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MOBILE6 Inspection / Maintenance Benefits Methodology for 1981 through 1995 Model Year Light Vehicles

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EXECUTIVE SUMMARY

List of Issues, Key Points, Assumptions and User Inputs
Regarding MOBILE6 I/M Credits

The methodology described in this document (M6.IM.001) covers 1981-95 model year cars and light-duty trucks. No significant FTP based data were available for the 1994 and 1995 model year vehicles, but these were included for I/M purposes with the earlier model years because of their general lack of On-Board Diagnostic (OBD) systems. The document also discusses I/M credits for running and start emissions. I/M credits are based on a simple distribution model in which every vehicle in the fleet is either a high emitter (FTP emission greater than 2 times HC or NOx standards or 3 times CO standards) or a normal emitter. The emission levels of the high and normal emitters are based on FTP data collected independently by EPA, AAMA and API as part of the organizations' in-use vehicle emission assessment programs. The frequency and distribution of high and normal emitters in the fleet is based on a large database of IM240 data collected in Dayton, Ohio in 1996 and 1997. The basic emission levels used in the model are a function of vehicle mileage, vehicle technology, and model year.

The basic assumption behind I/M is that a fraction of the high emitters in the fleet are identified and repaired down to lower emission levels during the I/M process. This process reduces the average emission level of the fleet by reducing the fraction of High emitters in the fleet. The I/M benefit is the difference in fleet emission levels between the No I/M baseline emission level and the after I/M fleet average.

MOBILE6 will allow various I/M scenarios to be modeled. Some of these are new to the MOBILE model series. The others have been changed or revamped in a significant manner. MOBILE6 will allow for some new features.

New Features:

1. Internal operation - Except for the constant ASM / IM240 ratio file, used to model an ASM based I/M program, and the TECH12 credit file used to model pre-1981 model year vehicles, there are No external I/M credit files to attach to the main program for 1981 and later model year vehicles.

2. I/M credits given for the IM240 test, the ASM tests, the Idle tests and OBD testing.

3. Custom user supplied cutpoints for IM240 can now be entered directly in the program. For example, the combination (1.5 g/mi HC, 55 g/mi CO, and 3.2 g/mi

NOX) can be entered for an IM240 scenario. Custom ASM test cutpoints cannot be entered directly into MOBILE6.

4. Ability to model up to seven different exhaust and evaporative I/M programs simultaneously.

5. Ability to model the exemption of the first “n” model years / ages in an I/M program. The “n” can be up to the first 25 model years / ages.

6. User input and default values for non-compliance with testing requirements, and cost waivers on failures can be specified.

7. I/M credits given for cost waivered vehicles.

Development of Important Parameters

1. The I/M methodology and associated parameters presented in this document are heavily based on four other EPA documents. These are “Determination of Running Emissions as a Function of Mileage for 1981-93 Model Year LDV and LDT Vehicles” - M6.EXH.001, and “Determination of Start Emissions as a Function of Mileage and Soak Time for 1981-93 Model Year Light Duty Vehicles.” - M6.STE.003. Also, the OBD and OBD I/M assumptions are discussed in the EPA MOBILE6.0 documents M6.EXH.007 and M6.EXH.009. The ‘007' document covers the Hydrocarbon (HC) and Nitrogen Dioxide (NOX) pollutants, and the ‘009' document covers the Carbon Monoxide (CO) pollutant. The reader is encouraged to obtain these documents from the EPA Web site and review them. The paper M6.STE.003 contains the start emission parameters (average normal and high start emission level), and the associated statistics.

2. Grouping Parameters - Most of the grouping of the data was done by model year and technology groups. Ported fuel injection (PFI) technology was split from throttle body injection (TBI) and carbureted technology. Model year groups were chosen based on engineering judgement regarding technology changes, or were grouped based on similar certification emission standards.

3. Basic emission rate and I/M analyses were done for both cars and light trucks separately. The same analysis approach was used for each vehicle type; however, different model year grouping were selected for cars and trucks because of the

different certification standards which were in effect. Also, MOBILE6 contains the MOBILE5 I/M estimates for Heavy-Duty Gasoline Vehicles. These were NOT updated in MOBILE6.

4. Basic Emission Rates - FTP emission factor data comes from significant EPA and industry testing (3,000+ FTP tests). It was corrected for recruitment bias (see M6.EXH.001) based on IM240 testing from Dayton, Ohio (211,000 IM240 tests).

5. Average emissions of Normals and Highs for start and running emissions - EPA / AAMA FTP data sample was used.

6. Identification Rate of High emitters - These are based on a sizeable database (900 vehicles) which received both the FTP and IM240 tests at an EPA contractor facility.

7. After I/M Repair Effects for running emissions - These are based on thousands of IM240 tests from Arizona on vehicles which were repaired to pass I/M.

8. After I/M Repair Effect for start emissions - These are based on FTP data collected by EPA.

9. Sawtooth Methodology - The Sawtooth algorithm has been removed from the MOBILE6 model exhaust I/M calculations for the 1981 and later model years. This change is a new and important feature of MOBILE6 since the previous Draft version of this document (EPA420-P-99-007) was released. The 'Sawtooth' was originally developed as part of the MOBILE2 model and was used in the MOBILE5 model. It was a methodology that attempted to account for fleet deterioration between successive I/M programs, and the standard practice of the auto industry to introduce its new model of vehicle in October of the previous calendar year.

   The Sawtooth algorithm was dropped from the exhaust model for a number of reasons. The primary reason is that it cannot accurately be programmed into the MOBILE6 model. This is because the sawtooth algorithm requires knowledge of emission levels and high emitter rates from one subsequent and two previous calendar years. Unfortunately, the structure of the MOBILE6 model is such that only the current calendar year is available to the program in a given run. Changes to this structure to incorporate a multiple calendar run algorithm would require a complete re-design and re-write of the MOBILE6 code. Without a complete re-design, incorporation of a more accurate version of the 'sawtooth' would have an extremely adverse effect on the execution time of MOBILE6.

Also, one of the important assumptions underlying the sawtooth methodology was the assumption that the emission deterioration of a fleet that did not have I/M was the same as the emission deterioration of a fleet between I/M inspections. On the surface, this sounds like a reasonable assumption given that no data to prove or disprove it currently exists. However, another line of reasoning suggests that once a vehicle has failed, it potentially could have a higher propensity to fail again even if it is brought back to specifications. This higher propensity is likely due to conditions beyond an I/M program's ability to control, such as poor manufacturer design, build, etc. ('a lemon'), or poor general maintenance or careless operation by the owner. To get an accurate picture of vehicle deterioration in an I/M program, a detailed multi-year study is required which tracks individual failures and passing vehicles, and determines the proper level of re-failure and its emission effects. In the absence of such a study, EPA now believes that the assumption of equal deterioration rates between the fleet 'on average' and the previously repaired vehicles is not likely valid, and has chosen to remove it from the MOBILE6 model.

A proper study of the long term behavior of vehicles in I/M has never been done. However, some limited work in this area has been done by Tom Wenzel at Lawrence Berkeley Labs using Arizona I/M and remote sensing data. This new work now suggests that I/M failures re-occur at a higher rate than the general fleet. For example, the work suggests that the re-failure rate is in the range of 30 to 40 percent; whereas the overall fleet failure rate is in the range of 15 to 20 percent. (Wenzel, Tom. "Evaluation of Arizona's Enhanced I/M Program", presentation at the 9th CRC On-Road Vehicle Emissions Workshop, April 21, 1999). These higher rates suggest that repaired failures are not as stable as assumed, or that many failures are not repaired as completely in first place as assumed.

The sensitivity of the emission result to the sawtooth algorithm was also investigated. It was discovered in the course of testing that the sawtooth methodology has only a very marginal effect on the size of the I/M benefits or the after repair emission levels. For example, it reduces them slightly, typically only one or two percent, to account for deterioration between calendar years. The change in I/M benefits from the Sawtooth is so marginal because the slope of the emission deterioration between calendar years is small. It is this 'slope' between inspections that the Sawtooth is attempting to model.

Despite the theoretical and practical problems associated with the Sawtooth algorithm, it was retained in the MOBILE6 model in three minor areas. First, it is still present in the I/M Evaporative calculations. Second, it is still present in the exhaust I/M calculations for pre-1981 model year vehicles. Finally, it is still present to an extremely limited degree in the Biennial I/M correction factors for the 1981 and later model years (see Point #10 below). Although, retention of the Sawtooth in these areas of the model produces some inconsistency, it was maintained in the model primarily because its removal would require considerable additional engineering analysis and re-programming. Also, in the case of the pre-1981 model years and the Biennial I/M correction factors, its effect will likely be non- existent for most current calendar year runs of the MOBILE6 model, or have an otherwise negligible effect.

10. One of the reasons to use the Sawtooth methodology in MOBILE6 was to account for the effects of a Biennial I/M program. In the absence of the Sawtooth, a new methodology was used that ratioed the Biennial I/M reductions from MOBILE5 with the Annual I/M reductions from MOBILE6. The resulting factor was applied to the annual I/M benefits in MOBILE6 to produce the reduced Biennial I/M reductions.

11. Waiver Repair Levels - In MOBILE6, cost waivered I/M failures will get some repair benefit. A value of a 20 percent reduction has been chosen. This value may updated in the future, if real data provides another value.

12. High Emitter Non-Compliance Rate - The definition of this parameter has been changed. In the draft version of this document, Non Compliance was defined as the fraction of the fleet which either do not show up for the I/M test in the first place (non participants), and the fraction of the failures which show up for the test, fail the test, but never show up again with either a successful repair or a waiver. In this case, the non participating vehicles were assumed to have the same emissions as the fleet average, and the fraction of the failures that did not show up were assumed to be High emitters. In the final version, vehicles in non-compliance will only include those vehicles which do not show up for the test, and it is assumed that they have the fleet average emission level. Vehicles that do not show up for the retest may also be considered non-compliant, and be assumed equivalent to those that do not show up for the initial test. MOBILE6 does not contain a default value for this parameter, but requires the user to specify one. The valid range is from 0 to 50 percent.

13. High Emitter Waiver Rate - This is now a required user input. It is the percent of I/M FAILURES that received a cost or hardship waiver to the full requirements of an I/M program. The basis for this rate is NOT the percent of the total fleet or the percent of the tested fleet.

14. MOBILE6 will assume that the ASM tests will have the same relative performance to the IM240 that they did in MOBILE5. This is necessary because no new ASM I/M test data matched with FTP data are available since MOBILE5 was released. New Idle and 2500RPM/Idle test data are available and new performance estimates have been computed, and will be installed in the MOBILE6 model. The ASM and Idle I/M test performance in comparison to the IM240 will be computed in the MOBILE6 model by adjusting the I/M test identification rate (IDR) factors.

15. The ASM tests assume the same after I/M repair emission levels as the IM240 tests. Only the IDR rates are different. The Idle test after repair rates are the same as the MOBILE5 Idle test repair rates, and these are generally higher (less effective) than the corresponding ASM and IM240 repair rates.

16. The MOBILE6 model will not have the capability of modeling a remote sensing test based program or a change of ownership I/M program. This omission is the result of insufficient time and resources to create this feature in the model. Code was developed to model RSD and change of ownership I/M. However, it proved to be unreliable and was removed from the MOBILE6 program development at the end of the process. If future versions of MOBILE6 are developed, they may contain the capability to model non-periodic inspection programs.

17. The MOBILE6 model WILL HAVE the capability to model 1996 and later model years using an exhaust I/M program. However, MOBILE6 will NOT have the capability of modeling an OBD type I/M program on pre-1996 model years. This change is a new and important feature of MOBILE6 since the previous Draft version of this document (EPA420-P-99-007) was released.

1.0 INTRODUCTION

This document describes EPA's new methodology for estimating exhaust emission Inspection / Maintenance (I/M) credits. This includes the methodology for various tests such as the IM240, the Idle test, the 2500 RPM/Idle test, and the ASM test. It includes the methodology used for all cars and light trucks for model years 1981 through 1995. The I/M credits for the pre-1981 model years are not being revised for MOBILE6. The I/M credits for post-1995 model years with OBD systems, and the evaporative emission I/M test credits will be discussed in a separate documents "Determination of Emissions, OBD, and I/M Effects for Tier1, TLEV, LEV, and ULEV Vehicles" - EPA documents M6.EXH.007, M6.EXH.009, and "Inspection / Maintenance Credits for Evaporative Control System Tests" - EPA document M6.IM.003.

MOBILE6 will handle I/M credits differently than previous MOBILE models. One major difference is the discontinuation of the TECH5 model. The TECH5 model was a complex external FORTRAN program which calculated and exported the exact I/M credit values. These credit values were then built into the MOBILE5 block data code or read as an external file. The new credit methodology will instead be built into the MOBILE6 code, and will operate automatically every time an I/M program is called by the MOBILE6 program. This change will give the MOBILE6 user the ability to vary the effect of cutpoints and other program parameters through changes to the MOBILE6 input file. No longer will it be necessary to develop special I/M credits using the TECH5 model, and attach them to the MOBILE program.

The new I/M credit methodology will also be updated to reflect the new basic emission rates (see "Determination of Running Emissions as a Function of Mileage for 1981-1993 Model Year Light-Duty Vehicles - Report Number M6.EXH.001"). In addition to being lower in magnitude, the new emission rates separate start and running emissions. MOBILE6 will account for these emissions separately, and produce separate start and running I/M credits.

