were no data that could be used to determine the appropriate exhaust running and engine start emission fractions. In these cases, the fractions used for these model years were taken from similar groupings. For example, we only have bag data for 1992 and newer model year motorcycles. The fractions calculated from these motorcycles will be applied to all model year motorcycle emission factors from MOBILE5. Similarly, light-duty diesel passenger car results were used for light-duty diesel trucks and low altitude diesel and motorcycle fractions were used for high altitude estimates.

Table 3 through Table 14 show the results of application of the appropriate exhaust running and engine start emission fractions to the MOBILE5 emission factors. The resultant emission rate coefficients for exhaust running and engine start emissions are used for light-duty diesel vehicles, motorcycles and the older (pre-1981 model year) gasoline passenger cars and light-duty trucks in MOBILE6.

Table 1
Engine Start Emissions Fractions

Pollutant	Model Years	Sample Size	Sample Average Bag 1 Emissions (g/mi)	Calculated Average HR505 Emissions (g/mi)	Sample Average Composite FTP Emissions (g/mi)	Engine Start Emissions Fraction Result
Low Altitude Light Duty Gasoline Vehicles						
THC	Pre-1968	724	10.371	6.870	10.356	0.162
THC	1968-69	712	7.838	4.745	7.276	0.204
THC	1970-71	896	6.538	3.750	5.896	0.227
THC	1972-74	1950	5.260	2.659	4.176	0.299
THC	1975-79	5050	3.189	0.829	1.682	0.672
THC	1980	599	1.615	0.317	0.680	0.914
CO	Pre-1968	724	113.950	20.630	114.408	0.391
CO	1968-69	712	100.338	15.994	87.482	0.462
CO	1970-71	896	81.491	12.822	67.294	0.489
CO	1972-74	1950	65.604	10.549	51.900	0.508
CO	1975-79	5050	43.874	5.109	26.304	0.706
CO	1980	599	20.733	1.620	8.557	1.071
NOx	Pre-1968	724	4.894	4.309	4.289	0.065
NOx	1968-72	2289	7.503	5.837	5.394	0.148
NOx	1973-74	1269	6.542	2.940	3.566	0.484
NOx	1975-76	2916	5.095	2.658	3.077	0.380
NOx	1977-79	2134	5.263	2.568	3.041	0.425
NOx	1980	599	2.219	1.645	1.741	0.158

Table 1 (continued)
Engine Start Emissions Fractions

Pollutant	Model Years	Sample Size	Sample Average Bag 1 Emissions (g/mi)	Calculated Average HR505 Emissions (g/mi)	Sample Average Composite FTP Emissions (g/mi)	Engine Start Emissions Fraction Result
High Altitude Light Duty Gasoline Vehicles						
THC	Pre-1968	114	12.808	6.807	10.114	0.284
THC	1968-69	74	10.145	4.641	7.104	0.371
THC	1970-71	128	8.942	4.001	6.188	0.382
THC	1972-74	365	6.690	3.730	5.712	0.248
THC	1975-76	367	4.077	1.712	2.782	0.407
THC	1977	125	3.355	0.840	1.585	0.761
THC	1978-79	302	4.313	1.556	2.607	0.507
THC	1980	69	2.419	0.463	0.955	0.981
CO	Pre-1968	114	153.912	23.278	129.744	0.483
CO	1968-69	74	130.575	17.980	97.410	0.554
CO	1970-71	128	128.921	17.571	94.451	0.565
CO	1972-74	365	103.537	17.776	91.826	0.448
CO	1975-76	367	72.609	10.875	52.409	0.566
CO	1977	125	44.966	4.825	24.669	0.780
CO	1978-79	302	70.976	9.103	45.464	0.652
CO	1980	69	48.981	5.314	25.672	0.815

