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Comparison of MOBILE6 Basic Emission Rates for 1981-1993 Model Year Cars and Light-Duty Trucks with FTP and IM240 Data

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1.0 INTRODUCTION

The MOBILE6 emissions inventory model will compute basic start and running emission rates (BERs) as a function of a vehicle's accumulated mileage. The equations proposed for use in these calculations were developed from Federal Test Procedure (FTP) and IM240 data, as described in a series of reports on in-use deterioration. This paper discusses analyses comparing FTP BER values from MOBILE6 (derived by a combined weighting of the start and running BERs) with FTP emission levels found in actual data. The purpose of this work is to obtain a measure of how well BER estimates from the model replicate real-world emissions.

Two types of comparison are presented. The first is a graphical display of average FTP emissions found in actual FTP data contrasted with MOBILE6 estimates of FTP emissions at the same vehicle mileage. This is intended to show in condensed form how well the MOBILE6 equations represent emissions found in real-world driving. In the second comparison, data from the Colorado inspection and maintenance (I/M) program are substituted for the Ohio program data used in MOBILE6 in order to measure the sensitivity of the model to state-specific characteristics.

The next section reviews the data sources used in these analyses. Section 3 describes how the comparisons were performed. Section 4 discusses conclusions drawn from the study.

2.0 DATA Sources

2.1 FTP Data

Since MOBILE6 can produce estimates of FTP emissions, it was decided to compare these estimates to available raw FTP data. Three sources of data were employed for these comparisons.

1. The California Surveillance program is an ongoing effort in that state to monitor its emission control activities. This program attempts to sample the population randomly to obtain a representative picture of the fleet. A sample of 559 FTP tests from the California program was obtained for use in this analysis.

2. Another source of FTP data is the 668 tests conducted on vehicles selected by EPA in Hammond, Indiana. The vehicles in this sample were recruited from I/M lanes as part of a program designed to establish the correlation between the IM240 and FTP tests. Because they were intentionally selected to over-represent high emitting vehicles, in the current analysis the Hammond data are reweighted so as to more accurately represent the I/M pass and fail rates in the population of vehicles.[1] This reweighting scheme involved deleting some observations and duplicating others, which resulted in a final sample of 998 observations.

The Hammond data are employed in MOBILE6 as part of an adjustment to the in-use deterioration equations that are fitted to the EPA/AAMA/API data. Due to concerns about possible sample bias in the FTP data of (1) above, the running emission functions in the MOBILE6 model were adjusted using IM240 data from Dayton, Ohio[2]. The Hammond data were used in this process to transform the Ohio IM240 measurements into estimates of running emissions. Thus, the Hammond data set considered in the analysis of this report played an indirect part in the development of the MOBILE6 BERs. Note that bias adjustment relied also on 270 IM240 and FTP tests on vehicles sampled in Phoenix, Arizona. These values were not used in this analysis because they were not included in the reweighting applied to the Hammond data.

3. The largest set of FTP data comes from tests conducted by EPA and industry. This set is referred to here as the EPA/AAMA/API data for the three organizations that sponsored these tests. These data also were used to develop estimates of running emissions versus mileage[3] and start emissions versus mileage[4] in MOBILE6. The API

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[1]Heirigs, P. and L.Caretto, "Data to be Used for CALIMFAC Model," memo to California Air Resources Board, March, 1994.

[2]Enns, P., E. Glover, P. Carey, and M. Sklar, "Analysis of Emissions Deterioration Using Ohio and Wisconsin IM240 Data," Report No. M6.EXH.002, October 1998.

[3]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, October 1998.

[4]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,

sample of 103 vehicles intentionally includes vehicles with high mileage accumulation. The EPA vehicles, tested over a number of years, show comparatively lower mileages. The AAMA data were collected only for 1990-93 vehicles with lower mileages also. All these samples were obtained through voluntary response to solicitations for test participation. This gives rise to concerns about their representativeness which were addressed in MOBILE6 by the use of an adjustment based on IM240 data.

Table 1 provides summary statistics for each of the three FTP data sets. The data are classified into the categories of vehicle type, fuel metering and model year group defined in MOBILE6. In the model, functions of emissions deterioration are fitted for each of these categories.

