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1.0 INTRODUCTION

This report documents the collection and analysis of IM240 data conducted in support of EPA's study of in-use deterioration and the revision of the MOBILE6 emissions inventory model. IM240 data have certain strengths and weaknesses relative to other emissions data. After extensively comparing results based on various data sources, IM240 data from Ohio were used to correct deterioration estimates computed from FTP data. These results and a description of the analysis are reported elsewhere.[1] In addition to this limited application, the IM240 test data have added considerably to the understanding of vehicle emissions in the overall fleet.

A substantial effort was devoted to collecting and studying data from state inspection and maintenance (I/M) programs that employ the IM240 test cycle. This cycle was developed to provide a relatively short (239 second) test that captures the essential features of the well-established Federal Test Procedure (FTP), which has long served as the standard for exhaust emissions testing. IM240 data offer two principle advantages. First, very large samples of data are available since state I/M programs aim to test all or most registered vehicles. Second, as a result of this comprehensive testing, the samples approach a census of all vehicles and are thus relatively unbiased.

There are several disadvantages to using IM240 data when compared with FTP testing. The test is shorter than the FTP and is therefore considered less representative of real driving. In particular, the IM240 test contains no cold start portion. Vehicle preconditioning and ambient temperature conditions are uncontrolled in IM240 testing. Data recording at IM test lanes is generally less thorough and accurate, especially with regard to odometer readings. Finally, it is necessary to make several transformations of the IM240 data to obtain FTP-comparable results. Thus, from the outset, IM240 data were considered less satisfactory than FTP data, and regarded as supplementary rather than primary.

In MOBILE6, vehicle exhaust emissions will be allocated between engine start (start emissions) and travel (running emissions). This split enables the separate characterization of start and running emissions for correction factors such as fuel effects and ambient temperature. It also allows a more precise weighting of these two aspects of exhaust emissions for particular situations such as morning commute, parking lots and freeways. Because the IM240 test does not contain a cold start, data from that test are appropriate only for the study of running emissions; start emissions are considered in a separate document.[2]

Section 2 describes the data obtained from Colorado, Arizona, Ohio, and Wisconsin, and provides a brief summary of the I/M programs in each state. Section 3 defines important terms and

[1]Enns, P., E. Glover, P. Carey, and M. Sklar, "Determination of Running Emissions as a Function of Mileage for 1981-1993 Model Year Light-Duty Cars," Report No. M6.EXH.001.

[2]Glover, E. and P. Carey, "Determination of Start Emissions as a Function of Mileage and Soak Time for 1981-1993 Model Year Light-Duty Vehicles," Report No. M6.STE.003.

describes the methodology and analysis of the data. Section 4 presents results and conclusions obtained from the analysis. Data from Phoenix, Arizona and Colorado were analyzed by an EPA contractor. The results from that work are described briefly, with details found in referenced reports. Data from Dayton, Ohio, are discussed more thoroughly in this paper. The Ohio data received special attention because that location had no previous I/M program; as a result, these data were considered more representative of intrinsic emissions deterioration.

2.0 IM240 DATA

2.1 Colorado and Phoenix

IM240 data collected by the state of Colorado between April and August, 1995, were supplied to an EPA contractor, Systems Application International, Inc. (SAI) for evaluation of emissions deterioration. The Colorado program uses a fast-pass procedure whereby most passing vehicles are not required to complete the full 240-second test. However, a special study was conducted on a random sample of vehicles that were required to complete the full test. These full test results comprised the data used by SAI.

A significant issue in working with IM240 test data concerns the accuracy of reported odometer readings. State I/M programs record odometer incidentally, and under closer scrutiny, numerous anomalies often are revealed. The most common problem is the occurrence of unrealistically low mileage given the vehicle's age. In addition, a few cases of exorbitantly high mileages were observed. The best explanation for many of these observations is that the recorder miscopied the left-most digit of the odometer, e.g., a car with 121,300 miles is recorded as having only 21,300 miles. For older vehicles, the odometer may only include five digits, precluding accurate recording of mileages greater than 99,999.