Table 1 (continued)
Engine Start Emissions Fractions

Pollutant	Model Years	Sample Size	Sample Average Bag 1 Emissions (g/mi)	Calculated Average HR505 Emissions (g/mi)	Sample Average Composite FTP Emissions (g/mi)	Engine Start Emissions Fraction Result
High Altitude Light Duty Gasoline Vehicles						
NOx	Pre-1968	114	2.304	2.014	2.046	0.068
NOx	1968-72	339	4.718	3.472	3.634	0.164
NOx	1973-74	228	4.919	2.001	2.539	0.551
NOx	1975-76	367	4.102	1.706	2.158	0.532
NOx	1977	125	5.323	1.472	2.225	0.829
NOx	1978-79	302	1.945	1.094	1.252	0.327
NOx	1980	89	1.101	0.744	0.820	0.209
Low Altitude Light Duty Gasoline Trucks (<6,000 lbs. GVW)						
THC	1975-78	239	3.135	1.201	2.024	0.458
THC	1979-80	91	2.167	0.675	1.219	0.588
CO	1975-78	239	40.727	5.596	26.576	0.634
CO	1979-80	91	29.217	3.454	15.591	1.004
NOx	1975-78	239	3.690	2.602	2.743	0.190
NOx	1979-80	91	2.554	1.839	1.950	0.176

Table 1 (continued)
Engine Start Emissions Fractions

Pollutant	Model Years	Sample Size	Sample Average Bag 1 Emissions (g/mi)	Calculated Average HR505 Emissions (g/mi)	Sample Average Composite FTP Emissions (g/mi)	Engine Start Emissions Fraction Result
Low Altitude Light Duty Gasoline Trucks (6,001-8,500 lbs. GVW)						
THC	1975-78	139	8.681	4.195	6.355	0.338
THC	1979-80	68	2.823	0.990	1.698	0.517
CO	1975-78	139	103.935	10.920	61.498	0.725
CO	1979-80	68	37.444	4.070	21.143	0.757
NOx	1975-78	139	5.481	4.686	4.642	0.082
NOx	1979-80	68	2.806	1.860	1.951	0.232
High Altitude Light Duty Gasoline Trucks (<6,000 lbs. GVW)						
THC	1975-78	28	3.665	1.368	2.271	0.485
THC	1979-80	7	5.113	2.035	3.300	0.447
CO	1975-78	28	62.060	8.588	41.724	0.614
CO	1979-80	7	98.271	13.592	68.612	0.592
NOx	1975-78	28	2.429	1.658	1.769	0.209
NOx	1979-80	7	1.467	.922	1.015	0.258
High Altitude Light Duty Gasoline Trucks (6,001-8,500 lbs. GVW)						
THC	1975-78	1	10.930	5.160	7.760	0.356
THC	1979-80	17	3.913	0.777	1.590	0.945
CO	1975-78	1	124.400	18.390	96.990	0.524
CO	1979-80	17	74.217	6.755	35.611	0.908
NOx	1975-78	1	2.910	2.54	2.520	0.070
NOx	1979-80	17	1.838	1.054	1.204	0.312

Table 1 (continued)
Engine Start Emissions Fractions

Pollutant	Model Years	Sample Size	Sample Average Bag 1 Emissions (g/mi)	Calculated Average HR505 Emissions (g/mi)	Sample Average Composite FTP Emissions (g/mi)	Engine Start Emissions Fraction Result
Low Altitude Light Duty Diesel Vehicles						
THC	Pre-1981	40	0.712	0.397	0.688	0.220
CO	Pre-1981	40	2.155	0.843	1.798	0.349
NOx	Pre-1981	40	1.577	1.537	1.626	0.012
Low Altitude Motorcycles						
THC	All	25	1.512	0.765	1.263	0.283
CO	All	25	15.563	5.055	16.597	0.306
NOx	All	25	1.067	0.592	0.680	0.335

Table 2
Exhaust Running Emission Fractions

Pollutant	Model Years	Sample Size	Calculated Average HR505 Emissions (g/mi)	Sample Average Bag 2 Emissions (g/mi)	Sample Average Composite FTP Emissions (g/mi)	Exhaust Running Emissions Fraction Result
Low Altitude Light Duty Gasoline Vehicles						
THC	Pre-1968	724	6.870	11.130	10.360	0.877
THC	1968-69	712	4.747	7.555	7.276	0.854
THC	1970-71	896	3.750	6.006	5.898	0.835
THC	1972-74	1950	2.659	4.010	4.176	0.805
THC	1975-79	5050	0.829	1.194	1.682	0.606
THC	1980	599	0.317	0.409	0.680	0.537
CO	Pre-1968	724	20.630	126.404	114.408	0.662
CO	1968-69	712	15.994	95.359	87.483	0.655
CO	1970-71	896	12.822	72.299	67.294	0.651
CO	1972-74	1950	10.549	54.242	51.900	0.642
CO	1975-79	5050	5.109	24.339	26.304	0.575
CO	1980	599	1.620	5.410	8.557	0.420
NOx	Pre-1968	724	4.309	3.522	4.289	0.909
NOx	1968-72	712	5.837	4.643	5.934	0.879
NOx	1973-74	896	2.940	2.272	3.566	0.727
NOx	1975-76	1950	2.658	2.171	3.077	0.781
NOx	1977-79	5050	2.568	2.120	3.041	0.767
NOx	1980	599	1.645	1.426	1.741	0.879