Using the EPA/AAMA/API and Hammond data in the construction of MOBILE6 casts suspicion on their use in validating the model. With the former, it is perhaps best to view the exercise as simply confirming that the model is indeed based on these data. But the path from the data to the final model equations is not entirely straightforward, especially in light of the bias adjustment step. With the Hammond data the relation between the model and the data is much less obvious, making these values more like a truly independent set of observations.

2.1 IM 240 Data

In addition to direct FTP comparisons, this report considers the impact of the IM240 bias-adjustment in terms of the state source of I/M data. EPA acquired a sample of approximately 1.2 million tests conducted in Colorado in 1995 and 1996. As described in Section 3.2, these data were substituted for the Ohio data in the adjustment phase of the development of MOBILE6 BER functions. The distribution of model year, vehicle type and technology for both the Colorado and Ohio IM240 data is given in Table 2.

3.0 COMPARISONS TO MOBILE6

3.1 FTP Data

In order to compare the MOBILE6 estimates with FTP data, it is necessary to combine the start and running estimates to compute composite FTP emissions. For this analysis the following equation is used:

$$FTP=(7.5*Running + .521*Start)/7.5$$

which yields a value in units of grams per mile.

October, 1998.

A variety of comparisons are possible between the FTP data and the MOBILE6 BER estimates. In the approach used here, a regression equation was estimated for each pollutant, data source, and model year-technology category. For example, in the category of 1988-93 TBI cars, the California surveillance sample contains 32 tests. Within this sample, both emissions and vehicle mileage vary for a given pollutant. This variation implies uncertainty about the true average emissions of vehicles in that category. To measure this uncertainty, confidence intervals for the mean of emissions were developed.

As an illustration, in Figure 1 the CO values for the same 32 tests are plotted against accumulated mileage. Also shown is a 95% confidence band, which can be used to estimate mean CO with 95% confidence at a given mileage level. The figure displays the characteristic pattern in which the confidence band widens as mileage diverges from the sample mean. For this analysis, it was decided to compare the sample data from each model year to MOBILE6. In order to synthesize results, the mean mileage of a model year subsample was used to compute the MOBILE6 estimate and also the corresponding 95% confidence interval from the regression of the sample data.

Figure 2 shows the outcome of these calculations for each of the vehicle type, fuel metering and model year categories. On a given graph, each vertical bar represents a 95% confidence interval of the type described above for a particular model year and data source. The horizontal axis gives the MOBILE6 estimate of emissions at the mean mileage for that model year subsample. A 45-degree line, labeled ‘1:1' is included to help visualize the comparison of actual data to the model fit. A point on this line represents exact equality of the data and the MOBILE6 estimate. Thus, if the bar lies above this line, the FTP data suggest actual FTP emissions higher than is predicted by MOBILE6. The opposite conclusion is implied by a bar falling below the 1:1 line. When the bar intersects the 1:1 line, evidence of a difference is inconclusive at the 95% level of confidence. Note that the number of intervals is not always the same from one data source to another because not all model years are represented in each of the data sets.

The size of the confidence intervals varies considerably, reflecting great differences in the group sample sizes as well as the inherent variation in emissions within a sample. The performance of the MOBILE6 estimates appear rather different among model year-technology groups. In general, the model tends to equal or overstate emissions in the newer fuel-injected vehicle classes. With the older model years the results are more mixed. In some cases, e.g., 1984-93 carbureted trucks, the direction of the discrepancies is clearly a function of the data source. The overall pattern appears to support the general hypothesis that MOBILE6 estimates equal or perhaps overestimate emission rates found in actual data.

That the model would overstate the data is clearly to be expected for the EPA/AAMA/API set since those data were used to fit the deterioration model before the bias adjustment. In most cases, that adjustment increased the emission rate using the Ohio IM240 data.