This document is structured into six primary sections, and an Appendix section. Section 2 briefly describes the databases used in the analysis and development of the credits. Section 3 describes the methodology for development of the running exhaust I/M credits based on the IM240 test. Section 4 describes the periodic I/M credit calculation is mostly mathematical terms. Section 5 describes the methodology for development of the start exhaust I/M credits. Section 6 describes the methodology for the development of credits for the other types of I/M tests (Idle, 2500/Idle, and ASM). Section 7 presents user and peer review technical comments and EPA's response to the comments. The document also contains an Appendix section which is listed A through D. Appendix A contains sample data plots, Appendix B contains sample calculations, and Appendices C and D contain statistical diagnostics for many of the parameters used in this model.

2.0 DATA

Four databases were utilized to develop the IM240 based credits. The first database was a large emission factor database which contained over 5,000 initial FTP tests on 1981 through 1993 model year cars. It was used in the I/M credit analysis to determine the average emissions of the "Normal" emitting vehicles and the "High" emitting vehicles. This is the same database which was used to generate the basic emission rates prior to the application of the High Emitter Correction Factor. It is described in greater detail in "Determination of Running Emissions as a Function of Mileage for 1981-1993 Model Year Light-Duty Vehicles" - report number M6.EXH.001.

The second database was a smaller I/M database. It was used to determine the high emitter identification rates for the IM240 test. It contained 910, 1981 and later cars and trucks which had both an IM240 test and a running LA4 test (derived from the FTP test). It contained data from EPA emission factor testing in Ann Arbor, Indiana and Arizona in which vehicles were randomly recruited and tested on both the FTP test and the IM240 test.

This second vehicle emission database contains many of the same FTP / lane IM240 test pairs that were used for the MOBILE5 I/M credits. In an attempt to update the MOBILE6 credits with newer model year data, additional vehicle data with FTP / lab IM240 test pairs were added where FTP / lane IM240 were not available. Use of a lab IM240 versus a lane IM240 for I/M credit purposes introduces some additional uncertainty in the analysis since a lab IM240 test is less similar to an actual state conducted IM240 I/M test than a lane IM240. However, inclusion of the FTP / lab test data, enabled the analysis to include some post 1991 model year vehicles and additional light trucks rather than extrapolate these points. Thus, it was concluded that these benefits outweighed the slight increase in uncertainty caused by using lab IM240 data.

The third database was the Arizona IM240 database obtained from official state testing. It contained several thousand before-and after-repair IM240 tests, and was used to determine the repair effects for the running LA4 IM240 credits. It contains data from a special test program that the State of Arizona conducts on a continuous basis to evaluate the performance of their I/M program. In this program, vehicles are randomly selected to receive the full IM240 test both initially, and if they fail, after all subsequent repair cycles until they pass. EPA document - EPA 420-R-97-001 "Analysis of the Arizona IM240 Test Program and Comparison with the TECH5 Model" provides some detail regarding this testing.

The fourth database of about 970 EPA tested vehicles contained both IM240 and FTP data before and after repair. It was used to calculate the effects of repair on start emissions.

3.0 I/M ALGORITHM FOR RUNNING EMISSIONS

3.1 Definition of Categories

The basic purpose of I/M is to identify and repair high emitting vehicles with broken emission control systems. These types of vehicles are termed "High" emitters, and typically have average emission levels which are considerably higher than the overall mean emission levels. The remainder of the fleet is considered to be the "Normal" emitters. These are low and average emitting vehicles, and their emission control systems are generally functioning properly. The overall fleet emission factor is assumed to be a weighted average of the high and normal emitters. For comparison, the use of two emitter classes differs from the methodology used in the previous TECH5 and MOBILE5 models. In those models, there were four emitter classifications (Normal, High, Very High, and Super).

The MOBILE6 model will generate specific I/M credits based on pollutant, model year group, and technology type. Credits for the three pollutants HC, CO, and NOX will be produced. Also, credits for the 1981 through 1993 model years will be stratified into seven separate groups. These are: 1988-93 (PFI), 1988-93 (TBI), 1983-87 (FI), 1986+ (CARB), 1983-85 (CARB), 1981-82 (FI), and 1981-82 (CARB). PFI means ported fuel injection, TBI means throttle body fuel injection, (FI) means all closed-loop fuel injected, and (CARB) means closed-loop carbureted and all open-loop vehicles combined together.

3.2 General I/M Algorithm

Figure 1 is a general graphical view of the I/M algorithm for running emissions. Specific algorithms for each of the model year / technology / pollutant groups will be programed into the MOBILE6 model. Four lines are shown in Figure 1 which show the basic emission rate, the normal emitter emission rate, the high emitter emission level, and the after repair emission levels of the high emitters which were identified and repaired. The basic emission rate is shown as Line A. This line represents the average emissions of the fleet without an I/M test. It includes both the normal vehicles and the high emitting vehicles.

Line B in Figure 1 represents the average emissions of the normal vehicles. These are the vehicles which are very unlikely to fail any IM240 test cutpoint in the range used by I/M programs, and should not require any significant emission related repair if they did fail. The line is shown as a linear function of mileage to reflect the gradual deterioration that normal vehicles experience due to general wear. In the data analysis these vehicles were defined as normal emitters for a specific pollutant if their FTP HC emissions were less than twice the applicable new car certification standard, or their FTP CO emissions were less than three times the applicable new car certification standard, or their FTP NOX emissions were less than twice times the new car certification standard. In MOBILE6, it is assumed that these vehicles never fail I/M; no repair adjustment are made to them.

Line C in Figure 1 represents the average emissions of the high vehicles. These are the vehicles which likely have "broken" emission control systems, and that should fail the IM240 test cutpoint, and receive repair. In the data analysis these vehicles were defined as high emitters for a specific pollutant if their FTP HC emissions or FTP CO emissions exceeded twice or three times the applicable new car certification standard, respectively, or their FTP NOX emissions were two times the new car certification standard. Because high NOX emissions often occur with low HC and/or low CO emissions, and sometimes even HC can be high and CO normal, the three categories were kept separate. Thus, a vehicle could be a high HC emitter, but a normal CO and NOX emitter.

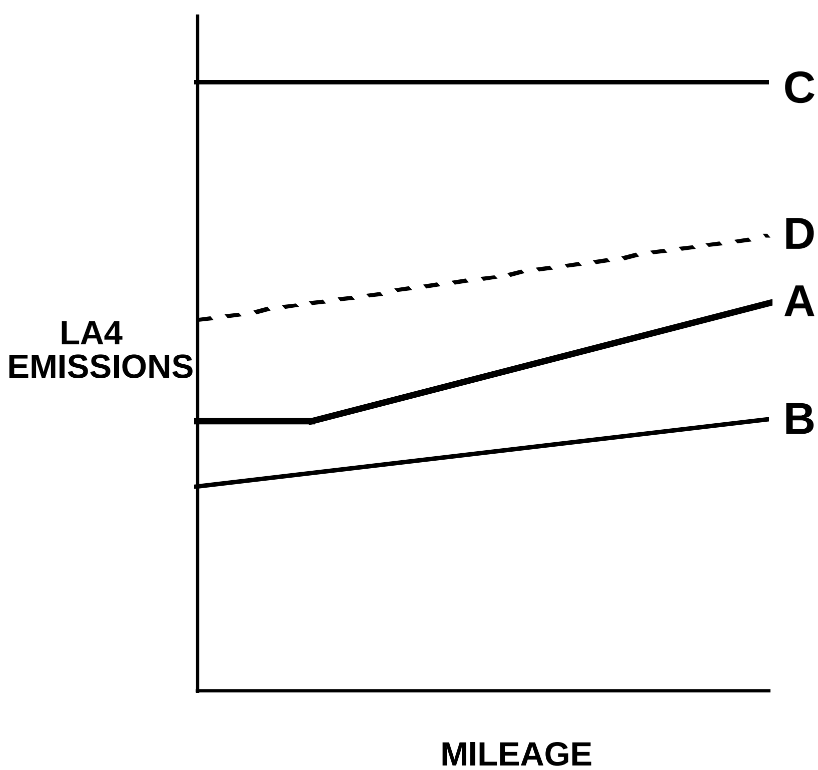
The selection of twice or thrice FTP certification standards for the boundary level between normals and highs is an engineering choice based on the literature on I/M and repair. Other reasonable boundary levels could also have been chosen. No formal analysis was done to prove that these levels were optimum. One of the reasons they were chosen is because they were used in MOBILE5, and have generally been shown in the past to be a good dividing point between high emitting broken vehicles and lower emitting vehicles which are not broken. Simple statistical analysis done on the data indicate that the two means are statistically different.

Line D represents the average emissions of the portion of high emitting vehicles that are identified and repaired because of the I/M process. This line is calculated as a function of vehicle age, and is a percentage (e.g., 150%) of Line B. The portion of the fleet which is identified by I/M will be repaired to a lower level on average. However, this level is generally not as low on average as the average of the normal vehicles. The justification for this assumption was an analysis of Arizona IM240 before and after repair data collected during 1995 and 1996. (See EPA report EPA-420-R-97-001 "Analysis of the Arizona IM240 Test Program and Comparison with the TECH5 Model" for a description of this dataset).

3.3 Calculation of Basic Running LA4 Emission Rates

Line A in Figure 1 represents the basic non-I/M emission rate for a given combination of vehicle type / pollutant / model year group / technology group. The units represented in Figure 1 are running LA4 emissions in grams / mile. The calculation methodology and databases used to determine these emission rates are fully documented in the report "Determination of Running Emissions as a Function of Mileage for 1981-1993 Model Year Light-Duty Vehicles," report M6.EXH.001. The reader is encouraged to review this document for more details. Selected emission rates were taken from M6.EXH.001 and used in this current report as examples.

FIGURE 1
GENERAL I/M CREDITS SCHEMATIC



3.4 Calculation of Running LA4 Emission Rates for Normal Emitters

Line B in Figure 1 represents the average emission rates for Normal emitters. These are the low emitting vehicles in the fleet which should not fail an I/M program. Line B was calculated by least squares regression of the emissions of the normal emitters versus mileage in the FTP dataset. Sample sizes were satisfactory in all cases. The regression was done for each pollutant / model year / technology group. The regression coefficients for cars are shown in Table 1a and light trucks in Table 1b. The column labeled ZML contains the zero mile coefficients, and the column DET contains the deterioration coefficients (slope) from the regressions (units are grams per mile per 1K miles). A sample scatterplot of the car data and the regression line is shown in Figure A-1 through A-3 in Appendix A.

Table 1a
Regression Coefficients for RUNNING LA4 Emissions from Normal Emitter Cars

MY Group	Tech Group	HC Coefficients		CO Coefficients		NOX Coefficients	
		ZML	DET	ZML	DET	ZML	DET
1988-93	PFI	0.0214	0.001385	0.4588	0.02293	0.2006	0.00376
1988-93	TBI	0.0042	0.001701	0.0000	0.01990	0.2253	0.00381
1983-87	FI	0.0942	0.001439	1.4448	0.01959	0.4798	0.00188
1986-89	Carb	0.0774	0.000812	0.5666	0.01371	0.4960	0.00170
1983-85	Carb	0.1266	0.001214	0.7276	0.01691	0.5555	0.00273
1981-82	FI	0.0970	0.002250	1.5762	0.02150	0.4597	0.00633
1981-82	Carb	0.1539	0.001271	1.3932	0.01389	0.5834	0.00233

Table 1b Regression Coefficients for RUNNING LA4 Emissions from Normal Emitter Light Trucks							
MY Group	Tech Group	HC Coefficients		CO Coefficients		NOX Coefficients	
		ZML	DET	ZML	DET	ZML	DET
1988-93	PFI	0.02989	0.002376	0.4927	0.02678	0.3024	0.003904
1988-93	TBI	0.04664	0.002998	0.7663	0.03442	0.3150	0.003171
1981-87	FI	0.13384	0.003280	1.6222	0.04311	0.3150	0.003171
1984-93	Carb	0.26835	0.002701	1.3553	0.06660	1.2872	0.00010
1981-83	Carb	0.49182	0.006485	7.4202	0.03293	1.6159	0.000025

3.5 Calculation of Running LA4 Emission Rates for High Emitters

Line C in Figure 1 represents the average emission rates for High emitters. These are the vehicles in the fleet which likely have problems with their emission control systems, and have emission levels which are considerably higher than the vehicles which do not have problems. In the analysis they were defined as those vehicles exceeding either twice FTP standards for HC or three times FTP standards for CO or twice NOX standards. The line used in MOBILE6 is a flat horizontal line (constant emission level) because the emissions of a high emitter were not found through regression analysis to be a strong function of mileage. One possible reason for the poor correlation is an insufficient sample size of high emitters over a large mileage range. This sample size makes the regression determined mileage coefficients statistically unreliable. The other possible reason is that the relationship does not exist, and that high emitter emission levels are fairly constant values (at high rates).

Various analyzes of failing cars in EPA test programs support the use of a flat emission rate for high emitters. Typically, what was found during the test programs on the newer closed loop vehicles is that if something goes seriously wrong with the emission control system it is likely to be catastrophic, and immediately leads to high emissions. Furthermore, the problems are likely to be fairly discrete in their occurrence (i.e., not mechanical wear in the carburetor that creates large numbers of high emitters over time, or built-in obsolescence at a particular mileage).