SAI identified problems with the reported odometer readings, and developed a procedure for modifying these values so that they would better conform with known properties of vehicle mileage accumulation. Their approach corrects the odometer based on a probabilistic model of the relation between vehicle age and mileage. Based on the results from its application to the Arizona and Colorado data, this methodology appears to have shortcomings. It produces corrected data sets with certain unnatural features of mileage distribution. The best explanation is that the method's assumptions are simply not sophisticated enough to describe the true error patterns in the data. A more satisfactory method was not developed, so this model was used in SAI's subsequent analyses and was also applied, in modified form, to EPA's study of Ohio IM240 data.

SAI also developed a statistical technique for identifying emission value outliers for the purpose of deleting unusually large or small values in the analyses of deterioration. A small percentage of emission values were adjusted on this basis. Extensive summary statistics were prepared for both the edited and unedited data.[3]

Data from the Phoenix, Arizona I/M program collected from January to June, 1996, were also analyzed by SAI. The Arizona program uses a fast-pass/fast-fail (FPFF) algorithm which can pass or fail the vehicle prior to the end of the IM240 sequence. The state also conducts full IM240 tests without using the FPFF algorithm on a randomly-selected two percent of the vehicle population. These random full IM240 test results comprised the data used by SAI. These data contained odometer anomalies of a somewhat different nature, so the contractor modified its correction software accordingly. It also applied the emission outlier screening procedure developed for the Colorado data to produce a modified Phoenix data set. Summary statistics were again generated for the raw and screened data.[4]

2.2 Ohio

IM240 data collected in Dayton, Ohio were of special interest in this study. This city had no previous I/M experience, so there is reason to believe that deterioration of measured emissions would be more "natural" than in regions with earlier I/M programs. Like Colorado, Ohio employs a fast-pass algorithm to speed up the testing process, but random full IM240 tests are not conducted. As a result, it is necessary to estimate full 240-second values from the fast-pass results. These estimates were developed using a regression model developed with data from the Wisconsin I/M program. Both data sets are discussed below.

The Ohio data includes IM240 test results on all of the 1981 and later registered cars and light-duty trucks scheduled to be tested from April, 1996 through March, 1997. Since the program testing frequency is biennial, the sample of vehicles represents approximately half of the overall vehicle population. Also, because the first month is April, the data set does not contain testing results collected during early startup in 1995 and the beginning of 1996. The original database contained more than one million vehicles from three separate Ohio cities (Cleveland, Akron/Canton, and Dayton/Springfield). Only the data from Dayton/Springfield (referred to as the "Dayton" data elsewhere in this report) were used in the analysis, and these data were further restricted to the valid initial tests (no post-repair retests were used). The sample was restricted to Dayton because it had never implemented any I/M or anti-tampering (ATP) program in the past. The other two sites had implemented decentralized I/M or ATP programs in the past. These programs may have had some influence on the prior condition of the vehicles, and thus potentially bias emissions in the sample from those cities.

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[3] Cohen, J.P., R.K. Iwamiya, and R.E. Looker, "In-Use Deterioration Data Analysis: Task 1, Initial Data Analysis and Quality Review of Colorado IM240 Data," SYSAPP-96/72d, Draft Report, Systems Application International, Inc., November, 1996.

[4] Cohen, J.P., R.K. Iwamiya, and R.E. Looker, "In-Use Deterioration Data Analysis: Task 1, Initial Data Analysis and Quality Review of Phoenix IM240 Data," SYSAPP-96/76d, Draft Report, Systems Application International, Inc., November, 1996.

The sample contained both cars and trucks, with significant numbers of data points for all model years from 1981 through 1995. A vehicle identification number (VIN) decoder developed by Radian Corp. was used to determine each vehicle's model year, vehicle type (car or truck), and fuel metering type (fuel injected or carbureted). The VIN decoder was believed to have achieved a high rate of proper decoding; nevertheless, because of undecodable VINs, voided or suspicious emission tests (unusually low or high CO2 emissions, i.e., less than 100 g/mi or greater than 1500 g/mi), or missing data in key fields, the sample size was reduced to approximately 211,000 vehicles from Dayton/Springfield. Table 1 provides a breakdown of the Dayton sample by model year, vehicle type, and technology (fuel delivery type).