Table 2 (continued)
Exhaust Running Emission Fractions

Pollutant	Model Years	Sample Size	Calculated Average HR505 Emissions (g/mi)	Sample Average Bag 2 Emissions (g/mi)	Sample Average Composite FTP Emissions (g/mi)	Exhaust Running Emissions Fraction Result
High Altitude Light Duty Gasoline Vehicles						
THC	Pre-1968	114	6.807	9.850	10.114	0.830
THC	1968-69	74	4.641	6.438	7.104	0.785
THC	1970-71	128	4.000	5.537	6.188	0.777
THC	1972-74	365	3.730	5.443	5.712	0.809
THC	1975-76	367	1.712	2.407	2.782	0.746
THC	1977	125	0.840	1.034	1.585	0.594
THC	1978-79	302	1.556	2.155	2.607	0.717
THC	1980	89	0.463	0.553	0.995	0.512
CO	Pre-1968	114	23.278	126.915	129.744	0.596
CO	1968-69	74	17.980	90.971	97.410	0.575
CO	1970-71	128	17.571	86.857	94.451	0.567
CO	1972-74	365	17.776	91.143	91.826	0.610
CO	1975-76	367	10.675	47.023	52.409	0.565
CO	1977	125	4.825	18.928	24.669	0.493
CO	1978-79	302	9.103	37.981	45.464	0.531
CO	1980	89	5.314	17.821	25.672	0.461

Table 2 (continued)
Exhaust Running Emission Fractions

Pollutant	Model Years	Sample Size	Calculated Average HR505 Emissions (g/mi)	Sample Average Bag 2 Emissions (g/mi)	Sample Average Composite FTP Emissions (g/mi)	Exhaust Running Emissions Fraction Result
High Altitude Light Duty Gasoline Vehicles						
NOx	Pre-1968	114	2.014	1.688	2.046	0.901
NOx	1968-72	74	3.472	2.905	3.634	0.874
NOx	1973-74	128	2.001	1.619	2.539	0.710
NOx	1975-76	367	1.706	1.417	2.158	0.721
NOx	1977	125	1.472	1.226	2.225	0.604
NOx	1978-79	302	1.094	0.912	1.252	0.798
NOx	1980	89	0.744	0.658	0.820	0.852
Low Altitude Light Duty Gasoline Trucks (<6,000 lbs. GVW)						
THC	1975-78	239	1.201	1.765	2.024	0.739
THC	1979-80	91	0.675	0.946	1.219	0.670
CO	1975-78	239	5.596	25.345	26.576	0.598
CO	1979-80	91	3.454	12.223	15.591	0.515
NOx	1975-78	239	2.602	2.010	2.743	0.836
NOx	1979-80	91	1.839	1.518	1.950	0.857

Table 2 (continued)
Exhaust Running Emission Fractions

Pollutant	Model Years	Sample Size	Calculated Average HR505 Emissions (g/mi)	Sample Average Bag 2 Emissions (g/mi)	Sample Average Composite FTP Emissions (g/mi)	Exhaust Running Emissions Fraction Result
High Altitude Light Duty Gasoline Trucks (<6,000 lbs. GVW)						
THC	1975-78	28	1.368	1.804	2.271	0.703
THC	1979-80	7	2.035	2.749	3.300	0.729
CO	1975-78	28	8.588	36.222	41.724	0.551
CO	1979-80	7	13.592	56.314	68.612	0.523
NO _x	1975-78	28	1.658	1.283	1.769	0.827
NO _x	1979-80	7	0.922	0.756	1.015	0.823
Low Altitude Light Duty Gasoline Trucks (6,001-8,500 lbs. GVW)						
THC	1974-78	139	4.195	6.016	6.355	0.809
THC	1979-80	68	0.990	1.422	1.698	0.716
CO	1974-78	139	10.930	57.407	61.498	0.571
CO	1979-80	68	4.070	17.769	21.143	0.530
NO _x	1974-78	139	4.686	3.462	4.642	0.872
NO _x	1979-80	68	1.860	1.376	1.991	0.807
High Altitude Light Duty Gasoline Trucks (6,001-8,500 lbs. GVW)						
THC	1974-78	1	5.160	7.100	7.760	0.795
THC	1979-80	17	0.777	0.723	1.590	0.471
CO	1974-78	1	18.390	96.000	96.990	0.607
CO	1979-80	17	6.755	19.217	35.611	0.372
NO _x	1974-78	1	2.540	1.850	2.520	0.865
NO _x	1979-80	17	1.056	0.925	1.204	0.821