The weaknesses of this simplified approach are: (1) that a certain percentage (extremely small) of the brand new vehicles will be modeled as being high emitters. This result occurs because at zero miles, the regression developed estimate of normal emitter's emission level is below the FTP and Ohio data developed estimate of the corresponding mean fleet emission level; and (2) massive quantities of state IM240 data on failing vehicles suggest that the average IM240 emission level of a failure is a function of age rather than a flat line. However, these data are unpreconditioned IM240 results rather than fully preconditioned FTP results. They are strongly influenced by the pass/fail cutpoint which is a function of model year, and may or may not completely represent a high emitter as defined in this document. Nevertheless, because of the importance of this assumption, future generations of the MOBILE6 model may use a non constant average high emitter level if the data warrants .

Table 2a shows the average emissions of the high emitters (cars only) for the 21 pollutant / model year / tech groups. Trucks are shown in Table 2b. Because of the small sample size of high emitters in most groups, some model year / technology groups were combined into another model year group and across technology groups, and an overall mean was computed for the combined group. This combination was particularly true for NOX emissions. For the cars and for each pollutant, the 1986-89 Carb and the 1983-85 Carb were combined and averaged together. Likewise the 1981-82 Carb and 1981-82 FI Car groups were combined and the emissions from the high emitters were averaged together. For the trucks, in some cases the fuel injected trucks were combined together and a common mean high emitter emission level was computed for each pollutant. This combination had the effect of producing more consistent means across groups. The high emitter HC emission level for the 1988-93 MY PFI group is also a special case. Due to a relatively small sample size of 1988-93 model year high emitters, and a very low average high emitter HC emission level (the average high emitter HC emission level was lower than the average emitter HC emission level at moderate mileages), the 1986 and 1987 model year PFI vehicles were added to the sub-sample of 1988-93 model year PFI vehicles. The principal effects of this operation were to almost double the number of high emitters in the sub-sample, increase the average high emission HC level from 1.10 g/mi HC to 1.74 g/mile, and to reduce the fraction of HC high emitters in the fleet from a theoretical 100 percent to a more reasonable level.

The impact of this approach of averaging between groups and adding selected vehicles to particular groups is that some high emitting vehicles contribute to the average high emitter level of their own model year group, and to another model year group. This does <u>not</u> affect the average non-I/M running emission estimates because the normal and high emitter split is not used to calculate the average non-I/M estimates. However, it <u>does</u> affect the I/M emission rate and I/M benefits because it changes the portion of a particular model year group's emission distribution between normals and highs. This changed emission distribution will affect the fraction of fleet emissions in MOBILE6 which are identified and repaired by I/M. It is difficult to predict the size of the overall emission impact (I/M and Non I/M) from this data combination because it simultaneously increases the average high emitter emission level, but decreases the fraction of high emitters in the fleet. This change also impacts (increases) the start emissions and the start I/M credits because it changes the fraction of high start emitters in the fleet (fraction of start high emitters is equal to the fraction of running LA4 high emitters), but does not affect the average start high emitter level.

An analysis of the Ohio IM240 data was also done to try and estimate the high emitter levels for running LA4 and start emissions. This was done because of the small numbers of high emitters in the EPA and AAMA FTP (running LA4 and Start) data samples. In this analysis, a large sample of Ohio vehicles were segregated into normal and high emitters, and the average high emitter emission levels were determined and compared with the FTP based estimates. They compared favorably. However, the analysis was plagued with uncertainties such as how to separate the normals from the highs when FTP data are not available, the inability to split PFI from TBI in the Ohio IM240 data, a questionable transformation of IM240 results into running LA4 and start emissions, and unknown and possibly inconsistent conditions between lab testing and IM240 lane testing. Because of these problems the Ohio IM240 data were not used to estimate the average high emitter emission levels.

Table 2a
Mean RUNNING Emissions of High Emitter Cars

MY Group	Tech Group	HC Mean	CO Mean	NOX Mean
1988-93	PFI	1.740	36.106	2.846
1988-93	TBI	3.394	46.527	2.872
1983-87	FI	2.372	37.933	2.951
1986-89	Carb	1.845	27.653	2.872
1983-85	Carb	1.845	27.653	2.872
1981-82	FI	2.372	37.933	2.951
1981-82	Carb	2.372	37.933	2.951

Table 2b Mean RUNNING Emissions of High Emitter Light Trucks				
MY Group	Tech Group	HC Mean	CO Mean	NOX Mean
1988-93	PFI	2.120	33.283	2.846
1988-93	TBI	3.241	33.283	2.846
1981-87	FI	2.446	43.870	2.846
1984-93	Carb	2.012	39.415	4.988
1981-83	Carb	3.710	80.726	5.014

3.6 Calculation of After Repair Percentages and Emission Levels

Line D in Figure 1 represents the average after repair emission level of high emitters that are properly identified and repaired. In comparison, Line C represents those high emitting vehicles that are not identified and repaired properly, or belong to owners who evade the program after failing the initial test. Line D is calculated by scaling up the normal emitter emission level (Line B) using a multiplicative factor process which is a function of age, pollutant and cutpoint level (derived from Arizona IM240 data). The normal emitter emission level is the basis for the after repair emission level, and is the lowest emission level to which high emitting vehicles can be repaired after adjustment for age and mileage. This assumes that the I/M process on average does not turn aged vehicles into brand new ones.

3.6.1 After I/M Repair Multiplicative Adjustment Factor

The after I/M repair multiplicative adjustment factor is a function of vehicle age and I/M cutpoint. It is calculated using a two step process. The first step is to calculate the multiplicative adjustment factor for the standard set of IM240 cutpoints which the State of Arizona used in its IM240 program. These are the phase-in cutpoints of 1.2 g/mi HC / 20 g/mi CO and 3.0 g/mi NOX. The second step involves computing and applying another ratio which is a function of IM240 cutpoint. It will allow the MOBILE6 program to assign a different after repair emission level as a function of IM240 cutpoint. The combined after I/M repair multiplicative adjustment factor is multiplied by the normal emitter emission level to calculate the after repair emission levels.

Phase-in Cutpoints

Equations 1 through 3 are the multiplicative adjustment factors used to calculate the after repair emission level for HC, CO and NOX under phase-in cutpoints. They were calculated from a large sample of Arizona IM240 data. The same coefficients are used for both cars and light trucks. The percent after repair I/M emission levels for the high emitters which were identified by I/M and repaired were developed by: (1) Stratifying the sample by age into 15 groups (ages 1 through 15); (2) Computing for each age group the average emission level of the vehicles passing their initial Arizona I/M test; (3) Computing for each age group the after repair passing emission values of the Arizona I/M failures; (4) Computing for each age group the ratio of the emissions of the repaired high emitters over the emissions of the initial passing vehicles; (5) Regressing the ratios versus age for each of the three pollutants to produce Equations 1 through 3.

Equations 1 through 3 are used to produce Line D for the phase-in cutpoints (1.2/20/3.0) by following the two steps.

First, Line D is calculated as a percentage of Line B using Equations 1 through 3.

HC ratio	=	2.2400 - 0.07595 * (vehicle age)	Eqn 1
CO ratio	=	2.1582 - 0.07825 * (vehicle age)	Eqn 2
NOX ratio	=	1.6410 - 0.04348 * (vehicle age)	Eqn 3

In these equations, vehicle age ranges between 1 and 15 years, and the percentage value at 15 years is used for all ages greater than 15. A value of 1.0 used in cases where the computed value is less than 1.0.

Second, the percentage values calculated in Eqns 1 through 3 (i percentage in Eqn 4) are transformed into emission units by multiplying the percentage values by the emission values in Line B (average emission of the normal emitters) using Eqn 4. The emission level of the Normals is a function of mileage.

After repair emissions pollutant i = i percentage * Emissions of Normals   Eqn 4

Other Cutpoint Combinations

Equations 1 through 4 are used to produce the after repair emission levels for an IM240 program which uses the phase-in cutpoints of 1.2/20/3 for HC, CO, and NOX respectively. Another adjustment factor is used to compute after repair emission levels for other cutpoints. It is a multiplicative factor which proportionally increases or decreases the after repair emission level computed for the 1.2/20/3 phase-in cutpoints to account for tighter or looser cutpoints.

The factor used to compute the after repair emission level for cutpoints other than 1.2/20/3 phase-in cutpoints is based on a limited amount of vehicle repair data collected by EPA in past testing programs. It was utilized to overcome the limitation of repair data collected at only one set of cutpoints in Arizona. This dataset was the same one used to develop MOBILE5 repair effects and technician training I/M credits. The repair effects dataset which was used consists of 273 vehicles from model years 1981 through 1992 tested by an EPA contractor in South Bend, Indiana and at the EPA lab in Ann Arbor, MI. All of these vehicles had before and after repair IM240 and FTP tests. The sample of vehicles were repaired to various FTP emission level targets. None of the after repair results included a catalyst replacement.

The principal goal of the data analysis was to determine as a function of IM240 cutpoint, the FTP after repair emission levels of vehicles which initially failed the IM240 tests and were repaired to pass the IM240 test. For MOBILE5, this analysis was done for seven different HC/CO cutpoint combinations and for five NOX cutpoints. These combinations are repeated in this document because they are the only after repair FTP data for a variety of cutpoints which currently exists. These cutpoint combinations are shown in Tables 2c and 2d. Also, shown in Tables 2c and 2d are the after repair emission levels for each cutpoint combination group, and the ratio of a given after repair emission level to the after repair emission level at 1.20 g/mi HC / 20 g/mi CO. For NOX, the individual cutpoint groups are ratioed to the 3.0 g/mi NOX group.

It also needs to be noted that the MOBILE6.0 program cannot model IM240 programs where the cutpoint is lower than 0.8 g/mi HC, 15 g/mi CO or 2.0 g/mi NOX. Table 2c and 2d contain values for low cutpoints that are not allowed to be modeled in MOBILE6. They are shown for purposes of completeness of the document.

Table 2c FTP After Repair HC and CO Emission Levels and Ratios versus IM240 HC/CO Cutpoint Combination					
HC Cutpt (g/mi)	**CO Cutpt (g/mi)**	**After Repair HC (g/mi)**	**After Repair CO (g/mi)**	**HC Ratio**	**CO Ratio**
1.2	20	1.26	13.46	1.00	1.00
0.8	15	1	11.85	0.79	0.88
0.6	15	0.88	11.94	0.70	0.89
0.6	12	0.87	11.15	0.69	0.83
0.6	10	0.86	10.50	0.68	0.78
0.4	10	0.78	11.30	0.62	0.84
0.4	15	0.74	11.71	0.59	0.87

Table 2d FTP After Repair NOX Emission Levels and Ratios Versus NOX IM240 Cutpoint					
NOX Cutpt (g/mi)		After Repair NOX (g/mi)		NOX Ratio	
1		0.91		0.489	
1.5		1.22		0.656	
2		1.48		0.796	
2.5		1.68		0.903	
3.0		1.86		1.000	

For MOBILE6, the ratios data in Tables 2c and 2d were regressed versus HC, CO and NOX cutpoint to produce an after repair emission level ratio for any HC, CO or NOX cutpoint (within the range allowed by MOBILE6) which the user may enter in MOBILE6 (the MOBILE6 user is no longer restricted to a set of seven cutpoint combinations). A least squares linear regression was used to produce the relationships for both HC/CO and NOX. The regression coefficients are shown in Table 2e. The equation form for the HC Ratio and the CO Ratio are:

$$\text{Ratio} = A * \text{HCCut} + B * \text{COCut} + C \qquad \text{Eqn 3b}$$

For NOX it is:

$$\text{Ratio} = B * \text{NOCut} + C \qquad \text{Eqn 3c}$$

A linear regression was used instead of some other functional form because it produced high r-squared values (0.99 for HC and NOX and 0.95 for CO). Also, note that the highest IM240 cutpoint for HC and CO are 1.2 and 20 g/mi. Repair effects at cutpoints higher than these will be linear extrapolation.

Table 2e
Regression Coefficients for Repair Effects Ratios

Ratio	A	B	C	r^2
HC Ratio	0.4990	-1.011e-04	0.398	0.996
CO Ratio	0.0249	0.0168	0.620	0.950
NOX Ratio		0.2538	0.2613	0.993

3.6.2 Application of the After Repair Adjustment Factors

The ratio equations are used in MOBILE6 to compute the after repair emission levels for cutpoints which are different from the standard 1.2 / 20 / 2.0 cutpoints used by Arizona. This is done by multiplying Equations 1 or 2 or 3 by Equation 3b or 3c to produce the repair effects ratio for the non standard (1.2/20/2.0) cutpoint. The final repair level is obtained by multiplying this ratio by the appropriate normal emitter emission level line (Line B). The normal emitter emission level is used as the final after repair emission level if it is larger than the calculated after repair emission.

The following example calculation of the after repair HC emission level for an HC/CO cutpoint combination of 0.80g/mi HC and 15 g/mi CO is shown below for clarity.

Aft Repair HC = (2.24-0.07595*age) * (0.4990*0.8g/mi - 1.01e-04*15.0g/mi + 0.398) * Norm_ave

where

Norm_ave is the average emissions of the normal emitters. It is a function of mileage and technology/model year group. For an eight year old 1990 PFI vehicle at 100,000 miles it is: 0.0214 + 0.001385 * 100 = 0.159 g/mi Running HC.