The State of Ohio does not conduct full IM240 tests on all its vehicles or on a random sample of vehicles. A small fraction of vehicles take the full 239 seconds to pass. All failures take the full 239 seconds. The vehicles displaying low emissions during the beginning of the test have their test terminated early under what is called a fast-pass (FP) procedure. The purpose of the FP test is to speed up the testing process and increase the lane volume so as to more efficiently utilize fixed testing resources. The FP test is not a standardized test in terms of length, because it can be terminated as early as 30 seconds into the cycle and as late as 238 seconds.

The FP results are also a function of the specific FP algorithm used to determine whether an individual vehicle passes out of the test early (fast-passes) or stays in the test the full 239 seconds. The algorithm is expressed as a large table of cut points (pass/fail standards) that is applied simultaneously for all three pollutants at each second of the test. The four states which conduct fast-pass IM240 testing use slightly different FP algorithms, which makes comparison between the states somewhat difficult. Ohio performs its fast-pass (FP) testing in accordance with an EPA fast-pass algorithm recommended in the "EPA High Tech I/M Guidance Document."

As with the Arizona and Colorado data, the mileage recorded in the Ohio data is of questionable quality for many of the individual vehicles. An odometer correction was judged to be necessary because of two systematic problems. First, in about 200 cases, the odometer value was found to be unrealistically high, i.e., over 300,000. The most likely explanation for these outliers is the accidental recording of the tenth's digit, with the effect of multiplying mileage by ten. For example, under this scenario, a proper reading of 61,000 miles becomes an unreasonable 610,000 miles. This problem was addressed by eliminating all readings over 300,000 miles. However, for vehicles with less than 300,000 miles it was difficult to determine whether improper recording of the tenth's digit occurred.

As with the Colorado and Arizona IM240 data, inspection of the Dayton, Ohio, data set suggests the second type of problem, odometer rollover. This problem was considered far more widespread and difficult to rectify. One reason for odometer rollovers is that many vehicle odometers in earlier model years were not designed to record mileage greater than 99,999, and frequently during the I/M process the inspector merely records the displayed mileage. Moreover, the collection of accurate odometer data by an I/M program usually is not an important priority, giving rise to concerns about the values even in newer vehicles. Consequently, in a substantial number of vehicles, mileage is unrealistically low for the given vehicle's age. Initially, a correction for this problem was attempted using a modified version of the methodology created by SAI for use with the data from

Colorado and Phoenix. In the modified approach, the odometer for a vehicle with low mileage may be incremented by 100,000 miles if it fits a particular profile. In effect, this procedure adds 100K miles to selected vehicles; the proportion of vehicles so adjusted grows with age. The choice of vehicles assigned a new mileage is made probabilistically according to distributions fitted to the data under certain assumptions underlying the SAI methodology. While not an ideal solution, it was felt that this method yielded an improvement to the uncorrected odometer values in the raw data. After reviewing the corrected odometers, however, a decision was made to use region-specific mileage accumulations instead for subsequent analysis.

2.3 Wisconsin Second-by-Second Data

Raw emission values from the Ohio data are not directly comparable to one another because they correspond to varying test durations. To address this concern, a model for predicting the full 239-second emissions rate from a partial fast-pass test score was developed. This model was fitted using second-by-second data from the Wisconsin IM240 test program. These data were collected as a random sample over three different months (December, 1995, April, 1996, and October, 1996). It contained data on 3,148 cars and 1,192 light trucks with a range of model years from 1981 through 1995. The Wisconsin IM240 data were chosen over data from the other two IM240 states (Arizona and Colorado) with second-by-second data because of the geographic, demographic, and meteorological similarities between Ohio and Wisconsin. Furthermore, both states use the same testing contractor, so analyzers and specific test procedures are likely to be similar. Results from the Wisconsin data analysis are reported in the next section.