It has been noted that the Hammond data also are used. The influence of the Hammond data on this adjustment is less obvious. Because the California surveillance data was not used in MOBILE6, its relation to the model’s estimates is perhaps most useful. There is no apparent overall tendency in the model to overstate or understate the California

values, although clear patterns are seen in individual model year-technology groups. It should be noted that emissions, in general, standards in California differ from those of the other states. For example, for 1988-93 cars the California CO standard is 7.0 grams per mile compared to the Federal standard of 3.4 gpm. For the same model years, the California NOx standard varies from 0.4 to 1.0 gpm while the Federal standard is 1.0 gpm. However, it is difficult to identify a clear pattern in the confidence interval graphs that is consistent with these differences in standards.

3.2 IM240 Data

The MOBILE6 bias adjustment procedure mentioned earlier relies on a sample of more than 200,000 IM240 test measurements collected in Dayton, Ohio during 1996 and 1997. In particular, these were fast-pass tests in which the test length was abbreviated to as little as 30 seconds for vehicles with sufficiently low emissions. To use these data, it was necessary to first estimate each vehicle's full 240 second emissions. The resulting values then were converted to running emission estimates using regression equations developed from the Hammond, Indiana data.

One question that is raised by this work concerns the sensitivity of the results to the state-specific characteristics of the IM240 program. State programs and driving conditions vary, suggesting the possibility that the Ohio IM240 data may not be typical of all regions. To examine this issue, EPA repeated the adjustment calculations using IM240 data from Colorado. In particular, regression equations developed from IM240 data collected in Wisconsin were used to estimate full IM240 values (reference 4). The Wisconsin data offered second-by-second measures of all 240 seconds, enabling the proper correlation of partial test to full test emissions. Using the same conversion procedure for both Ohio and Colorado should provide the most direct and specific comparison of the effects of the two states' data.

The adjustment for FTP sample bias is captured in a term that is added to the running emissions component of the FTP as computed in MOBILE6. In Version 6, vehicle emissions are separated into start and running components to provide the model's users greater flexibility. Start emissions, measured in grams, are the emissions occurring at the beginning of a trip when the engine is turned on. Running emissions are produced during actual driving and are measured in grams per mile. The basic emission rate of a vehicle, start or running, is a function of the vehicle's accumulated mileage. The IM240-based bias adjustment term increases linearly with mileage, starting at zero for a new vehicle. It is applied only to running emissions because the IM240 test does not properly measure start emissions. For each pollutant, model year-technology group and vehicle type, the adjustment factor was calculated from the Colorado IM240 data in the same way as for the Ohio data. Table 3 shows a comparison of the two states' adjustment factors. In general, the Colorado-based factors are larger than those of Ohio. To gauge these differences in the context of FTP emissions, graphs were constructed showing the proposed MOBILE6 deterioration of emission rates versus mileage and the modified deterioration rates using Colorado's data in place of Ohio's (Figure 3). The graphs also include the in-use deterioration modeled by

MOBILE5 for representative model years. Because MOBILE5 has different deterioration line for each model year, the years 1981, 1987 and 1992 were chosen as representative of their MOBILE6 model year groups. The graphs for model year 1981 are of questionable value since the Colorado IM240 data contain only a few vehicles from that year. The method of computing the adjustment factor for a given model year group requires at least two model year points (see reference 1). Since one of the two years in the 1981-82 group is poorly represented, the resulting adjustment factor is dubious.

Several observations can be made. First, differences between the two states are considerably muted when the adjusted running emission value is merged with start emissions to form an FTP estimate. Second, the effect of the difference is obviously smaller at low mileage accumulation than at higher mileages. Finally, these differences are quite small relative to the change from version 5 to version 6 of MOBILE.

4.0 Conclusions

The estimates of FTP emission rates generated by MOBILE6 appear to agree rather well on average with rates observed in actual data measurements. Some of the evidence presented here must be qualified due to the relation between the data and model itself. Additional sources of independent FTP data would help better illuminate this issue.

State IM240 data play a key role in the MOBILE6 estimates of running emissions. The analysis presented here suggests that substituting Colorado IM240 data for that of Ohio increases these estimates substantially. When combined with start emission estimates to obtain full FTP values, the relative effect of this substitution is considerably diminished, and with either state's data the new model emission rates are much smaller than in MOBILE5.