0.8g/mi HC is the HC cutpoint; 15.0g/mi is the CO cutpoint.

Substituting the value of 0.159 g/mi and 8 years old into the After Repair HC equation produces an after repair emission level of <u>0.206</u> g/mi running HC at a cutpoint of 0.80 g/mi HC and 15 g/mi CO for an eight year old vehicle with 100,000 miles. This compares with an after repair emission level for the same age and mileage of <u>0.260</u> g/mi running HC at a cutpoint combination of 1.2/20 g/mi HC/CO. In this example, the after repair emission level (0.206 g/mi HC) is above the value of the normal emitter (0.159 g/mi HC). However, if the calculation produced a value which was lower, then the normal emitter value would be used.

3.6.3 Discussion of the After Repair Adjustment Factors

This approach attempts to utilize the large sample of before and after repair IM240 data collected in Arizona. These data are an improvement over the MOBILE5 assumptions since they are a large sample, and are representative of the actual I/M experience. The in-use data reflects the fact that regular commercial mechanics performed the repairs under actual cost conditions. Also, the repairs were targeted to passing the actual state IM240 test. Many of these technicians also received some training and orientation to the IM240 program provided or encouraged by the State of Arizona prior to its implementation. The principal assumption underlying this approach is the ratio between the after repair IM240 emission level and the emission level of the vehicles passing the state IM240 test is the same as the ratio of the after repair running LA4 emission level and the normal emitter running LA4 emission level. This is not an unreasonable assumption; however, there are potential differences between the unpreconditioned IM240 and the preconditioned running LA4 test.

One drawback to the approach is that the Arizona data (and other states' data) were available at only one cutpoint level (phase-in cutpoints). This made it impossible to determine the sensitivity of repair levels to the IM240 cutpoint. To overcome this obstacle the previous FTP databases used for MOBILE5 were used to make the after repair effects a function of cutpoint. A drawback to the use of these FTP data is that they are a relatively small sample, the repairs were often performed by expert emission control system technicians rather than commercial technicians, cost was usually not a factor in the repairs, and specified numerical repair targets based on the FTP test were used. Also, running LA4 were not available so the FTP data were used directly under the assumption that the ratio between cutpoints is same for the FTP and the running LA4.

3.6.4 Technician Training Effects

MOBILE5 had built-in I/M credits available for IM240 programs which conducted some form of technician training for people involved in I/M repairs. In MOBILE6, the after repair emission levels discussed previously in Section 3.6 already include the effects of technician training. This is because Arizona conducted a technician training program prior and during implementation of their IM240 program from which the repair effects data are based.

MOBILE6 will use as a default, after repair emission levels which are those 'with technician training'. For I/M programs which do not conduct a technician's training program - 'w/o technician training', the after I/M repair emission levels will be increased by the percentages shown in Table 2f.

The percentages shown in Table 2f are based on a limited study done by EPA to evaluate technician training in an IM240 program. In the program, eleven experienced technicians in Arizona were trained on the eve of the IM240 implementation in 1995 to repair emission failures using a training program developed by Aspire, Inc., and taught by an expert emission control system technician/trainer under EPA contract. Each participant received the training and three vehicles to repair following the training. Unfortunately, budget limitations prevented a good pre-training baseline of the technicians' performance to be established. The study is fully documented in SAE Paper 960091.

The emission results shown in columns 2 and 3 of Table 2f are IM240 test results in units of grams per mile. The Student Tech column shows two numbers. The first number is the before any repair emission level. It is shown for comparison only, and to demonstrate that the technicians made sizeable emission reductions from repairs. The second number is the average after repair IM240 emission levels of the vehicles after the students completed their work. The Master Tech column shows the average after repair IM240 levels after the instructor completed any additional repairs which were needed to bring the vehicle into complete compliance. On a few vehicles this included a new catalytic converter.

The % Difference column is the percent difference between the after repair student tech and the after repair master tech emission results with the after repair master tech results as the basis. It demonstrates the potential difference in performance between a master tech and a trainee (journeyman) tech. It is proposed for MOBILE6 to calculate the 'w/o tech training' after repair levels (w/o means without) by increasing the 'with tech training' values by the % Difference values in Table 2f.

Table 2f **Technician Training Emission Effects**			
Pollutant	Master Tech IM240 (g/mi)	Student Tech IM240 (g/mi)	% Difference
HC	0.38	2.16 / 0.68	78 %
CO	3.00	26.4 / 8.21	174 %
NOX	1.11	3.66 / 1.54	39 %

Use of these limited data in MOBILE6 for technician training effects requires two important assumptions. First, that the after repair levels developed in the previous sections already contain the effects of technician training. This is a reasonable assumption since Arizona did institute a technician training program, and the after repair emission levels are at relatively low levels. Second, that the difference on a percentage basis between the master tech performance and the student tech performance is the same as the percentage difference between the with and w/o technician training in the overall fleet. This assumption is a little tenuous since the performance of typical trained technician is not as high as the master tech in this study. This would have a tendency to produce a larger percentage increase than in actuality. On the other hand, the student tech results were collected after the training rather than before the training, and do not strictly represent un-trained technicians. This factor would have a tendency to produce a smaller percentage increase than in actuality.

3.7 Waiver Repair Line

Not shown in Figure 1 is the waiver vehicle repair line. However, this line falls between the high emitter level and the after proper repairs line. These are failing vehicles which received a waiver from program requirements because a minimum amount of money was spent on unsuccessful or only partially successful repairs. Typically, in most I/M programs this means that between $200 and $450 was spent on the vehicle, and it still fails the I/M test. The waiver repair line is below the high emitter line, despite the vehicle's failing status, because even some limited or ineffective repair translates into reduced emissions on average.

Because no analysis has yet been conducted on data from operating IM240 programs to estimate the after I/M emission level of vehicles which were waived from the requirement to pass the test, an assumed reduction percentage will have to be used, or the individual user will have to provide a value. The default value will be a 20 percent reduction from the high emitter line for all pollutants.

3.8 Percentage of High and Normal Emitters in the Fleet

Figure 1 shows in a general sense the overall fleet average emission level, the average emissions of the normal emitters, and the average emissions of the high emitters. The fleet average emission level was developed independent of the I/M credits, and the methodology for its development is documented in EPA document M6.EXH.001. In-order to compute the I/M credits, the percentage of high emitters and normal emitters in the fleet must also be calculated. Fortunately, this is an easy task since the average emission rate is a weighted average of the normal emission rate and the high emission rate. The weighting factors are simply back calculated to make this true at all odometers.

The fraction of High and Normal emitters is calculated for each combination of vehicle type / pollutant / model year / technology group using the following general equations.

Where:

Highs = fraction of High emitters at each age point
Normals = fraction of Normal emitters at each age point
LA4 is the average emission rate at each age point (determined in M6.EXH.001)
High_ave is the high emitter emission average at each age point
Norm_ave is the normal emitter emission average at each age point

$$\text{Highs} + \text{Normals} = 1 \qquad \text{Eqn 5}$$

and

$$\text{LA4} = \text{High\_ave} * \text{Highs} + \text{Norm\_ave} * \text{Normals} \qquad \text{Eqn 6}$$

Solving for the variables Highs and Normals produces:

Highs = (LA4 - Norm_ave) / (Highave - Norm_ave) Eqn 7

Normals = 1 - Highs Eqn 8

For the model year groups of 1981-82 and 1983-85 HC and CO emissions, it was found that the base emission factors at higher mileage levels become higher than the average emissions of the high emitters. It occurs because at high mileages the basic emission factors are data extrapolations. However, under the structure of the model, this is not possible, and it implies that the fleet contains more than 100 percent high emitters. To overcome this inconsistency, it was assumed that the average base emission factors could not continue to rise after it reaches the average of the high emitters, and that it would be set to the average of the high emitters. Typically, the cross-over point is between 150,000 and 200,000 miles, and after this point is reached, it is assumed that the percentage of highs in the fleet for this model year group / technology is 100 percent. This flattening of the emission factor line at very high mileages is consistent with some remote sensing studies. A physical explanation would be that while some surviving vehicles continue to deteriorate, the worst emitters are progressively scrapped out of the fleet in the high mileage range.

3.9 High Emitter Identification Rates

The high emitter identification rate (IDR) represents the ability of an I/M test to identify (fail) vehicles which are high emitters. It is represented as the percentage of the total sum of emissions from the high emitters in the fleet. For example, the IDR would be 100 percent if it identified all of the running LA4 emissions from the high emitters in the fleet. For the HC and CO I/M credits, the IDR is a function of the IM240 HC and CO cutpoints. For NOX I/M credits, it is a function of the NOX cutpoints only. In MOBILE6, the user will be able to supply the exact IM240 cutpoints which are desired, and the program will automatically calculate the IDR and the credits. The IM240 cutpoints will need to be in the ranges: HC: 0.80 to 5.0 grams/mile; CO: 15.0 to 100.0 grams/mile; and NOX: 2.0 to 5.0 grams/mile.

The I/M IDRs equations were calculated from the 910 vehicle database that contained vehicle emission data from both running LA4 tests (FTP tests) and IM240 tests on lane fuel on cars and trucks. Cars and trucks will have the same IDR rates in MOBILE6 at a given cutpoint. However, separate cutpoints will be allowed for cars and trucks and for each model year in a given MOBILE6 run. The analysis to develop the IDRs consisted of several steps:

(1) The sample was split into two groups - the high HC and CO emitters, and the high NOX emitters. There was some overlap between the groups. These two groups were kept separate throughout the rest of the IDR analysis. (2) The total HC, CO, and NOX emissions from all of the High emitters in the sample was calculated. (3) A total of 75 HC / CO cutpoint combinations were developed. These ranged from (0.5g/mi HC / 5g/mi CO) to (5.0g/mi HC / 100g/mi CO). For NOX, eight cutpoints were used that ranged from 1.0 g/mi to 5.0 g/mi. (4) The running LA4 emissions identification rate (IDR) was determined for each cutpoint combination. For example, the strict cutpoint combination of 0.5 g/mi HC / 5.0 g/mi CO might identify 90 percent of the total emissions of the high emitters whereas the lenient cutpoint combination of 5.0 g/mi HC / 100 g/mi CO might identify only 10 percent of the total emissions. (5) The identification rate (IDR) were calculated for 75 HC/CO cutpoint combinations, and these points were least squared regressed versus the natural logarithms of the HC and CO cutpoint. Natural log regressions were used because they produced better fits, and better satisfied the inherent assumptions behind least squares linear regression. The logarithm form also makes sense physically given the skewed distribution of emissions. For example, a change of the HC cutpoint from 1.0 to 1.5 g/mi has a larger effect on IDR than a change from 4.0 to 4.5 g/mi. The regression coefficients are shown in Equations 9 and 10. (6) The NOX emission identification rate (IDR) were also calculated for eight cutpoints and fitted to a cubic equation. The cubic form was chosen because it provides a very good fit, and does not create anomalous results such as an IDR decrease as the cutpoint gets more stringent (See Appendix D). Simpler, linear fits for both the HC/CO cutpoint and the NOX cutpoint IDR, and a fit including all three pollutants simultaneously were also investigated. These were rejected due to poor statistical correlation, and anomalous results for the case of all three pollutants.

In MOBILE6, the IDRs for all 1981 and later cars and light trucks are represented by Equations 9 through 11. Where ln(HCcut), ln(COcut), and ln(NOcut) are the cutpoints transformed into natural logarithm space.

$$\text{HC IDR} = 1.1451 - 0.1365*\ln(\text{HCcut}) - 0.1069*\ln(\text{COcut}) \qquad \text{Eqn 9}$$

$$\text{CO IDR} = 1.1880 - 0.1073*\ln(\text{HCcut}) - 0.1298*\ln(\text{COcut}) \qquad \text{Eqn 10}$$

The NOX IDR equation is a cubic form:

$$\text{NOX IDR} = 0.5453 + 0.7568*\text{NOcut} - 0.3687*\text{NOcut}^2 + 0.0406*\text{NOcut}^3 \qquad \text{Eqn 11}$$

The statistics for both the logarithmic fit and the cubic fit are shown in Appendix D.

3.10 I/M Non-Compliance Rates

One potential problem in I/M is that of non-compliant vehicles. By definition, the compliance rate is the percentage of vehicles in the fleet that complete the I/M program and receive either a certificate of compliance or a waiver. The Non-Compliance rate is therefore, the percentage of vehicles in the fleet that do NOT complete the I/M program with either a certificate or a waiver.

A non-compliant vehicle may occur in one of two mechanisms. In the first method vehicles simply do not show up for their initial test (owners ignore I/M or go out of their way to avoid it). If these vehicles are normal emitting vehicles (passing the I/M test) they have no effect on the result; however, if they are high emitters then they should have the same effect as the initial failures which never pass or get waived. Unfortunately, because they do not show up for I/M it is impossible to determine these statistics. As an approximation, the model assumes that a non-compliant vehicle emits at the level of the average vehicle in the fleet (i.e., mixture of failures and passes).