3.0 METHODOLOGY AND ANALYSES

3.1 Colorado and Phoenix

SAI performed an extensive analysis of emissions deterioration for the combined Phoenix/Colorado data set. A variety of regression models was investigated, and several are discussed in detail.[5] They focus on the logarithmic transformation of emissions, which tends to give better model fits than the untransformed raw data. Model coefficients estimated in this way provide multiplicative adjustments to a baseline zero-mile emission rate. In general, the models do not fit the data especially well due to the lack of good baseline values for individual vehicles. Highlights of SAI's findings include the following:

1. As expected, emissions deteriorate with increasing mileage.

2. The rate of deterioration of emissions is less at higher mileages and in older model year

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[5] Cohen, J.P., R.K. Iwamiya, and R.E. Looker, "Analysis of In-Use Deterioration of Emissions Using I/M 240 Data," SYSAPP-97/06d, Draft Final Report, Systems Application International, Inc., February, 1997.

vehicles.

3. CO and HC emissions in Colorado tend to be higher than in Arizona; with NOx, the opposite effect is observed.

3.2 Fast-Pass to Full IM240 Conversion

3.2.1 EPA Approach

As noted earlier, the Ohio IM240 test uses a fast pass algorithm, i.e., the test is terminated prematurely for vehicles displaying low emissions at an elapsed time of as little as 30 seconds. Partial and full test emissions are all measured in grams per mile. Nevertheless, examination of second-by-second data gives ample evidence that emissions from tests of varying duration are not directly comparable, since the speed-acceleration mix changes over the cycle. Therefore, estimation of a “simulated” full IM240 test score was undertaken for all passing vehicles for which only a fast pass score was available.

From the Wisconsin second-by-second data, regression models were constructed in which the full IM240 emissions are predicted based on several independent variables using only the tests from passing vehicles. The natural logarithm of emissions was used as the independent variable. Model regressors include vehicle type (car or truck), fuel metering type, model year, and simulated length of test (in seconds). The simulated test length was determined by applying the fast-pass algorithm used in Ohio to the second-by-second emissions. These models give good fits, with R-squared values ranging from 70% to 82%. Table 2 reports the coefficients for these models.

The coefficients from these models were then used to predict full IM240 scores for each Ohio fast pass test. Because the models fit the natural logarithm of emissions, the antilog transformation was employed to obtain values in IM240 space.

3.2.2 RFF Approach

An alternative approach to estimating full IM240 scores from fast-pass scores was proposed by Resources for the Future (RFF). This methodology involves regressing the IM240 emissions against emissions at a given time point in the test using all tests. The RFF model includes the model year variable (but not vehicle type or fuel metering system). This approach produces a different equation for every test duration between 30 and 239 seconds. This approach avoids the problem of correlation between the regressor and error terms that may affect the EPA models. However, there is concern that it may be inappropriate to use tests from failing cars with high emissions in fitting an equation intended to represent a fast pass (i.e., low-emission) outcome.

RFF tested its method on second-by-second data from Arizona, with acceptable results. When applied to the Ohio data, the EPA and RFF models produced similar mean estimates of full IM240 scores (see Table 3). Therefore, it was decided to use the values generated by the EPA approach.

3.3 IM240 to Running LA4 Conversion

The next step involved estimating running LA4 scores for each Ohio vehicle. (The Running LA4 is a test cycle comprised of the 1372-second LA4 trace that underlies the FTP, with no start component. Unlike previous versions of MOBILE, MOBILE6 will treat start and running emissions separately.[1]) This estimation was achieved using two sets of regression models. The first set of models was developed from a sample of 77 tests conducted for the purpose of estimating a Running LA4 from a conventional three-bag FTP. This test program and its analysis are described in a separate report.[6] The results of this work were then used with a sample of FTP and IM240 paired tests conducted on vehicles chosen from I/M lanes in Hammond, Indiana and Phoenix, Arizona. This sample was comprised of 997 vehicles, of which 938 are from model year 1981 or later. Coefficients from the 78-vehicle study were used to convert the FTP bag scores to Running LA4 values for subsequent correlation with matching IM240 scores.

The IM240 tests at the inspection lane were, of course, based on the vehicle's tank fuel. When moved to the lab, each vehicle's fuel was replaced with Indolene in accordance with standard test protocol. Then, in addition to the FTP, a lab IM240 was conducted. For this analysis, however, the IM240-to-FTP conversion was made between the lane IM240 (tank fuel) and the lab FTP (Indolene), since IM240 data from Ohio is based on tank fuel tests.