Table 2 (continued)
Exhaust Running Emission Fractions

Pollutant	Model Years	Sample Size	Calculated Average HR505 Emissions (g/mi)	Sample Average Bag 2 Emissions (g/mi)	Sample Average Composite FTP Emissions (g/mi)	Exhaust Running Emissions Fraction Result
Low Altitude Light Duty Diesel Vehicles						
THC	All	40	0.397	0.733	0.688	0.831
CO	All	40	0.843	1.671	1.798	0.709
NO _x	All	40	1.537	1.712	1.626	1.001
Low Altitude Motorcycles						
THC	All	25	0.765	1.216	1.263	0.792
CO	All	25	5.055	15.629	16.597	0.637
NO _x	All	25	0.592	0.449	0.680	0.761

Table 3
Calculated MOBILE6 Basic Exhaust Emission Rates
for Total Hydrocarbons (THC)
Low Altitude
Light Duty Gasoline Vehicles and Trucks

Model Years	MOBILE5 ZML (g/mi)	MOBILE5 DET (g/mi/10k mi)	Engine Start MOBILE6 ZML (grams)	Engine Start MOBILE6 DET (g/10k mi)	Exhaust Running MOBILE6 ZML (g/mi)	Exhaust Running MOBILE6 DET (g/mi/10k mi)
Light Duty Gasoline Vehicles						
Pre-1968	7.250	0.180	8.799	0.218	6.361	0.158
1968-69	4.430	0.250	6.762	0.382	3.781	0.213
1970-71	3.000	0.370	5.092	0.628	2.506	0.309
1972-74	3.380	0.160	7.558	0.358	2.722	0.129
1975-78	1.060	0.280	5.339	1.410	0.642	0.170
1979-80	0.360	0.205	2.466	1.404	0.193	0.110
Light Duty Gasoline Trucks (<6,000 lbs. GVW)						
Pre-1968	7.250	0.180	24.869	0.617	5.356	0.133
1968-69	4.430	0.250	15.196	0.858	3.273	0.185
1970-71	3.000	0.370	10.291	1.269	2.216	0.273
1972-74	3.360	0.170	11.525	0.583	2.482	0.126
1975-78	1.800	0.270	6.174	0.926	1.330	0.199
1979-80	0.870	0.280	3.830	1.233	0.583	0.187
Light Duty Gasoline Trucks (6,001-8500 lbs. GVW)						
Pre-1970	9.570	0.180	24.248	0.456	7.746	0.146
1970-73	6.280	0.250	15.912	0.633	5.083	0.202
1974-78	6.280	0.170	15.912	0.431	5.083	0.138
1979-80	0.870	0.280	3.372	1.085	0.623	0.200

Table 4
Calculated MOBILE6 Basic Exhaust Emission Rates
for Total Hydrocarbons (THC)
Low Altitude
Motorcycles, Light Duty Diesel Vehicles and Light Duty Diesel Trucks

Model Years	MOBILE5 ZML (g/mi)	MOBILE5 DET (g/mi/10k mi)	Engine Start MOBILE6 ZML (grams)	Engine Start MOBILE6 DET (g/10k mi)	Exhaust Running MOBILE6 ZML (g/mi)	Exhaust Running MOBILE6 DET (g/mi/10k mi)
Motorcycles						
Pre-1978	8.78	0.75	18.643	1.592	6.952	0.594
1978-79	2.40	1.44	5.096	3.058	1.900	1.140
1980-81	1.93	1.15	4.098	2.442	1.528	0.911
1982-84	1.65	0.95	3.503	2.017	1.306	0.752
1985-87	1.31	0.75	2.782	1.592	1.037	0.594
1988+	1.20	0.70	2.548	1.486	0.950	0.554
Light Duty Diesel Vehicles						
Pre-1975	1.310	0.080	2.156	0.132	1.089	0.067
1975-79	0.420	0.070	0.691	0.115	0.349	0.058
1980+	0.290	0.030	0.477	0.049	0.241	0.025
Light Duty Diesel Trucks						
Pre-1981	0.860	0.080	1.416	0.132	0.715	0.067
1981+	0.043	0.040	0.708	0.066	0.358	0.033