In the second method, vehicles show up for the initial test, fail the initial test, but never return for a successful retest or a waiver. Clearly, these vehicles are failures, and getting them and other failures repaired is the goal of I/M. Failure to repair such vehicles should seemingly impose a larger credit loss than a simple random participation loss that is imposed for non-compliance mechanism one. Nevertheless, the one mitigating factor in this case is the fact that the outcome of such vehicles is unknown. For example, some research done by Colorado and Arizona to identify and track such vehicles, suggests that many are sold outside of the I/M program area or are scrapped. If such is the case, then the excess emissions created by these vehicles has been eliminated by the I/M program. Thus, as an approximation, the MOBILE6 model assumes that a non-compliant vehicle of mechanism two emits at the level of the average vehicle in the fleet (i.e., mixture of failures and passes).

4.0 I/M Credit Calculation

4.1 General Considerations of the I/M Algorithm

In this section all of the individual parameters discussed in previous sections such as High and Normal emitter rates and emission levels, waiver and non-compliance rates, and I/M identification rates are shown in mathematical form, and utilized together to calculate the I/M benefits. This section supercedes Section 4.0 in previous Draft versions of this document that discussed the 'Sawtooth" methodology. The 'Sawtooth" methodology has been replaced in favor of this new simpler methodology. The Executive summary of this document contains a brief rationale for this decision.

Throughout the calculations, the MOBILE6 program does not use "continuous" regression lines of emissions versus mileage (No I/M and I/M) or the fleet fraction of High emitters versus mileage. Instead, all of the calculations are done at discrete points on these lines. Each point on the line represents a particular vehicle age that ranges from 1 to 26 years and a corresponding mileage that is associated with each age.

4.2 Mathematical Description of the I/M Algorithm

The MOBILE6 model generates separate I/M credits for each combination of vehicle type / pollutant / model year group / technology class / EPA certification standard type for all 1981 and later model years. The I/M credits (percent reduction) for each combination are generated by computing the percent difference between the basic emission rate line with No I/M (No I/M EF) and the average emission line with the effects of I/M included (With I/M EF). Mathematically, this is shown in Equation 12a and Equation 12b.

I/M Benefit = (No I/M EF - With I/M EF) Eqn 12a

%I/M Credit = I/M Benefit / No I/M EF Eqn 12b

The 'I/M Benefit' in units of grams per mile (or grams for start emissions) is calculated using Equation 13a and 13b (Equation 13b is a simplified version of Equation 13a). Equation 13a shows that theoretically the IM Benefit is the sum of the repair benefits of the high emitting vehicles and the normal emitting vehicles.

I/M Benefit = (HighEF - Repair_Net) * High + (NormEF - NormRepair) * (1.0 - High) Eqn 13a

Where, ‘HighEF’ is the high emitter emission level, ‘Repair_Net’ is the net after repair emission level for the high emitters, ‘NormEF’ is the normal emitter emission level, ‘NormRepair’ is the after repair emission level of the normal emitters, and ‘High’ is the fraction of high emitters in the fleet prior to I/M.

In MOBILE6, it is assumed that overall an I/M program has no effect on the emission level of normal emitters. Thus, the terms NormEF and NormRepair are equivalent and cancel each out. This allows the simplified form of Equation 13a to be written as Equation 13b, and allows the I/M benefit to be stated as the difference between the High emitter emission level (HighEF) and a “Composite” Repaired High emitter emission level (Repair_Net). The term BienADJ is also added to equation 13b to correct for program inspection frequency. An annual frequency program has a value of 1.0 for this term. The values for a biennial program are discussed in Section 4.4.

I/M Benefit = (HighEF - Repair_Net) * High * BienADJ   Eqn 13b

The term ‘Repair_Net’ is the weighted composite after repair emission level based on four possible outcomes in an I/M scenario. Equation 14 shows the mathematical equation used to calculate ‘Repair_Net’. The four possible outcomes are described as follows, and are shown in Equation 14 as the ‘RepairX’ variables.

Repair_Net = Repair1 + Repair2 + Repair3 + Repair4   Eqn 14

1. High emitters NOT identified by the I/M process and remain in the fleet (Equation 15a).
2. High emitters in general non-compliance of the I/M test requirements (i.e., they do not show up for the initial test (Equation 15b).
3. High emitters properly identified by the I/M process, but are not repaired sufficiently to pass the test (Waivered). However, they are assumed to receive some effective repair (Equation 15c). In MOBILE6 this is assumed to be a 20 percent reduction from the High emitter level. (WAVRDC = 1.0 - 0.20 = 0.80). See Section 3.7 for more discussion.
4. High emitters properly identified by the I/M process, and are effectively repaired. These vehicles are responsible for the majority of the I/M benefits (Equation 15d).

Repair1 = HighEF * %NTIDD   Eqn 15a

Repair2 = HighEF * %NCOMP   Eqn 15b

Repair3 = HighEF * WAVRDC * %WVRS   Eqn 15c

Repair4 = Repaired * %Repaired   Eqn 15d

The values for the variable 'Repaired' emissions in Equations 15a through 15d are presented and discussed in detail in Section 3.6 of this document.

The variables '%XXXX' in Equation 15a through 15d are the weighting factors for each of the Repair outcomes. They are mathematically shown (as fractions not percentages) and described in Equations 16a through 16d.

%NTIDD is the weighting factor used to account for the High emitting vehicles which are not identified by the I/M process. Mathematically, it is shown in Equation 16a. The terms 'IDR' and 'NonCom' are the identification rate for the I/M test (described in Section 3.9), and the non compliance rate (described in Section 3.10).

%NTIDD = (1.0 - IDR) * (1.0 - NonCom)   Eqn 16a

%NCOMP is the weighting factor used to account for the vehicles which do not show up for the I/M test and for those vehicles which disappear from the I/M process immediately after the first failing test. Mathematically, it is shown in Equation 16b.

%NCOMP = NonCom   Eqn 16b

%WVRS is the weighting factor used to account for the vehicles which fail the initial I/M, get some repair, but do not pass the final test. Mathematically, it is shown in Equation 16c. The term 'Waiver' is defined as the waiver rate of the program (See Section 3.7).

%WVRS = IDR * Waiver * (1.0 - NonCom)   Eqn 16c

%Repaired is the weighting factor used to account for the vehicles which fail the initial I/M test, and are effectively repaired to pass the final test. Mathematically, it is shown in Equation 16d.

%Repaired = IDR * (1.0 - Waiver) * (1.0 - NonCom)   Eqn 16d

4.3 Effect of Exemptions on I/M Credits

I/M exemptions are a provision granted to some vehicles which would ordinarily be subject to an I/M inspection that excuses them from all of the testing and repair requirements of I/M. In practice, this means that the motorist does not have to bring the vehicle in for an I/M test; however, it may require the motorist to have received a roadside remote sensing device (RSD) "clean screening" test(s), or to have paid a fee in-lieu of the test.

4.4 Biennial I/M Credits

One of the benefits of the previous 'sawtooth' I/M methodology was its explicit ability to account for vehicle deterioration between inspection cycles. This explicit deterioration function made it possible to account for biennial or even longer inspection cycles by varying the deterioration function over time. In the new methodology the 'sawtooth' has been replaced with a multiplicative correction factor. This factor is simply the ratio of the biennial and annual credits from the MOBILE5 model. It was created by averaging by model year the MOBILE5 biennial and annual I/M credits from the IM240 test with phase-in cutpoints to create a single set of multiplicative correction factors that is a function of age and pollutant. These are shown in Table 3a - "Annual to Biennial I/M Correction Factors".

The biennial credits are applied in the MOBILE6 model by first calculating the respective annual credits (See Section 4.2), and then applying the biennial correction factors in Table 3a. This was shown in Section 4.2 in Equation 13. The values of 0.0000 for the biennial test correction factors in Table 3a reflect the MOBILE5 (and MOBILE6) assumption that vehicles less than one year in age are exempt from program requirements. The reader should also note that the biennial adjustments gradually rise with age, and become almost equivalent for vehicle ages 15 and greater.

Table 3a Annual to Biennial I/M Correction Factors			
Age	HC	CO	NOX
0	0.0000	0.0000	0.0000
1	0.4966	0.4976	0.5167
2	0.5877	0.5991	0.6136
3	0.6900	0.7100	0.7000
4	0.7400	0.7600	0.7500
5	0.7773	0.8000	0.7804
6	0.8000	0.8300	0.8100
7	0.8356	0.8640	0.8372
8	0.8740	0.8943	0.8730
9	0.8914	0.9083	0.8966
10	0.9200	0.9300	0.9134
11	0.9393	0.9469	0.9246
12	0.9468	0.9530	0.9353
13	0.9532	0.9589	0.9439
14	0.9595	0.9632	0.9515
15	0.9648	0.9673	0.9568
16	0.9689	0.9709	0.9615
17	0.9729	0.9744	0.9670
18	0.9755	0.9769	0.9720
19	0.9776	0.9788	0.9741
20	0.9794	0.9813	0.9757
21	0.9810	0.9829	0.9781
22	0.9828	0.9836	0.9793
23	0.9844	0.9849	0.9815
24	0.9852	0.9864	0.9826

5.0 I/M ALGORITHM FOR START EMISSIONS

5.1 General I/M Algorithm

The MOBILE6 model will also compute I/M credit reductions for start emissions in addition to the running LA4 emissions. The start I/M credits will be small in magnitude since the typical I/M test (i.e., IM240, idle, etc) does not intentionally involve testing a vehicle during start or warm-up. The I/M credits for start emissions will reflect this fact by assuming that vehicles with high start emissions are identified in conjunction with a running emission failure.

The generalized structure of the start I/M credit algorithm is the same structure as used for the running LA4 emission credits (See Figure 1). However, the Y-axis represents start emissions in units of grams per start and the X-axis represents mileage. Line A shows the basic start emission factor line before an I/M reduction. Line B shows the average start emissions of the normal emitting vehicles. Line C shows the average start emissions of the high emitting vehicles.

5.2 I/M Start Emission Rates

The basic emission rates for start emissions (Line A of Figure 1) and the methodology used to develop them can be found in the EPA document "Determination of Start Emissions as a Function of Mileage and Soak Time for 1981-1993 Model Year Light-Duty Vehicles" - Report Number M6.STE.003.

Table 4 contains the start emission regression coefficients for the normal emitting vehicles for all seven technology and model year groups. Table 5 contains the average start emissions (grams per start) from the high emitting vehicles (high emitters are defined based on twice or thrice FTP standards - see Section 3.2). Table 6 shows the average after repair level of the high emitting vehicles in units of grams per start. The values shown in Table 6 are based on after repair emission testing. In these cases high emitting vehicles (high FTP emissions or IM240 failures) were tested, repaired and retested.

Table 4a **Regression Coefficients for START Emissions from Normal Emitter CARS**							
MY Group	Tech Group	HC Coefficients		CO Coefficients		NOX Coefficients	
		ZML	DET	ZML	DET	ZML	DET
1988-93	PFI	1.9987	0.006830	18.972	0.00703	1.444	0.00220
1988-93	TBI	1.9019	0.002679	19.233	0.00000	2.300	0.00000
1983-87	FI	2.3589	0.001388	19.949	0.00000	1.461	0.00141
1986-89	Carb	1.4934	0.018238	24.698	0.10947	1.405	0.00000
1983-85	Carb	1.5892	0.009408	24.442	0.10577	0.748	0.00524
1981-82	FI	2.3543	0.008533	20.038	0.22673	1.530	0.00059
1981-82	Carb	2.1213	0.013610	28.637	0.22673	1.601	0.00000

Table 4b **Mean START Emissions of High Emitter CARS**				
MY Group	Tech Group	HC Mean	CO Mean	NOX Mean
1988-93	PFI	4.829	38.06	Same as Normals
1988-93	TBI	3.293	27.16	Same as Normals
1983-87	FI	5.313	65.31	Same as Normals
1986-89	Carb	10.520	92.82	Same as Normals

1983-85	Carb	10.520	92.82	Same as Normals
1981-82	FI	5.313	92.82	Same as Normals
1981-82	Carb	10.520	92.82	Same as Normals

Table 5a
Regression Coefficients for START Emissions from Normal Emitter Light Trucks

MY Group	Tech Group	HC Coefficients		CO Coefficients		NOX Coefficients	
		ZML	DET	ZML	DET	ZML	DET
1988-93	PFI	2.873	0.00000	32.178	0.0168	1.597	0.00000
1988-93	TBI	4.073	0.01309	42.456	0.1411	4.294	0.00324
1981-87	FI	2.599	0.00964	23.497	0.0613	1.384	0.00000
1984-93	Carb	3.916	0.00854	78.286	0.2564	0.143	0.00436
1981-83	Carb	6.817	0.00154	98.432	0.3240	1.082	0.00000

Table 5b **Mean START Emissions of High Emitter Trucks**				
MY Group	Tech Group	HC Mean	CO Mean	NOX Mean
1988-93	PFI	5.212	83.862	Same as Normals
1988-93	TBI	5.212	83.862	Same as Normals
1981-87	FI	5.826	60.319	Same as Normals
1984-93	Carb	9.406	162.115	Same as Normals
1981-83	Carb	17.865	179.549	Same as Normals

Table 6 **START Emission Regression Coefficients for High Emitters After Repair** **Cars and Trucks**							
MY Group	Tech Group	HC Coefficients (g/start)		CO Coefficients (g/start)		NOX Coefficients (g/start)	
		ZML	DET	ZML	DET	ZML	DET
1990-93	PFI	2.60	0.00000	18.90	0.00000	1.48	0.00000
1990-93	TBI	2.60	0.00000	18.90	0.00000	1.48	0.00000
1986-89	FI	3.11	0.00000	30.05	0.00000	1.49	0.00000
1986-89	Carb	3.11	0.00000	30.05	0.00000	1.49	0.00000
1983-85	FI	2.70	0.00000	28.33	0.00000	1.84	0.00000
1983-85	Carb	2.70	0.00000	28.33	0.00000	1.84	0.00000
1981-82	FI	2.70	0.00000	28.33	0.00000	1.84	0.00000
1981-82	Carb	2.70	0.00000	28.33	0.0000	1.84	0.00000

5.3 Fraction of High and Normal Emitters in the Fleet

The basic start emission factor is computed from a weighted average of the highs and normals. The fraction of high emitters (fraction of normal emitters = 1 - fraction of high emitters) in the fleet is the weighting factor. The fraction of high start emitters is assumed to be the same fraction as the one used for the running emissions calculations. Tables 3a and 3b and Appendix A in EPA document M6.STE.003 "Determination of Start Emissions as a Function of Mileage and Soak Time for 1981-1993 Model Year Light-duty Vehicles" show and explain the fraction of HC and CO high emitters in the fleet at selected mileages / ages for each pollutant. The fraction of NOX high emitters is not shown because for NOX the Normals and Highs are assumed to have the same emission rate (no start NOX highs are assumed to exist).