Table 4 shows the results of modeling the log of running LA4 emissions as a function of log of IM240 plus dummy variables representing vehicle fuel metering technology and model year group (defined in the table). The coefficients from these models were then applied to the Ohio data to produce fitted Running LA4 scores for that much larger data set. The modeling approach is similar to that used to simulate full IM240 scores from fast pass scores. The fitted values of the natural log of Running LA4 are converted to gram per mile space using the antilog transformation.

4.0 RESULTS AND CONCLUSIONS

Inspection and maintenance programs provide large samples of emission test data. These data are not subject to the types of recruitment bias found in samples collected for other purposes such as the EPA emissions factor program. The IM240 test is designed to better emulate actual on-road driving than older I/M procedures. Therefore, these data offer a number of possibilities for improved modeling of emissions deterioration and other types of behavior. Despite these benefits, as this report explains, currently available IM240 test data also suffer from shortcomings that need to be addressed before the data can be used directly in modeling emissions.

For MOBILE6, the Ohio IM240 data are used indirectly to modify emission rates derived from FTP data. In this application, FTP data are employed to determine running LA4 deterioration for Tier 0 cars. The resulting emission rates are then adjusted by applying a high emitter correction

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[6] Brzezinski, D., E. Glover and P. Enns , "The Determination of Hot Running Emissions From FTP Bag Emissions," Report No. M6.STE.002.

factor based on the Ohio IM240 data. These correction factors were judged necessary to adjust for possible bias in the samples of FTP test data collected by EPA and the vehicle manufacturers. This bias is attributed to questions concerning vehicle owner willingness to participate in emissions testing programs. The Ohio IM240 scores were used to develop the high emitter correction factors, but regional-specific annual average odometer readings by vehicle age were substituted for the reported odometers. This approach takes advantage of the Ohio IM240 data set, which represents a large sample of vehicles not subject to a previous I/M program, while also limiting one of the major shortcomings of the Ohio IM240 data, i.e., the reported odometer readings. The methodology used to develop the high emitter correction factors is described in the paper cited earlier.[1]

Table 1
Distribution of Dayton, Ohio IM240 Data

	VEHICLE						ALL		
	CAR			TRUCK					
	FUEL METERING			FUEL METERING			FUEL METERING		
	CARB	FI	ALL	CARB	FI	ALL	CARB	FI	ALL
MODEL YEAR									
1981	924	140	1,064	158	7	165	1,082	147	1,229
1982	2,767	882	3,649	862	19	881	3,629	901	4,530
1983	2,791	998	3,789	739	5	744	3,530	1,003	4,533
1984	7,105	4,146	11,251	2,182	87	2,269	9,287	4,233	13,520
1985	4,329	4,542	8,871	1,749	316	2,065	6,078	4,858	10,936
1986	6,771	11,207	17,978	1,805	2,873	4,678	8,576	14,080	22,656
1987	2,777	8,041	10,818	626	2,278	2,904	3,403	10,319	13,722
1988	3,092	16,367	19,459	443	5,236	5,679	3,535	21,603	25,138
1989	1,399	10,117	11,516	82	3,231	3,313	1,481	13,348	14,829
1990	267	16,606	16,873	119	4,271	4,390	386	20,877	21,263
1991	7	9,519	9,526	6	3,074	3,080	13	12,593	12,606
1992	.	16,604	16,604	.	5,289	5,289	.	21,893	21,893
1993	.	10,646	10,646	.	3,517	3,517	.	14,163	14,163
1994	.	13,740	13,740	.	5,061	5,061	.	18,801	18,801
1995	.	7,895	7,895	.	2,528	2,528	.	10,423	10,423
1996	.	783	783	8	230	238	8	1,013	1,021
ALL	32,229	132,233	164,462	8,779	38,022	46,801	41,008	170,255	211,263

Table 2
Fast-Pass to Full IM240 Regression Models
Using Wisconsin Second-by-Second IM240 Data

These models use the following independent variables:

LFxx = Natural Log(fast past gram/mile value of pollutant xx)
F=0 (carbureted fuel metering), =1 (fuel injected)
V=0 (truck), =1 (car)
D_i=0 (not model year i), =1 (model year i) , i=1981 to 1994
D_i*LFxx = Crossproduct to capture slope change with model year

The Di and crossproduct coefficients are not shown.
The dependent variable is Lxx = Natural Log(240-second gram/mile value of xx).