Table 5
Calculated MOBILE6 Basic Exhaust Emission Rates
for Carbon Monoxide (CO)
Low Altitude
Light Duty Gasoline Vehicles and Trucks

Model Years	MOBILE5 ZML (g/mi)	MOBILE5 DET (g/mi/10k mi)	Engine Start MOBILE6 ZML (grams)	Engine Start MOBILE6 DET (g/10k mi)	Exhaust Running MOBILE6 ZML (g/mi)	Exhaust Running MOBILE6 DET (g/mi/10k mi)
Light Duty Gasoline Vehicles						
Pre-1968	78.270	2.250	229.196	6.589	51.815	1.490
1968-69	56.340	2.550	195.003	8.826	36.929	1.671
1970-71	42.170	3.130	154.481	11.466	27.453	2.038
1972-74	40.940	2.350	155.909	8.949	26.279	1.508
1975-79	17.720	2.460	93.751	13.015	10.191	1.415
1980	6.090	1.958	48.830	15.699	2.558	0.823
Light Duty Gasoline Trucks (<6,000 lbs. GVW)						
Pre-1968	78.270	2.250	371.439	10.678	46.784	1.345
1968-69	56.340	2.550	267.368	12.101	33.676	1.524
1970-71	42.170	3.130	200.123	14.854	25.206	1.871
1972-74	40.780	2.440	193.526	11.579	24.375	1.458
1975-78	24.550	2.590	116.505	12.291	14.674	1.548
1979-80	12.280	2.430	92.382	18.281	6.319	1.250
Light Duty Gasoline Trucks (6,001-8500 lbs. GVW)						
Pre-1970	93.980	225	510.242	12.216	53.707	1.286
1970-73	60.080	2.55	326.190	13.845	34.334	1.457
1974-78	60.080	2.44	326.190	13.247	34.334	1.394
1979-80	12.280	2.43	69.588	13.770	6.509	1.288

Table 6
Calculated MOBILE6 Basic Exhaust Emission Rates
for Carbon Monoxide (CO)
Low Altitude
Motorcycles, Light Duty Diesel Vehicles and Light Duty Diesel Trucks

Model Years	MOBILE5 ZML (g/mi)	MOBILE5 DET (g/mi/10k mi)	Engine Start MOBILE6 ZML (grams)	Engine Start MOBILE6 DET (g/10k mi)	Exhaust Running MOBILE6 ZML (g/mi)	Exhaust Running MOBILE6 DET (g/mi/10k mi)
Motorcycles						
Pre-1978	33.42	3.22	76.612	7.382	21.272	2.050
1978-79	24.39	3.56	55.911	8.161	15.524	2.266
1980-81	17.51	2.53	40.140	5.800	11.145	1.610
1982+	17.40	2.46	39.888	5.639	11.075	1.566
Light Duty Diesel Vehicles						
Pre-1975	2.710	0.130	7.091	0.340	1.920	0.092
1975-79	1.170	0.090	3.062	0.236	0.829	0.064
1980+	1.150	0.040	3.009	0.105	0.815	0.028
Light Duty Diesel Trucks						
Pre-1981	1.97	0.100	5.155	0.262	1.396	0.071
1981+	1.33	0.040	3.480	0.105	0.943	0.028

Table 7
Calculated MOBILE6 Basic Exhaust Emission Rates
for Oxides of Nitrogen (NO_x)
Low Altitude
Light Duty Gasoline Vehicles and Trucks