Table 1: Distribution of Vehicles by Model Year and Technology for the Combined FTP Data set

		SOURCE					
		CAL SURVEIL		EPA/AAMA/API		HAMMOND REWGT*	
		ODOMETER		ODOMETER		ODOMETER	
		MEAN	N	MEAN	N	MEAN	N
VEH TYPE	MY-TECH						
CARS	81-82 CARB	130,028	13	33,954	1166	92,408	84
	81-82 FI	126,617	12	42,609	126	87,439	9
	83-85 CARB	104,863	50	34,940	253	83,629	57
	83-87 FI	104,615	107	53,556	726	70,988	384
	86-93 CARB	100,565	40	56,097	96	56,002	54
	88-93 PFI	70,975	162	40,759	1605	37,869	202
	88-93 TBI	72,035	32	49,127	444	38,524	108
	ALL	90,078	416	41,960	4416	61,703	898
TRUCKS	81-83 CARB	167,371	13	34,934	180	.	.
	81-87 FI	119,129	27	59,413	94	.	.
	84-93 CARB	109,451	38	47,952	134	.	.
	88-93 PFI	72,045	50	44,486	330	.	.
	88-93 TBI	76,373	15	38,427	467	.	.
	ALL	99,995	143	42,261	1205	.	.

*Weighted total from original sample of 668 tests.

Table 2: Distribution of Vehicles by Model Year and Technology for the Colorado IM240 Data set

	COLORADO				OHIO			
	CARS		TRUCKS		CARS		TRUCKS	
	FI	CARB	FI	CARB	FI	CARB	FI	CARB
MY								
1981	2	6	0	2	140	924	7	158
1982	5,269	17,079	176	7,209	882	2,767	19	862
1983	9,393	23,346	129	12,210	998	2,791	5	739
1984	16,064	27,429	660	20,430	4,146	7,105	87	2,182
1985	29,209	29,306	2,129	24,403	4,542	4,329	316	1,749
1986	34,996	22,937	14,670	11,914	11,207	6,771	2,873	1,805
1987	47,897	20,519	19,768	6,436	8,041	2,777	2,278	626
1988	52,663	14,601	27,238	2,177	16,367	3,092	5,236	443
1989	60,572	11,816	29,956	1,761	10,117	1,399	3,231	82
1990	64,924	1,087	27,493	2,038	16,606	267	4,271	119
1991	71,911	320	34,487	233	9,519	7	3,074	6
1992	60,421	64	33,407	108	16,604	0	5,289	0
1993	70,135	2	42,666	45	10,646	0	3,517	0
1994	62,901	0	45,567	0	13,740	0	5,061	0
1995	33,049	0	19,985	0	7,895	0	2,528	0
ALL	619,406	168,512	298,331	88,966	131,450	32,229	37,792	8,771

Table 3: IM240-Based Additive Adjustment Factors
Colorado vs. Ohio, grams/mile per 1000 miles

CARS

	HC		CO		NOX	
	STATE		STATE		STATE	
	COLORADO	OHIO	COLORADO	OHIO	COLORADO	OHIO
MY-TECH						
81-82 CARB	0.0087	0.0048	0.2402	0.1419	0.0002	0.0002
81-82 FI	0.0113	0.0094	0.1443	0.1825	-0.0065	-0.0060
83-85 CARB	0.0029	0.0003	0.0209	-0.0200	0.0000	0.0003
83-87 FI	0.0013	-0.0001	0.0031	-0.0048	0.0026	0.0023
86-93 CARB	0.0045	0.0039	0.0854	0.0729	0.0025	0.0021
88-93 PFI	0.0018	0.0013	0.0356	0.0313	0.0022	0.0010
88-93 TBI	0.0018	0.0013	0.0356	0.0313	0.0022	0.0010

TRUCKS

GROUP						
81-83 CARB	0.0094	0.0018	0.3499	0.1044	-0.0020	0.0008
81-87 FI	-0.0008	-0.0037	0.0973	0.0550	-0.0015	-0.0028
84-93 CARB	-0.0012	-0.0053	0.0097	-0.0658	-0.0034	-0.0040
88-93 PFI	0.0021	0.0013	0.0471	0.0329	0.0015	0.0002
88-93 TBI	0.0021	0.0013	0.0471	0.0329	0.0015	0.0002