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Report Number M6.IM.002

Janet C. Kremer

Assessment and Modeling Division
Office of Mobile Sources
U.S. Environmental Protection Agency

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May 1999
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Introduction

When the MOBILE model calculates credits from Inspection and Maintenance (I/M) programs, one important input is the difference between emissions before and after successful I/M repairs. These "repair effects" may vary with vehicle type and model year. They also may vary with test type and test cutpoints, and may be different for running and start emissions.

This document examines the repair effects on start emissions. It describes how the database for this analysis was developed. It also describes how to calculate cold start emissions from the Federal Test Procedure (FTP) bag results. The analysis in this report covers Light Duty Vehicles (LDVs) and Light Duty Trucks (LDTs) with model years ranging from 1983 through 1991. Repair effects for running emissions are found in EPA report number M6.IM.001.

Background

The current version of the MOBILE model is MOBILE5. MOBILE5 calculates I/M credits using a module called TECH5. TECH5 is an external FORTRAN program which calculates and exports the I/M credit values to MOBILE5 as built-in code or as an external file.

For MOBILE6, the new I/M credit methodology will be built into the model's code. This new methodology will operate automatically every time an I/M program is called by the model. The MOBILE6 I/M credits will have several new features. They will incorporate new basic emission rates and I/M credits will be calculated for start and running emissions separately. Also MOBILE6 has new classifications for defining emitter categories. In MOBILE5, there were four emitter classifications: normal, high, very high, and super. For MOBILE6, the emitter categories are handled by two classifications, normal and high. Normal emitters are low emitting vehicles with emission control systems that generally function properly. High emitters have average emission levels which are considerably higher than the overall mean emission levels.

MOBILE6 will apply separate benefits to start and running emissions to generate I/M credits for 1981 and later model year vehicles. MOBILE6 will apply the same benefits to start and running emissions for pre-1981 model year vehicles.

More information on the new methodology for I/M credits can be found in the report "MOBILE6 Inspection / Maintenance Benefits Methodology for 1981 through 1993 Model Year Light Vehicles," report number M6.IM.001.

Data

A lack of "real world" data on repair effects was a constraint on this analysis. In order to be selected for this analysis a vehicle had to meet the following set of criteria:

- Model year 1981 and later (I/M credits for pre-81 will not be updated in MOBILE6)
- Gasoline vehicles only
- LDV or LDT only
- Not tested in California or Colorado (because of different standards and effects of higher altitudes respectively)
- Failed its "as received" test and passed its after-repair test
- Vehicle has both I/M240 and corresponding FTP results (FTP results are necessary to evaluate cold start emissions, i.e., emissions after 12+ hour soak)

The only available data meeting these criteria were in EPA's Emissions Factor Database. After eliminating vehicles that did not meet the above criteria, the remaining vehicles, with their FTP and IM240 results, created the database used in this analysis. This database contained 369 LDVs and 41 LDTs with model years ranging from 1983 through 1993.

Analysis

Calculating Start and Running Emissions

In order to examine repair effects on start emissions, it is necessary to determine what start emissions are. The FTP results were split into start and running fractions using the methodology explained in detail in report number M6.STE.002 and report number M6.STE.003.

Determining Emitter Categories

All the vehicles included in this analysis were classified as meeting "Tier 0" certification standards and were defined as either normal or high emitters. Normal emitters were defined as vehicles with FTP emission rates less than or equal to two times the standard for hydrocarbons (HC) and oxides of nitrogen (NOx) and FTP emission rates less than or equal to three times the standard for carbonmonoxide (CO). High emitters were defined as vehicles with FTP emission rates greater than two times the standard for hydrocarbons or oxides of nitrogen or FTP emission rates greater than three times the standard for carbon monoxide. The cutpoints used in defining an emitter category can be found in Table 1.

Table 1: Cutpoints used in determining emitter category

Vehicle Type	Model Year	2 x HC Stand. (g/mi)	3 x CO Stand. (g/mi)	2 x NOx Stand. (g/mi)
LDV	81 - 93	.82	10.2	2.0
LDT	81 - 87	1.6	30	4.6
LDT1* LDT2	88 - 93	1.6	30	2.4 3.4

*Light Trucks have different NOx standards based on vehicle weight

For the purpose of this analysis, additional criteria have been used for determining emitter-class designation. In cases where a vehicle exceeds the emission cutpoint for either HC or CO, it is considered an HC/CO high emitter. In this report, this emitter category will be known as "Emitter Class A." Vehicles which exceed the NOx cutpoint are considered NOx high emitters. This emitter category will be referred to in this report as "Emitter Class B." It is then possible for a vehicle to be a normal emitter for Emitter Class A and a high emitter for Emitter Class B or vice versa.