Model Years	MOBILE5 ZML (g/mi)	MOBILE5 DET (g/mi/10k mi)	Engine Start MOBILE6 ZML (grams)	Engine Start MOBILE6 DET (g/10k mi)	Exhaust Running MOBILE6 ZML (g/mi)	Exhaust Running MOBILE6 DET (g/mi/10k mi)
Light Duty Gasoline Vehicles						
Pre-1968	3.440	0.000	1.686	0.000	3.127	0.000
1968-72	4.350	0.000	4.824	0.000	3.823	0.000
1973-74	2.860	0.050	10.371	0.181	2.079	0.036
1975-76	2.440	0.040	6.938	0.114	1.906	0.031
1977-79	1.790	0.110	5.695	0.350	1.374	0.084
1980	1.500	.0102	1.775	0.121	1.319	0.090
Light Duty Gasoline Trucks (<6,000 lbs. GVW)						
Pre-1968	3.440	0.000	4.898	0.000	2.877	0.000
1968-72	4.350	0.000	6.194	0.000	3.638	0.000
1973-74	2.870	0.040	4.086	0.057	2.400	0.033
1975-78	2.700	0.030	3.844	0.043	2.258	0.025
1979-80	1.770	0.060	2.328	0.079	1.518	0.051
Light Duty Gasoline Trucks (6,001-8500 lbs. GVW)						
Pre-1970	5.440	0.000	3.346	0.000	4.744	0.000
1970-73	6.450	0.000	3.967	0.000	5.625	0.000
1974-78	4.610	0.040	2.835	0.025	4.020	0.035
1979-80	1.770	0.060	3.082	0.104	1.429	0.048

Table 8
Calculated MOBILE6 Basic Exhaust Emission Rates
for Oxides of Nitrogen (NO_x)

Low Altitude

Motorcycles, Light Duty Diesel Vehicles and Light Duty Diesel Trucks

Model Years	MOBILE5 ZML (g/mi)	MOBILE5 DET (g/mi/10k mi)	Engine Start MOBILE6 ZML (grams)	Engine Start MOBILE6 DET (g/10k mi)	Exhaust Running MOBILE6 ZML (g/mi)	Exhaust Running MOBILE6 DET (g/mi/10k mi)
Motorcycles						
Pre-1978	0.250	0.030	0.627	0.075	0.190	0.023
1978-79	0.680	0.000	1.705	0.000	0.517	0.000
1980+	0.850	0.000	2.132	0.000	0.647	0.000
Light Duty Diesel Vehicles						
Pre-1975	1.460	0.040	0.129	0.004	1.462	0.040
1975-80	1.400	0.040	0.124	0.004	1.402	0.040
1981-84	1.310	0.030	0.116	0.003	1.312	0.030
1985+	0.870	0.030	0.077	0.003	0.871	0.030
Light Duty Diesel Trucks						
Pre-1981	1.830	0.080	0.162	0.007	1.832	0.080
1981-87	1.480	0.030	0.131	0.003	1.482	0.030
1988-89	1.070	0.030	0.094	0.003	1.071	0.030
1990+	1.030	0.030	0.091	0.003	1.031	0.030

Table 9
Calculated MOBILE6 Basic Exhaust Emission Rates
for Total Hydrocarbons (THC)
High Altitude
Light Duty Gasoline Vehicles and Trucks

Model Years	MOBILE5 ZML (g/mi)	MOBILE5 DET (g/mi/10k mi)	Engine Start MOBILE6 ZML (grams)	Engine Start MOBILE6 DET (g/10k mi)	Exhaust Running MOBILE6 ZML (g/mi)	Exhaust Running MOBILE6 DET (g/mi/10k mi)
Light Duty Gasoline Vehicles						
Pre-1968	9.350	0.018	19.917	0.383	7.758	0.149
1968-69	5.600	0.025	15.578	0.695	4.397	0.196
1970-71	4.580	0.037	13.104	1.059	3.557	0.287
1972-74	4.620	0.016	8.595	0.298	3.738	0.129
1975-76	2.000	0.028	6.104	0.855	1.491	0.209
1977	0.930	0.028	5.299	1.595	0.552	0.166
1978-79	2.080	0.028	7.898	1.063	1.491	0.201
1980	0.780	0.205	5.732	1.506	0.400	0.105
Light Duty Gasoline Trucks (<6,000 lbs. GVW)						
Pre-1968	9.350	0.180	33.948	0.654	6.569	0.126
1968-69	5.600	0.250	20.332	0.908	3.934	0.176
1970-71	4.580	0.370	16.629	1.343	3.218	0.260
1972-74	4.580	0.170	16.629	0.617	3.218	0.119
1975-78	3.400	0.270	12.345	0.980	2.389	0.190
1979-80	1.660	0.280	5.560	0.938	1.211	0.204
Light Duty Gasoline Trucks (6,001-8500 lbs. GVW)						
Pre-1970	12.350	0.180	32.967	0.480	9.821	0.143
1970-73	8.560	0.250	22.850	0.667	6.807	0.199
1974-78	8.560	0.170	22.850	0.454	6.807	0.135
1979-80	1.660	0.280	11.755	1.983	0.782	0.132