5.4 I/M Start Identification Rates

The algorithm for start emissions is based on test data that indicates that a portion of the vehicles with high running emissions that are identified by the I/M process will also have high start emissions, and that these will be identified and corrected in conjunction with the repairs to pass the I/M test. Also, because significant NOX emissions usually form only after the vehicle is warm, it was assumed that an I/M program could only reduce HC and CO start emissions.

A mathematical function that relates HC / CO cutpoint with the start emissions identification rate (IDR) was developed from the 910 vehicle sample used to develop the running emissions IDR. The same methodology was used to develop the Start emission IDR as was used to develop the running emission IDR (See Section 3.9 for a more detailed explanation). This function also has the same range of HC and CO cutpoints (HC ranges from 0.80 g/mi to 5.0 g/mi and CO ranges from 15.0 g/mi to 100 g/mi) used in the running emission analysis. It predicts the percentage of start emissions from high emitters which are identified at a specific HC/CO cutpoint level. This is the percentage of the emissions from high emitters at Line C in Figure 1 that are reduced down to average fleet emission levels (Line A in Figure 1). The statistical results are shown in Appendix D. The functions are:

Start HC IDR = 0.9814 - 0.1590*ln(HCCUT) - 0.1409*ln(COCUT) Eqn 32

Start CO IDR = 1.1460 - 0.1593*ln(HCCUT) - 0.1707*ln(COCUT) Eqn 33

5.5 Average Start Emissions After I/M

The equation used to calculate the average start emissions after I/M is very similar in form to Equation 12a used to calculate the average running emissions after I/M. Several of the parameters are the same such as the fraction of high emitters in the fleet, the waiver rate, the waiver repair percentage, and the non-compliance rate. The principal differences are the different IDR rates (the start IDRs are calculated in Equations 32 and 33), and the different after repair emission levels. Equation 34 is used to calculate the After I/M start emissions (S_EIM). S_IDR is the start emission IDR from Equations 32 and 33, and S_RLEV is the after successful repair emission level (in units of grams per start) given in Table 6. The after repair start emission levels in grams per start (S_RLEV) shown in Table 6 are used to model I/M start emissions instead of the running emission algorithm discussed in Section 3.6.

6.0 I/M Credits for Non-IM240 Tests

The previous sections discussed the general algorithm and methodology used to develop the I/M credits for MOBILE6. The IM240 test was used as the basis for the credits because of the large amount of IM240 data which are available to develop the IDR estimates and the after repair levels. I/M credits for other tests are also needed such as the Idle test, the 2500 RPM / Idle test, and the ASM tests. The algorithm used to mathematically implement these test types in MOBILE6 is analogous to the IM240 algorithm. The difference between the various I/M test types in MOBILE6 will be based on the differences in the IDRs for each test.

6.1 Other I/M Tests

The MOBILE6 model will also compute I/M credits for tests other than the IM240 test. The test options which will be built into the model are (1) Idle test, (2) 2500 RPM / Idle test and the Loaded / Idle test, (3) ASM tests, and (4) On-board Diagnostic (OBD) I/M tests. The OBD I/M test parameters and algorithm are discussed in EPA papers M6.EXH.007 and M6.EXH.009.

The default I/M tests in addition to the IM240 test which MOBILE6 will able to model are:

1. Annual Two-Mode ASM 2525/5015 with Phase-in Cutpoints
2. Annual Two-Mode ASM 2525/5015 with Final Cutpoints
3. Annual Single-Mode ASM 5015 with Phase-in Cutpoints
4. Annual Single-Mode ASM 5015 with Final Cutpoints
5. Annual Single-Mode ASM 2525 with Phase-in Cutpoints
6. Annual Single-Mode ASM 2525 with Final Cutpoints
7. Annual Idle Test
8. Annual 2500 RPM / Idle Test
9. Annual Loaded / Idle Test
10. Biennial Two-Mode ASM 2525/5015 with Phase-in Cutpoints
11. Biennial Two-Mode ASM 2525/5015 with Final Cutpoints
12. Biennial Single-Mode ASM 5015 with Phase-in Cutpoints
13. Biennial Single-Mode ASM 5015 with Final Cutpoints
14. Biennial Single-Mode ASM 2525 with Phase-in Cutpoints
15. Biennial Single-Mode ASM 2525 with Final Cutpoints
16. Biennial Idle Test
17. Biennial 2500 RPM / Idle Test

18. Biennial Loaded / Idle Test
19. OBD I/M

6.2 ASM Tests

Unfortunately, new paired ASM and FTP test data are not available on any ASM I/M tests in-order to compute new and specific IDR rates or repair effectiveness rates. As a result, the relative size of the I/M credits of these tests versus the IM240 will remain the same between MOBILE5 and MOBILE6. This was accomplished by first computing the ratio of the MOBILE5 I/M credit value for an alternative ASM test over the MOBILE5 I/M credit value for the IM240 at final cutpoints of 0.8 HC / 15 CO / 2.0 NOX. When done for each combination of model year, age and pollutant, this produces a large array of ratios (25 ages x 18 model year x 3 pollutants). Separate arrays of ASM/IM240 credit ratios were calculated for three ASM tests (ASM5015, ASM2525 and ASM Two Mode), and for both Phase-in and Final ASM cutpoint combinations. A large array containing all six test type/cutpoint combinations was then assembled for use in MOBILE6. Rather than store all those ratios in the MOBILE6 program, the ratio data are read into the program from a separate data file if MOBILE6 is asked to calculate the effects of ASM I/M. The ratios are used in MOBILE6 to calculate ASM IDR rates. This is done by multiplying the appropriate ASM ratio by the IM240 ratio.

The advantage of this approach is that it enables the ASM I/M test procedure credits to be easily assimilated into the MOBILE6 I/M approach. It also preserves a similar relative effectiveness of ASM versus IM240 as was present in the MOBILE5 model. This is reasonable since no new ASM data are available in conjunction with FTP data to update the ASM credits. One drawback of this approach is that it does not update the effect of different after repair levels, and assumes that the ASM after repair levels are the same as those for the IM240. This means that the after repair levels for the 0.8/15/2.0 HC, CO and NOX IM240 cutpoints will be used for the final ASM cutpoint after repair levels. Similarly, the 1.2/20/3.0 HC, CO and NOX IM240 cutpoints will be used for the phase-in ASM cutpoint after repair levels. Also, it assumes that the ratio between the ASM and IM240 credits in MOBILE5 based on FTP emissions can be equally applied for both running and start ASM credits in MOBILE6.

6.3 Idle and 2500RPM/Idle Tests

The I/M credits for the Idle and 2500RPM/Idle tests were not developed like the ASM credits by ratioing the MOBILE5 Idle test results with the MOBILE5 IM240 results and applying the ratio to the MOBILE6 IM240 results to get the MOBILE6 Idle test credits.

Instead, the Idle and Idle/2500 RPM test credits were developed from a new analysis of the available paired Idle / 2500RPM/Idle and FTP data sources collected by EPA from 1981 through 1998. The Loaded / Idle I/M test credits were developed in a completely analogous fashion to the ASM I/M test credits by ratioing the MOBILE5 credits. No new data were available on the Loaded / Idle test.

6.3.1 Available Data

Two primary EPA datasets were available. The first dataset is called the “4MID” dataset. The abbreviation “4MID” stands for “Four Mode Idle dataset”. It contains virtually all of EPA’s paired Idle and FTP data collected at EPA’s various labs from 1981 through 1998. The four mode test is a special EPA Idle I/M test procedure developed for research work that simulates in-use Idle tests. The first mode is an unpreconditioned idle, the second mode is a 2500 RPM segment used to precondition the third Idle mode, and used to pass or fail vehicles for the 2500RPM/Idle test. The third mode is a preconditioned Idle, and the fourth mode is an idle in drive mode. Only the 2500 RPM mode and the third mode (pre-conditioned Idle) were used to develop the credits. Only the HC emissions from the 2500 RPR mode were used in the development of the 2500RPM/Idle credits. The analogous CO 2500 RPM mode readings were not used because of their tendency to produce false failures due to evaporative canister purge during the 2500 RPM mode. The preconditioned Idle test was used in both the Idle test and the 2500RPM/Idle test credits. The unpreconditioned Idle mode and the Idle in Drive modes were not used for the I/M credit development.

Test results from the Restart /Idle test used to test some early 1980's Ford vehicles were not used in this analysis due to their inconsistent availability in the dataset. The effect of this is thought to be very negligible. However, since the basis of the IDR consists only of High emitting vehicles, use of the Four mode test instead of the Restart / Idle test for Ford vehicles could potentially overstate the Idle test credits slightly if the higher readings from the Four Mode test identify more high emitters that the Restart / Idle test would identify.

The second primary dataset was the “IMLane” dataset. It consisted of I/M lane Idle and 2500RPM/Idle test results from EPA’s pilot I/M lane test program conducted in both Hammond, IN and Phoenix, AR by ATL. These data were paired with vehicle FTP data collected at ATL’s laboratory. The test procedure consisted of a 2500RPM mode, and a subsequent preconditioned Idle mode. The unpreconditioned Idle and the Idle in Drive modes were not performed. The advantage of these data over the 4MID sample is that they were collected in an actual I/M lane rather than in the EPA laboratory like the 4MID sample.

For the final results, both databases were combined together to produce overall IDR rates for the Idle test and the 2500RPM/Idle test. Despite the slight differences in the I/M test procedures, the combination of the data makes sense for several reasons. First, it produces a larger sample of vehicles. This is important because for this analysis only the High emitters are used to compute the IDRs, and the number of High emitters can get small in some model year groups. Also, both databases seem to complement each other in terms of model year coverage. For example, the "4MID" sample has a large preponderance of its data in the 1981 and 1982 model years; however, it does have some newer mid 1990's vehicles and trucks. The ATL sample on the other hand contains only cars, and is mostly represented by late 1980's to early 1990's cars. Tables 8a and 8b show the model year and technology breakdown for both databases.

Table 8a

Four Mode Idle / 2500RPM Idle and FTP Test Pairs

	Cars			Trucks		
MY	CARB	TBI	PFI	CARB	TBI	PFI
1981	962	15	29	120		4
1982	125	66	5	45		
1983	87	122	59	10		
1984	32	44	34	48		1
1985	90	52	61	63	13	6
1986	41	52	86	17	23	41
1987	16	64	92			
1988	15	60	103			
1989	22	35	82			
1990		46	85			
1991		4	59			2
1992		2	37			
1993		4	16			2
1994			27		1	1
1995			2			

Table 8b IM Lane Idle / 2500RPM Idle and FTP Test Pairs						
	Idle Test			2500 RPM / Idle Test		
MY	CARB	TBI	PFI	CARB	TBI	PFI
1981	39	1	2	39	1	2
1982	37	3	1	37	3	1
1983	22	18	11	22	18	10
1984	21	56	29	21	56	29
1985	14	65	48	14	63	47
1986	11	61	47	11	61	47
1987	9	39	48	9	39	48
1988	4	41	61	4	40	60
1989	1	34	53	1	34	53
1990	1	25	33	1	25	33
1991		6	17		5	17
1992		2	18		2	18
1993			6			6

6.3.2 Idle and 2500RPM/Idle Test IDRs

The calculation of the IDRs for the Idle and 2500RPM/Idle tests is very similar to the calculation done for IM240 IDRs in Section 3.9. One difference is that IDRs for a range of cutpoints was not performed. Instead only one set of Idle and 2500RPM/Idle cutpoints were developed. These were at the CO/HC cutpoints of 1.2%CO and 220ppm HC. Also, IDRs for only HC and CO emissions for running and start were developed. Idle and 2500RPM/Idle IDRs for NOX emissions were not developed. Neither the Idle Test or the 2500RPM/Idle test will produce NOX benefits or NOX “Dis-benefits” for MOBILE6. In comparison, MOBILE5 contained NOX “Dis-benefits” if an Idle or 2500RPM Idle test were performed.