Dependent Variable: LCO - Log(IM240 CO)

Root MSE	0.68473	R-square	0.7034
Dep Mean	1.17901	Adj R-sq	0.7013
C.V.	58.07704		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.042493	0.04651906	-0.913	0.3611
LFCO	1	0.497165	0.01568796	31.691	0.0001
F	1	-0.238492	0.03735494	-6.384	0.0001
V	1	0.070382	0.02377776	2.960	0.0031
FSEC	1	0.003180	0.00019780	16.075	0.0001

Table 2 (Continued)

Dependent Variable: LHC - Log(IM240 HC)

Root MSE	0.50372	R-square	0.8189
Dep Mean	-1.37212	Adj R-sq	0.8176
C.V.	-36.71100		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-1.594231	0.04709904	-33.848	0.0001
LFHC	1	0.529476	0.01496448	35.382	0.0001
F	1	-0.109558	0.02765615	-3.961	0.0001
V	1	0.161715	0.01776551	9.103	0.0001
FSEC	1	0.003870	0.00014103	27.444	0.0001

Dependent Variable: LNOX - Log(IM240 NOX)

Root MSE	0.43297	R-square	0.7359
Dep Mean	-0.26214	Adj R-sq	0.7340
C.V.	-165.16871		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.681601	0.03277202	-20.798	0.0001
LFNO	1	0.480133	0.01264385	37.974	0.0001
F	1	-0.023815	0.02363659	-1.008	0.3137
V	1	0.082967	0.01511348	5.490	0.0001
FSEC	1	0.001471	0.00011878	12.382	0.0001

Table 3
Comparison of EPA and RFF Full 240-Second Means by Model Year
Carbureted Vehicles

MODEL YEAR	RFF FP HC	RFF IM240 HC	EPA FP HC	EPA IM240 HC	RFF FP CO	RFF IM240 CO	EPA FP CO	EPA IM240 CO	RFF FP NOX	RFF IM240 NOX	EPA FP NOX	EPA IM240 NOX
1980	1.42	1.22	1.42	1.32	21.15	20.25	21.16	22.66	1.85	1.91	1.85	1.96
1981	1.84	1.74	1.85	1.79	29.69	29.69	29.70	31.23	2.13	2.27	2.14	2.17
1982	1.88	1.76	1.89	1.95	27.73	27.52	27.73	34.48	2.22	2.33	2.22	2.24
1983	1.67	1.52	1.67	1.55	23.44	23.14	23.44	22.71	2.13	2.25	2.14	2.19
1984	1.55	1.38	1.56	1.47	23.90	23.19	23.91	25.68	1.93	2.02	1.93	1.92
1985	1.57	1.37	1.57	1.46	22.91	22.06	22.92	23.03	1.95	2.00	1.95	2.04
1986	1.28	1.07	1.29	1.17	18.97	18.07	18.97	21.70	1.79	1.83	1.79	2.14
1987	1.13	0.90	1.13	1.00	17.24	15.81	17.24	16.83	1.68	1.69	1.68	1.71
1988	0.89	0.64	0.89	0.77	13.10	11.14	13.10	13.50	1.35	1.36	1.35	1.53
1989	0.75	0.51	0.75	0.56	12.30	10.01	12.30	11.08	1.28	1.22	1.28	1.23
1990	0.96	0.62	0.96	0.61	11.92	10.05	11.93	10.51	1.02	0.99	1.02	0.93
1991	0.81	0.72	0.82	0.78	13.71	12.98	13.72	13.81	1.11	1.08	1.11	1.11
1996	0.40	0.11	0.41	0.20	4.93	1.59	4.94	3.15	0.45	0.38	0.46	0.42