Table 10
Calculated MOBILE6 Basic Exhaust Emission Rates
for Total Hydrocarbons (THC)
High Altitude
Motorcycles, Light Duty Diesel Vehicles and Light Duty Diesel Trucks

Model Years	MOBILE5 ZML (g/mi)	MOBILE5 DET (g/mi/10k mi)	Engine Start MOBILE6 ZML (grams)	Engine Start MOBILE6 DET (g/10k mi)	Exhaust Running MOBILE6 ZML (g/mi)	Exhaust Running MOBILE6 DET (g/mi/10k mi)
Motorcycles						
Pre-1978	11.430	0.750	24.269	1.592	9.050	0.594
1978-79	3.020	1.440	6.412	3.058	2.391	1.140
1980-81	2.950	1.150	6.264	2.442	2.336	0.911
1982-84	2.520	0.950	5.351	2.017	1.995	0.752
1985-87	2.000	0.750	4.247	1.592	1.583	0.594
1988+	1.840	0.700	3.907	1.486	1.457	0.554
Light Duty Diesel Vehicles						
Pre-1975	3.010	0.080	4.955	0.132	2.503	0.067
1975-79	0.970	0.070	1.597	0.115	0.807	0.058
1980-81	0.670	0.030	1.103	0.049	0.557	0.025
1982-83	0.400	0.030	0.658	0.049	0.333	0.025
1984+	0.290	0.030	0.477	0.049	0.241	0.025
Light Duty Diesel Trucks						
Pre-1981	1.976	0.080	3.253	0.132	1.643	0.067
1981+	0.988	0.040	1.626	0.066	0.821	0.033

Table 11
Calculated MOBILE6 Basic Exhaust Emission Rates
for Carbon Monoxide (CO)
High Altitude
Light Duty Gasoline Vehicles and Trucks

Model Years	MOBILE5 ZML (g/mi)	MOBILE5 DET (g/mi/10k mi)	Engine Start MOBILE6 ZML (grams)	Engine Start MOBILE6 DET (g/10k mi)	Exhaust Running MOBILE6 ZML (g/mi)	Exhaust Running MOBILE6 DET (g/mi/10k mi)
Light Duty Gasoline Vehicles						
Pre-1968	117.700	2.250	425.443	8.133	70.100	1.340
1968-69	85.540	2.550	354.961	10.582	49.183	1.466
1970-71	79.640	3.130	337.061	13.247	45.165	1.775
1972-74	75.680	2.350	253.750	7.879	46.153	1.433
1975-76	47.030	2.460	199.524	10.437	26.573	1.390
1977	19.630	2.460	114.670	14.370	9.686	1.214
1978-79	41.830	2.460	204.371	12.019	22.194	1.305
1980	22.800	1.958	139.225	11.956	10.507	0.902
Light Duty Gasoline Trucks (<6,000 lbs. GVW)						
Pre-1968	117.700	2.250	541.504	10.352	64.839	1.239
1968-69	85.540	2.250	393.545	10.352	47.123	1.239
1970-71	79.640	3.130	366.401	14.400	43.873	1.724
1972-74	75.630	2.440	347.952	11.266	41.664	1.344
1975-78	58.010	2.590	266.887	11.916	31.957	1.427
1979-80	44.250	2.430	196.060	10.767	23.121	1.270
Light Duty Gasoline Trucks (6,001-8500 lbs. GVW)						
Pre-1970	141.350	2.250	554.639	8.829	85.729	1.365
1970-73	107.720	2.550	422.679	10.006	65.333	1.547
1974-78	107.720	2.440	422.679	9.574	65.333	1.480
1979-80	44.249	2.430	300.935	16.526	16.461	0.904

Table 12
Calculated MOBILE6 Basic Exhaust Emission Rates
for Carbon Monoxide (CO)
High Altitude
Light Duty Diesel Vehicles and Trucks