Table 9a Idle and 2500RPM / Idle Test IDRs for Each Sample						
	IDRs Based on I/M Lane Sample					
	Hot Running LA4 HC			Hot Running LA4 CO		
Test	Carb	PFI	TBI	Carb	PFI	TBI
Idle	63.3	58.7	53.2	54.9	57.5	60.6
2500/Idle	76.5	59.3	53.9	68.8	57.5	60.6
	Cold Start HC			Cold Start CO		
Test	Carb	PFI	TBI	Carb	PFI	TBI
Idle	41.9	39.1	33.9	29.1	23.6	20.9
2500/Idle	48.6	40.2	34.8	29.1	23.6	20.9
	IDRs Based on Four Mode Sample					
	Hot Running LA4 HC			Hot Running LA4 CO		
Test	Carb	PFI	TBI	Carb	PFI	TBI
Idle	48.8	74.3	52.2	53.4	81.1	40.7
2500/Idle	66.1	74.3	61.6	63.8	81.1	55.7
	Cold Start HC			Cold Start CO		
Test	Carb	PFI	TBI	Carb	PFI	TBI
Idle	20.2	42.6	17.7	21.4	57.8	30.1
2500/Idle	24.4	42.6	25.4	27.1	57.8	33.9

Table 9a shows the Hot Running LA4 and Cold Start IDR rates for the Idle and 2500RPM/Idle tests for each of the two datasets. It is further broken down into three technology groups. These are Carbureted, Throttle Body Injection (TBI), and Ported Fuel Injection (PFI). The IDRs were not made a function of model year because of the small sample sizes in many individual model years. Table 9b shows the IDR results for the combined dataset. The two datasets were combined together based on total emissions from the high emitters rather than on the number of vehicles in the sample. The IDRs are shown as a percentage in both tables, but will be programmed into MOBILE6 as fractions. They represent the fraction of emissions from high emitters which are identified by the prospective I/M test. Separate IDRs for each pollutant and technology were developed for Hot Running LA4 emissions and Start emissions based on Bagged FTP data. The PFI and TBI Identification rates were subsequently combined together for analysis to create a larger and more statistically significant sample size. Table 9b shows the results separately for PFI and TBI, and Table 9c shows the average value used in MOBILE6. The values in Table 9b were weighted together by the overall sample size to produce the values shown in Table 9c.

Table 9b
Idle and 2500RPM / Idle Test IDRs Based on the COMBINED Sample

	IDRs Based on I/M Lane Sample					
	Hot Running LA4 HC			Hot Running LA4 CO		
Test	Carb	PFI	TBI	Carb	PFI	TBI
Idle	54.6	63.5	52.8	54.0	63.0	53.5
2500/Idle	70.2	63.9	56.8	65.9	62.9	58.8
	Cold Start HC			Cold Start CO		
Test	Carb	PFI	TBI	Carb	PFI	TBI
Idle	25.5	40.8	29.5	23.3	37.8	25.1
2500/Idle	30.3	41.3	32.3	27.6	37.8	26.8

Table 9c
Idle and 2500RPM / Idle Test IDRs Based on the COMBINED Sample

	IDRs Based on I/M Lane Sample					
	Hot Running LA4 HC			Hot Running LA4 CO		
Test	Carb	PFI	TBI	Carb	PFI	TBI
Idle	54.6	58.3	58.3	54.0	58.4	58.4
2500/Idle	70.2	60.5	60.5	65.9	60.9	60.9

	Cold Start HC			Cold Start CO		
Test	Carb	PFI	TBI	Carb	PFI	TBI
Idle	25.5	35.3	35.3	23.3	31.7	31.7
2500/Idle	30.3	36.9	36.9	27.6	32.5	32.5

6.3.3 After Repair Emission Level for Idle and Idle/2500 Tests

The Idle Test after repair emission levels for MOBILE6 were calculated from a dataset which was used for MOBILE5 development. It consisted of 36, 1981 and later vehicles which initially failed the idle test, were repaired, and passed the final idle test at standard cutpoints. These data were collected as part of an EPA test program conducted to evaluate the effect of repair on idle test failures. The repairs were conducted by qualified technicians. The vehicle sample mean FTP emission values after Idle test I/M repair were found to be 1.89 g/mi HC and 20.0 g/mi CO. These compare with means of 1.26 g/mi HC and 13.46 g/mi CO for the IM240 at the 1.2/20 HC and CO cutpoint. Idle test repair effects for NOX emissions are not computed because MOBILE6 will not give NOX benefits or disbenefits to an idle test program.

The ratio of the idle test after repair FTP emission level to the IM240 after repair FTP emission level at 1.2/20/3.0 cutpoints is computed from the data and used to generate the after repair idle test emission level for running LA4 emissions. A consistent ratio based on the FTP will be used for all mileages, vehicle types, and model years. The ratios which are used for HC and CO are:

HC Ratio:	1.89 g/mi / 1.26 g/mi	=	1.5
CO Ratio:	20.0 g/mi / 13.46 g/mi	=	1.5

They are used in MOBILE6 to generate the idle test after repair running LA4 emission level by multiplying the ratio by the IM240 after repair emission level at 1.2/20/3.0 cutpoints. The same after repair emission levels will be used for the Idle test and the Idle/2500 RPM test.

6.4 OBD I/M Tests

This document does not explicitly cover vehicles which are equipped with an OBD system. However, most OBD equipped vehicles will continue to receive exhaust based I/M tests such as the IM240 or the Idle test for much of their early lives. Thus, the topic is mentioned briefly in this document as an introduction. For more complete details on EPA's modeling of OBD equipped vehicles (1996+ model years) please read EPA document M6.EXH.007 "Determination of Emissions, OBD, and I/M Effects for Tier1, TLEV, LEV, and ULEV Vehicles" and EPA document M6.EXH.009.

The OBD system is an electronic diagnostic system built into most 1996 and later and some 1994 and 1995 model year vehicles. It is designed to (1) continuously monitor the performance of the car's emission control system, and detect serious problem(s) which cause the vehicle's FTP emissions to exceed 1.5 times its applicable certification standards, (2) register a code in the vehicle's computer and turn on a dashboard warning light to notify the owner. The system will also have the capability to be electronically accessed in an I/M lane. The vehicle will be required to pass the OBD test (no trouble codes are present) in-order to pass the state I/M program requirements.

In MOBILE6 an I/M program conducting an OBD check on properly equipped OBD vehicles will be assigned an IDR of 85 percent (fraction 0.85). This value will be given regardless of whether an exhaust I/M test such as the IM240 or the ASM test is performed or not performed. Also, the with and without technician training levels in an OBD I/M program will be equivalent. It is assumed that the technicians specializing in OBD diagnosis and repair will either be fully qualified, or not involved in the industry.

6.5 Tampering Rates and Anti-Tampering Program Credits in MOBILE6.

Vehicle Tampering and Anti-Tampering Programs (ATP) have long been associated with Inspection / Maintenance programs (I/M). This is because for many years tampering was often the cause of excess emissions from vehicles. To help understand the nature and extent of the tampering problem numerous field studies were done by EPA during the 1970s and 1980s to quantify the problem. The results from these studies were incorporated into the MOBILE series models.

Unfortunately, for MOBILE6, no new studies were available that quantify the extent of vehicle tampering in the fleet. This is largely the result of the belief that deliberate vehicle emission control system tampering is no longer much of an issue. Also, it is now felt that much of the effects of tampering are properly captured in the High Emitter rates, High Emitter emission levels, and the High Emitter Correction Factor that are discussed earlier in this document and in other MOBILE6 documents. (M6.EXH.002 - M6.EXH.005).

As a background, the High Emitter Correction Factor was a multiplicative factor that was added to the Base Emission rates originally developed for the MOBILE6 model. It was developed because it was thought that the underlying vehicle data used to develop the base emission factors contained a disproportionate percentage of low emitting vehicles and consequently did not contain a high enough percentage of High emitting vehicles. It was developed by comparing the Base Emission factor data collected in the EPA and AAMA labs with a large sample of in-use IM240 data collected in Dayton, Ohio.

The tampering algorithm used in MOBILE6 is as follows:

1. For the Pre-1981 model year vehicles there is no change from the MOBILE5 model in terms of the tampering rates or ATP effectiveness assumptions.

2. For the 1981 through 1995 model year vehicles, there is a tampering offset that is built into the emission factors (i.e., high emitter correction factor). Thus, the tampering subroutines do not add any additional tampering correction factors like in MOBILE5. However, the same subroutines are still used in the MOBILE6 model to calculate the ATP and I/M benefits in reducing the occurrence of tampering. These subroutines subtract a portion of the high emitter correction factor.

3. For the 1996 and later model years there is assumed to be no tampering in the fleet This assumption was made because strong engineering reasons and anecdotal evidence suggests that deliberate tampering of emission control devices is not common on today's late model vehicles. This is because the reasons for tampering such as the ability to misfuel, perceived improved performance and perceived cost savings on vehicle operation do not exist anymore. Also, the advent of OBD systems should also discourage tampering, because the immediate result of tampering is an OBD warning light. The effect of this assumption is that tampering effects will be completely removed from the MOBILE6 model by calendar year 2021.

7.0 Response to Peer Review and Stakeholder Comments

Section 7.0 discusses issues and comments submitted by interested parties during the formal stakeholder review period, and by paid reviewers of this document.

1. A key element missing from the overall methodology is the inability of the model to account for any possible actions that vehicle owners may take to adjust their vehicles to just ‘look clean’ for the test.

   It is true that the so called phenomenon of ‘clean for a day’ is not accounted for in the MOBILE6 model. Part of the difficulty with modeling this phenomenon is obtaining definitive data on it. The problem stems from the fact that the vehicles that only ‘look clean’ (adjusted only to pass the test) are identical in terms of numerical test score to vehicles that pass either on their initial test or upon a retest. Therefore, it is difficult to identify these vehicles from standard test programs and even from large scale I/M test samples. One possible way of determining the impact of these vehicles (if they even exist) is through some type of very sophisticated remote sensing program, and subsequent and immediate confirmation test follow up. Multiple tests might be necessary in-order to eliminate natural test-to-test variability. Unfortunately, such data are not available.

   Another factor influencing the clean for a day phenomenon is advancing technology in vehicles and in I/M programs. On-board diagnostic (OBD) tests make such ‘clean for a day’ strategies by non-complying motorists more difficult to achieve or less cost effective. For example, it will be much more difficult and expensive for a motorist to alter a vehicle’s electronic OBD system to obtain a false pass reading, than it would be to adjust a vehicle’s carburetor to obtain a temporary low emission reading. Also, with the advent of advanced technology and emission control system designs that are fully integrated into the operation of the vehicle and significantly affect the performance of the vehicle, one must ask the question “what are the real and perceived benefits of fixing a vehicle to pass a test only for a short time versus fixing it permanently?”

2. One peer reviewer suggested that the results from the statistical analysis be presented in tabular form in the document. This will allow for easier review.

   EPA agrees with this suggestion. The revised version of this document will contain important statistic results in tabular form.

3. One peer reviewer asked why, given the huge size of the Arizona IM240 database,

the after repair analysis did not consider technology as an independent variable.

EPA agrees that technology might be an important variable in determining after repair emission levels. Unfortunately, the database could not be resolved down into technology categories that were fine enough for use. The necessary resolution was by PFI, TBI and Carbureted technology. Some auto industry experts consider an even finer breakdown of the PFI category to be useful. The VIN decoder used to process the 17 digit individual vehicle VINs could not produce fuel delivery system resolution. As a result, the after repair emission levels were made a function of model year. Model year implicitly contains technology information since the progress of automotive technology has been steady for years. For example, most 1990's cars are PFI technology and many 1980's cars are TBI.

4. One peer reviewer expressed concern over the fact that only laboratory data that may not be replicated in actual repair effectiveness was used to determine the repair effects at lower cutpoints. They suggested that such data could lead to an overestimation of the benefits of lower cutpoints. For the next version of MOBILE, EPA should obtain data from vehicles that undergo actual field repairs to various cutpoints for use in the model.

   EPA recognizes that the use of lab repair data may be problematic. However, obtaining actual field data from programs that use substantially different cutpoints may be a problem, since virtually all states use the same or similar sets of cutpoints.

5. One peer reviewer points out that the calculation methodology (for the high emitter, normal emitter, average fleet emission level and the Ohio data high emitter correction factor) implicitly assumes that the effect from the Ohio data high emitter correction factor is only an increase in the number of high emitters. This assumption in turn leads to the next assumption that the average emission level of the high emitters are the same in Ohio and in the EPA/AAMA samples.

   Mathematically, this observation is certainly true. The Ohio data high emitter correction factor was developed based on the assumption that the EPA / AAMA samples contained an under-representative fraction of high emitters. This under-representation is thought to occur because motorists who tamper (commit an illegal act) and otherwise severely mal-maintain their vehicle are probably less likely to lend it to the government or the auto industry for research purposes. However, the EPA analysis did assume that the EPA / AAMA data base contained enough high emitters so as to characterize the emission level of a high emitter, but could not be reliably used to determine the frequency of such high emitters in the fleet. Therefore, the effect of holding the average High emitter and average Normal emitter emission level constant while boosting the overall average emission higher (high emitter correction factor) leads to the mathematical result of a greater number of high emitters in the fleet.

The assumption that the average high emitter emission level is constant before and after adding the High Emitter correction factor to the algorithm is the same as assuming that a high emitter in the EPA/AAMA database is equivalent to a high emitter in the Dayton, Ohio database. Unfortunately, this assumption could not be determined directly, since the Dayton data is based on the IM240 and IM240 fast pass driving schedule, and the EPA/AAMA sample is based on the FTP, running LA4 and Start emission factors. However, the assumption that on average high emitters have generally consistent emission levels can be investigated by looking at various state IM240 data on failing vehicles.