Determining Pass or Fail with Cutpoint Combinations

Determining whether a vehicle passed or failed its as-received or after-repair tests depends on the cutpoint for the test. The EPA developed six different sets of cutpoint combinations for this analysis that reflected the range of cutpoints currently being used in I/M lanes. These combinations are listed in Table 2. Different cutpoint combinations were analyzed to determine whether cutpoint selection would greatly affect the amount of emission reduction.(Of course, as described in M6.IM.001, cutpoints do affect identification rates and thus I/M credits) These cutpoints were applied to both LDVs and LDTs for all model years. As in actual I/M tests, a vehicle had two chances to pass for HC and CO pollutants. As set by IM240 standards, "if the composite emission level is equal to or below the composite standard or if the Phase 2 gram per mile emission level is equal to or below the applicable Phase 2 standard, then the vehicle shall pass the test for the exhaust component."(EPA Report Number: EPA-AA-EPSD-IM-93-1) Phase 2 in this context means the average emissions in the last 129 seconds of the IM240 test. An example of this pass/fail technique would be if a vehicle's IM240 composite HC emissions were 1.0 grams per mile and its Phase 2 emission were 0.5 grams per mile and the cutpoint combination being used was combination #2 in Table 2, the vehicle would fail the composite standard but would pass the Phase 2 standard therefore passing the test. This same vehicle would fail the test if it were examined using cutpoint combination #1. Each vehicle in the data set was given a pass or fail for each cutpoint combination.

Table 2: **Cutpoint Combinations Used to determine Pass or Fail for Composite (C) and Phase 2 (P2) test data.**

	Comb. #1		Comb. #2		Comb. #3		Comb. #4		Comb. #5		Comb. #6	
	C	P2	C	P2	C	P2	C	P2	C	P2	C	P2
HC	0.6	0.4	0.8	0.5	1.0	.63	1.2	.75	2.0	1.25	2.4	1.5
CO	10	8	15	12	20	16	30	24	60	48	78	60
NOx	1.5		2.0		2.5		3.0		4.0		6.0	

For this analysis, the EPA examined those vehicles that failed their as-received test and passed their after-repair test based on HC, CO and NOx cutpoints and both emitter Class A and Class B. Each vehicle's percent reduction for start and running emissions were calculated.

Calculating Percent Emission Reduction

Percent emission reduction can be calculated using a vehicle's before- and after-repair emission rates. Emission reductions for each pollutant were calculated using the following equation.

$$Percent\ Emission\ Reduction = \frac{E_{BR} - E_{AR}}{E_{BR}} \times 100$$

Where E_{BR} = Emissions Before Repair and E_{AR} = Emissions After Repair

Results

Table 3 and 4 contain the results of this evaluation. Vehicles were divided into categories based on their vehicle type and emitter category. Results showed that when repairing vehicles that were classified as HC/CO high emitters, there is a noticeable increase in NOx emissions. This would seem to indicate that I/M programs that test and repair vehicles based only on HC and CO failures (i.e., HC/CO high emitters) would on average increase the fleet NOx emissions. This phenomenon has been called NOx disbenefit and is discussed in more detail in EPA report number M6.IM.001.

ANOVA

After examining the start emission results from this table, it appears that on average, no matter which cutpoint combination was chosen, the same average after-repair emission levels were achieved. Based on this hypothesis, an analysis of variance (ANOVA) was performed on the data, examining model year, vehicle type and cutpoint combination as independent variables. Interest in model year and vehicle type significance comes from the fact that we want to be able to split the start emission rates in MOBILE6 by model year and vehicle type. Table 5 contains the results of this analysis.

TABLE 5: Analysis of Variance Results

Analysis of Variance Results (ANOVA p-values)*			
HC/CO High Emitters			
Variables	**HC**	**CO**	**NOx**
Model Year	.0188	.0001	.0001
Vehicle Type	.0001	.0014	.6968
Model Year x Vehicle Type	.0504	.0184	.9311
Cutpoint Combination	.4640	.6959	.7630
NOx High Emitters**			
Model Year	.0087	.0001	.0001
Vehicle Type	.6155	.0116	.0006
Cutpoint Combination	.9887	.9049	.9740

*in log space
** model year x vehicle type not applicable here because of lack of data

The statistical analysis showed that repair effects vary significantly by model year and also vary by vehicle type for all but NOx emissions of HC/CO high emitters and HC emissions of NOx high emitters. This analysis also verified that cutpoint combination was not a significant variable for all three pollutants.

Conclusions

After reviewing the results of this analysis EPA has chosen to use one cutpoint combination when determining the repair effects on start emissions. Cutpoint combination #2 at .8 g/mi. HC / 15 g/mi. CO / 2 g/mi. NOx was chosen because it is felt to be the most common cutpoint combination used by I/M programs because it is the cutpoint combination EPA suggests in the I/M test procedure guidance, EPA Report Number EPA-AA-EPSD-IM-93-1. Based on the results of the ANOVA analysis, the data was stratified by model year group based on EPA standards. Using cutpoint combination #2, the mean cold start after-repair emission levels were determined for LDVs and LDTs for Emitter Class A & B. These cold start after-repair emission levels, found in Tables 6 and 7, will be used to develop repair effects that will be applied to all starts in MOBILE6. It is these newly developed repair effects that will be used to compute I/M credits for start emissions. The methodology used to compute repair effects on starts and to calculate I/M credits can be found in EPA report number M6.IM.001.