Model Years	MOBILE5 ZML (g/mi)	MOBILE5 DET (g/mi/10k mi)	Engine Start MOBILE6 ZML (grams)	Engine Start MOBILE6 DET (g/10k mi)	Exhaust Running MOBILE6 ZML (g/mi)	Exhaust Running MOBILE6 DET (g/mi/10k mi)
Motorcycles						
Pre-1978	50.130	3.220	114.918	7.382	31.908	2.050
1978-79	37.070	3.560	84.979	8.161	23.595	2.266
1980-81	33.090	2.530	75.855	5.800	21.062	1.610
1982+	32.890	2.460	75.397	5.639	20.935	1.566
Light Duty Diesel Vehicles						
Pre-1975	4.740	0.130	12.403	0.340	3.359	0.092
1975-79	2.050	0.090	5.364	0.236	1.453	0.064
1980-83	2.010	0.040	5.260	0.105	1.424	0.028
1984+	1.150	0.040	3.009	0.105	0.815	0.028
Light Duty Diesel Trucks						
Pre-1981	3.446	0.100	9.017	0.262	2.442	0.071
1981+	1.723	0.040	4.509	0.105	1.221	0.028

Table 13
Calculated MOBILE6 Basic Exhaust Emission Rates
for Oxides of Nitrogen (NO_x)
High Altitude
Light Duty Gasoline Vehicles and Trucks

Model Years	MOBILE5 ZML (g/mi)	MOBILE5 DET (g/mi/10k mi)	Engine Start MOBILE6 ZML (grams)	Engine Start MOBILE6 DET (g/10k mi)	Exhaust Running MOBILE6 ZML (g/mi)	Exhaust Running MOBILE6 DET (g/mi/10k mi)
Light Duty Gasoline Vehicles						
Pre-1968	1.960	0.000	0.995	0.000	1.767	0.000
1968-72	2.910	0.000	3.581	0.000	2.544	0.000
1973-74	1.920	0.050	7.922	0.206	1.363	0.035
1975-76	1.700	0.040	6.776	0.159	1.226	0.029
1977	1.370	0.110	8.511	0.683	0.827	0.066
1978-79	0.970	0.110	2.373	0.269	0.774	0.088
1980	0.820	0.102	1.281	0.159	0.699	0.087
Light Duty Gasoline Trucks (<6,000 lbs. GVW)						
Pre1968	1.960	0.000	3.069	0.000	1.620	0.000
1968-69	2.910	0.000	4.557	0.000	2.406	0.000
1970-71	1.910	0.040	2.991	0.063	1.579	0.033
1972-74	1.880	0.030	2.944	0.047	1.554	0.025
1975-78	0.970	0.060	1.519	0.094	0.802	0.050
1979-80	0.970	0.060	1.871	0.116	0.798	0.049
Light Duty Gasoline Trucks (6,001-8500 lbs. GVW)						
Pre-1970	3.100	0.000	1.634	0.000	2.682	0.000
1970-73	4.320	0.000	2.277	0.000	3.738	0.000
1974-78	3.070	0.040	1.618	0.021	2.656	0.035
1979-80	0.970	0.060	2.270	0.140	0.796	0.049

Table 14
Calculated MOBILE6 Basic Exhaust Emission Rates
for Oxides of Nitrogen (NO_x)
High Altitude
Motorcycles, Light Duty Diesel Vehicles and Light Duty Diesel Trucks

Model Years	MOBILE5 ZML (g/mi)	MOBILE5 DET (g/mi/10k mi)	Engine Start MOBILE6 ZML (grams)	Engine Start MOBILE6 DET (g/10k mi)	Exhaust Running MOBILE6 ZML (g/mi)	Exhaust Running MOBILE6 DET (g/mi/10k mi)
Motorcycles						
Pre-1978	0.140	0.030	0.351	0.075	0.107	0.023
1978-79	0.450	0.000	1.128	0.000	0.342	0.000
1980+	0.570	0.000	1.429	0.000	0.434	0.000
Light Duty Diesel Vehicles						
Pre-1975	1.460	0.040	0.129	0.004	1.462	0.040
1975-80	1.400	0.040	0.124	0.004	1.402	0.040
1981-84	1.310	0.030	0.116	0.003	1.312	0.030
1985+	0.870	0.030	0.077	0.003	0.871	0.030
Light Duty Diesel Trucks						
Pre-1980	1.830	0.080	0.162	0.007	1.832	0.080
1981-87	1.480	0.030	0.131	0.003	1.482	0.030
1988-89	1.070	0.030	0.094	0.003	1.071	0.030
1980+	1.030	0.030	0.091	0.003	1.031	0.030