Table 3 (continued)
Fuel Injected Vehicles

MODEL YEAR	RFF FP HC	RFF IM240 HC	EPA FP HC	EPA IM240 HC	RFF FP CO	RFF IM240 CO	EPA FP CO	EPA IM240 CO	RFF FP NOX	RFF IM240 NOX	EPA FP NOX	EPA IM240 NOX
1980	0.74	0.48	0.75	0.53	9.27	7.36	9.28	7.80	1.19	1.15	1.20	1.24
1981	1.69	1.53	1.70	1.54	23.37	23.73	23.37	23.21	1.87	2.09	1.88	1.88
1982	1.42	1.30	1.43	1.40	17.21	17.53	17.21	21.42	2.70	2.83	2.71	2.67
1983	1.35	1.18	1.36	1.15	16.19	16.09	16.19	14.60	2.42	2.55	2.43	2.42
1984	1.34	1.13	1.34	1.14	15.88	15.38	15.89	14.98	2.33	2.43	2.33	2.27
1985	1.37	1.10	1.37	1.12	15.58	15.65	15.58	14.02	1.96	2.05	1.96	2.03
1986	1.25	0.93	1.26	0.98	13.11	12.18	13.11	12.91	1.56	1.66	1.57	1.92
1987	1.10	0.79	1.11	0.85	12.16	10.99	12.17	10.66	1.64	1.67	1.64	1.64
1988	0.99	0.65	1.00	0.75	10.86	8.98	10.86	9.56	1.42	1.43	1.42	1.59
1989	0.90	0.56	0.91	0.59	10.76	8.36	10.77	8.10	1.37	1.32	1.37	1.30
1990	0.75	0.43	0.76	0.40	10.13	7.29	10.13	6.79	1.26	1.16	1.27	1.12
1991	0.59	0.38	0.59	0.42	8.24	6.49	8.25	7.00	1.17	1.04	1.17	1.03
1992	0.50	0.29	0.51	0.39	7.50	5.46	7.51	7.39	0.96	0.84	0.96	1.12
1993	0.43	0.21	0.43	0.26	6.51	4.32	6.52	4.65	0.90	0.75	0.91	0.76
1994	0.31	0.11	0.31	0.20	5.03	2.86	5.03	3.78	0.57	0.52	0.58	0.78
1995	0.23	0.06	0.24	0.12	4.21	2.02	4.22	2.25	0.46	0.42	0.47	0.38
1996	0.16	0.03	0.17	0.09	2.58	0.95	2.58	1.53	0.33	0.32	0.34	0.30

Table 4
Regression models: Running LA4 vs. IM240

These models use the following independent variables:

LFxx = Natural Log(fast past gram/mile value of pollutant xx)
FI=0 (carbureted fuel metering), =1 (fuel injected)
M1=1 (model years 1981-82), =0 (otherwise)
M2=1 (model years 1983-87), =0 (otherwise)

The dependent variable is

LxxRUN = Natural Log(Running LA4 gram/mile value of xx).

Dependent Variable: LHCRUN - Log(Running LA4 HC)

Root MSE	0.79242	R-square	0.7068
Dep Mean	-1.00124	Adj R-sq	0.7055
C.V.	-79.14334		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.750184	0.09554650	-7.852	0.0001
LHCIM	1	0.948738	0.02344691	40.463	0.0001
FI	1	-0.006354	0.08638848	-0.074	0.9414
M1	1	0.827859	0.12575290	6.583	0.0001
M2	1	0.383417	0.05923913	6.472	0.0001

Table 4 (continued)

Dependent Variable: LCORUN - Log(Running LA4 CO)

Root MSE	0.91602	R-square	0.6434
Dep Mean	1.65384	Adj R-sq	0.6419
C.V.	55.38721		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.700927	0.11976277	-5.853	0.0001
LCOIM	1	0.956897	0.02533007	37.777	0.0001
FI	1	0.173259	0.09985916	1.735	0.0831
M1	1	0.770544	0.14457986	5.330	0.0001
M2	1	0.193573	0.06678826	2.898	0.0038

Dependent Variable: LNOXRUN - Log(Running LA4 NOX)

Root MSE	0.57696	R-square	0.6533
Dep Mean	-0.34445	Adj R-sq	0.6518
C.V.	-167.50296		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.623836	0.06824633	-9.141	0.0001
LNOXIM	1	0.849380	0.02276379	37.313	0.0001
FI	1	-0.089006	0.06267262	-1.420	0.1559
M1	1	0.280035	0.09190557	3.047	0.0024
M2	1	0.209848	0.04307749	4.871	0.0001