6. One stakeholder reviewer questioned the assumption of a constant High emitter emission level with respect to mileage.

   This assumption is in general sensitive to the definition of a High emitter. However, given EPA's definition, statistical analysis of the High emitter data showed that the emission level of a high emitter was not a function of mileage. The rate of high emitters in the fleet was a function of mileage and is modeled in MOBILE6 as such.

7. The peer and stakeholder reviewers state that the DRAFT I/M algorithm made the questionable assumption that the deterioration rate of failed vehicles is the same as that of a fleet average vehicle.

   EPA is sensitive to the criticism and widespread comments that have been received regarding this assumption. Clearly, sound logical arguments can be made for revising it so that failed vehicles are given a higher or possibly lower probability of failing a subsequent test than a vehicle selected randomly from the overall fleet. Thus, in the final version of MOBILE6, this assumption was rejected.

   However, in the next generation of models, EPA will likely take a rigorous look at the overall question of deterioration rate between I/M failures and the general fleet. The overall model would probably benefit from a more sophisticated approach regarding the role of repeat failure, non complying vehicles and waivered vehicles. Data sources that would prove useful for this analysis are (1) long term I/M test results over three complete I/M cycles on a sizeable sample that show the progress of both failing and passing vehicles over time, (2) good test data on the benefits of partial repair of waivered vehicles and the frequency of such vehicles. (3) solid data on the frequency, whereabouts and emission levels of non complying vehicles and non participating vehicles.

8. One peer reviewer mentioned the lack of information regarding start emissions and the lack of statistic results presented in a tabular form.

   EPA report M6.STE.003 has been updated to include regression statistics on start emissions in tabular form.

9. The peer and stakeholder reviewers expressed concerns regarding the use of least-squared regressions to simulate ASM / IM240 test credits. He felt that the actual ratios should be built into the MOBILE6 program rather than the regression coefficients from the ratios.

   EPA agrees on this point. The actual ASM / IM240 ratios will be used in MOBILE6. They will be read into the program from an external data file. The original approach of using regression coefficients to model the ASM credits introduced unnecessary errors into the algorithms, and offered very little reduction in the code size or flexibility in the programming.

10. One peer reviewer suggested that the ASM / IM240 ratio should be applied in MOBILE6 as the overall I/M credit rather than as the relative ASM I/M identification rate (IDR).

    This is a reasonable suggestion. However, due to the design of the MOBILE6 code, it is impractical to implement and would require a substantial rewrite of the code. In addition, the results from both methods (ASM/IM240 ratio as an overall correction factor and the ASM/IM240 ratio as the IDR) should yield essentially the same results, since both the ASM tests and the IM240 test use similar after repair rates.

11. The peer reviewer commented that Idle and Idle/2500 RPM test credits were available only at one set of I/M standards (i.e., 1.2% CO and 220 ppm HC).

    This was done because these are the lowest Idle test I/M standards which are covered by the 207(b) warranty provisions. Thus, it is believed that very few states will want to use alternative Idle test standards.

12. A stakeholder reviewer wondered about the impact of the new emission factors and I/M credit methodology on the size of the I/M performance standards and rate of progress issues.

This is not a direct MOBILE6 issue, but instead falls in the area of I/M and state program guidance. Subsequent to the release of MOBILE6, EPA will likely develop the necessary policy guidance to resolve these types of questions.

13. Several stakeholders commented that they would like the MOBILE6 program to have the capability of modeling a more exact I/M start date that can be resolved down to the monthly level.

    Unfortunately, the program code cannot model an I/M program start year to the monthly level resolution. The user is encouraged to pick the closest January 1 start calendar year date to the actual start date.

14. Several users commented on the desire to better control I/M IDR rates and other parameters such as the fraction of High emitters in the fleet by using MOBILE6 inputs.

    Unfortunately, the I/M IDR rate and the fraction of High emitter in the fleet cannot be directly changed in the model using standard inputs.

15. Several reviewers mentioned the need for the model to be able to disable the impact of the 1990 Clean Air Act for Rate of Progress SIPs and other I/M program issues.

    Although, not mentioned in this document, this feature <u>will</u> be allowed in MOBILE6.

16. One reviewer expressed concern about an I/M credit discount applied to decentralized I/M program vis-a-vis centralized program. This discount was a standard feature in MOBILE5.

    The MANDATORY 50 percent discount for decentralized I/M programs that was built into MOBILE5 has been removed in MOBILE6. It has been replaced by a new EFFECTIVENESS command that allows the user to set their own level of program effectiveness or discount.

17. Several reviewers commented on credit issues if two ASM tests are performed and wondered about the relative size of the ASM test credit and the IM240 test credit.

    The MOBILE6 program will allow the modeling of the two mode ASM test, and the test will receive more I/M credits than a single mode ASM test. The ASM test credit is not a function of the ASM cutpoint because there were too many ASM cutpoints; however, the IM240 test is a function of cutpoint. Thus, the answer to the IM240 versus ASM test comparison is ... it depends on the IM240 cutpoint under evaluation. However, at comparable phase-in or final cutpoints, the credit is almost the same for both tests with the IM240 receiving slightly more credit than the ASM test.

18. Several reviewers have asked if additional I/M credit will be given to a state that conducts both exhaust I/M testing and OBD I/M testing on the same vehicles.

    Theoretically, some small additional credit may be possible by conducting two or even more I/M tests on a given vehicle. However, because of a lack of data on this topic, and the general inability of the MOBILE6 program to model two different I/M program types on the same vehicle model year, no additional credit will be given to States that conduct both tests.

19. One stakeholder reviewer asked about "Appropriate I/M", and the MOBILE5 policy of given I/M credit to LEV vehicles by reducing their deterioration rate.

    The concept of "Appropriate I/M" was not explicitly included in MOBILE6. However, LEV, Tier2 and other advanced vehicle technology types will still be able to receive I/M credit. After the release of MOBILE6, EPA will provide guidance and policy regarding the use of MOBILE6.

20. One reviewer suggested that human behavior should be included in the MOBILE I/M modeling process. This behavior might include the motorist taking advantage of 'test to test variability' effects (i.e., continued retesting without repairs until the vehicle passes the test), the effect of motorists registering outside of the I/M program area, and the effect of motorist's who never show up for the test in the first place.

    The effect of registering outside of the I/M area or never showing up for the test in the first place can be accounted for in MOBILE6 using the non compliance and participation rate inputs.

    Theoretically, test to test variability will always be an issue with an exhaust test with a defined cutpoint standard. Every vehicle exhaust measurement has a natural uncertainty associated with it and upon multiple retesting this uncertainty could overlap both the "pass" level "fail". The larger the variability the more likely an untrue passing or failing reading could occur. However, it is believed that most 'true' High emitters will have a high enough emission level and small enough variability so that repeated testing is not likely to produce a false passing reading. On the other hand, it is also hoped that multiple repeat testing eliminates false failures and lack of preconditioning failures before the repair process begins by giving the vehicle another opportunity to pass.

The advent of OBD I/M testing should also help mitigate the issue of test to test variability. Because it is an electronic test, it produces only an objective pass or fail result. It is also believed that the vehicle OBD systems and the OBD I/M test equipment and procedures will be designed properly to minimize both false passing tests and false failing tests. Only time and yet to be collected data will answer these questions.

21. One stakeholder reviewer wondered if the without technician training emission levels are below the I/M cutpoints emission levels.

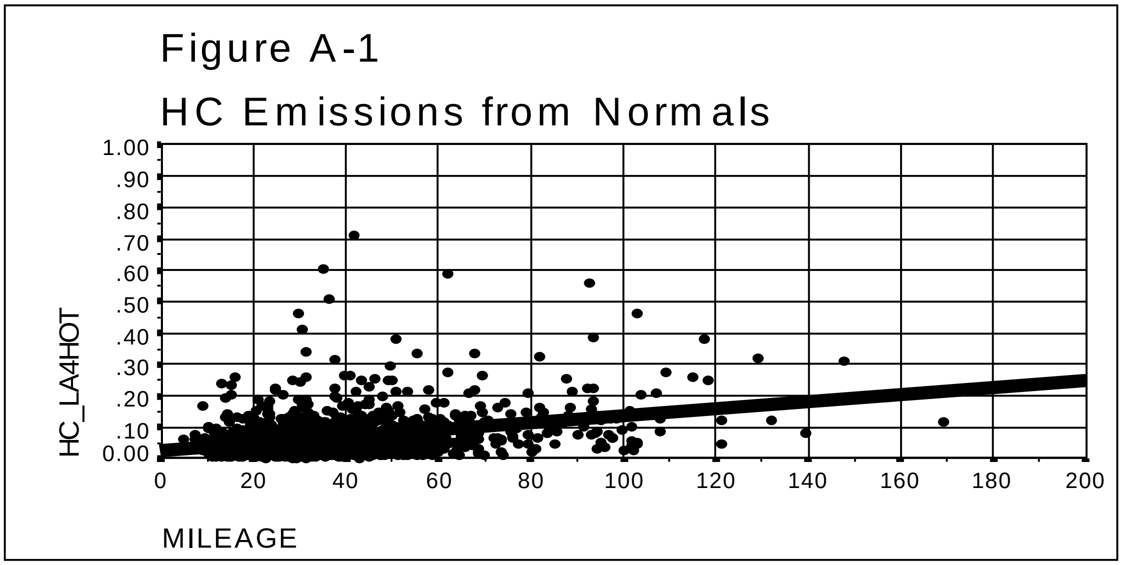
This comparison is not particularly straightforward, because MOBILE6 calculates and reports emission in terms of FTP cycle 'unit', and typical I/M test reports emissions in terms of concentration units or in the case of IM240 gram per mile numbers based on a different cycle. Nevertheless, even with the increases in the after repair levels due to the no technician training effects, these levels are lower than a failing high emitter's level.

OBD provided a special case for the no technician training effects since the presence of the MIL light is triggered if the FTP emission are greater than 150% of the certification standard. To solve this dilemma the no technician training effects were eliminated for an OBD I/M program under the assumption that virtually all technicians that repair modern vehicles equipped with OBD will have to have some training on the OBD systems, the use of the diagnostic tools, and general investigative and repair skills. Gone are the days when a virtually uneducated mechanic could simply turn a few carburetor screws and replace an air filter and call it an I/M repair.

22. As a result of the need for MOBILE6 Loaded / Idle I/M test credits by a couple of State I/M programs, the Loaded / Idle test credits will be inserted into the MOBILE6 program. However, these credits will be identical in all respects to the 2500/Idle I/M credits. The rational for this assumption is that there are no new data available to develop special Loaded / Idle test I/M credits, and in practice the loaded portion of the test is just a preconditioning phase rather than an additional pass / fail requirement. The pass / fail determination for the test is based solely on the results of the idle mode. This is completely analogous to the 2500 / Idle test in which only the idle portion of the test is used to pass or fail a vehicle.

APPENDIX A

Running LA4 Emissions from 1990-93 MY PFI Normal Emitters



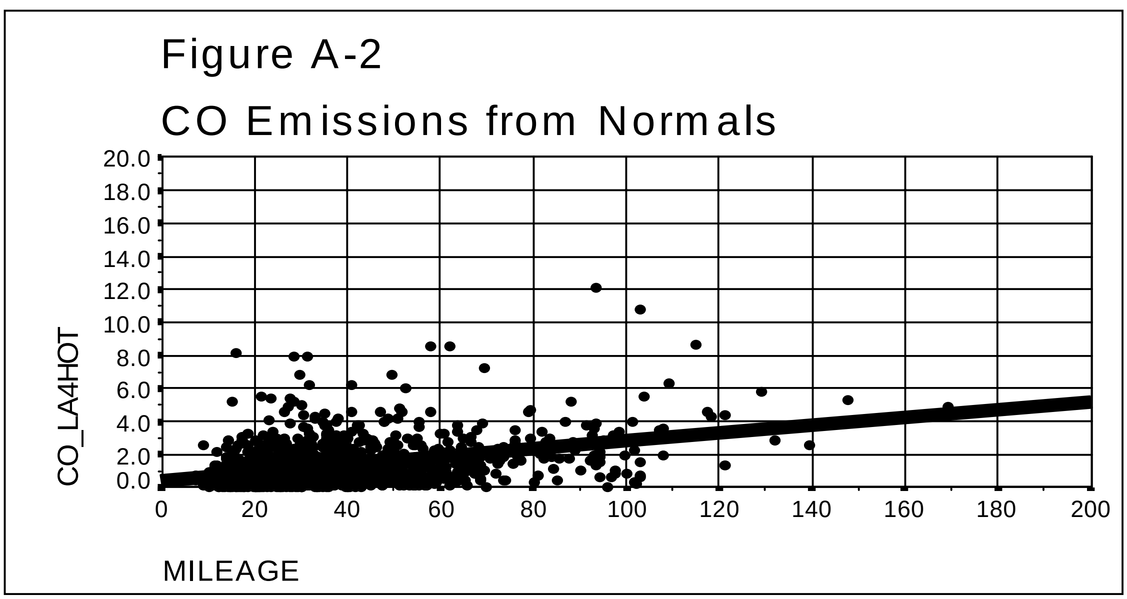
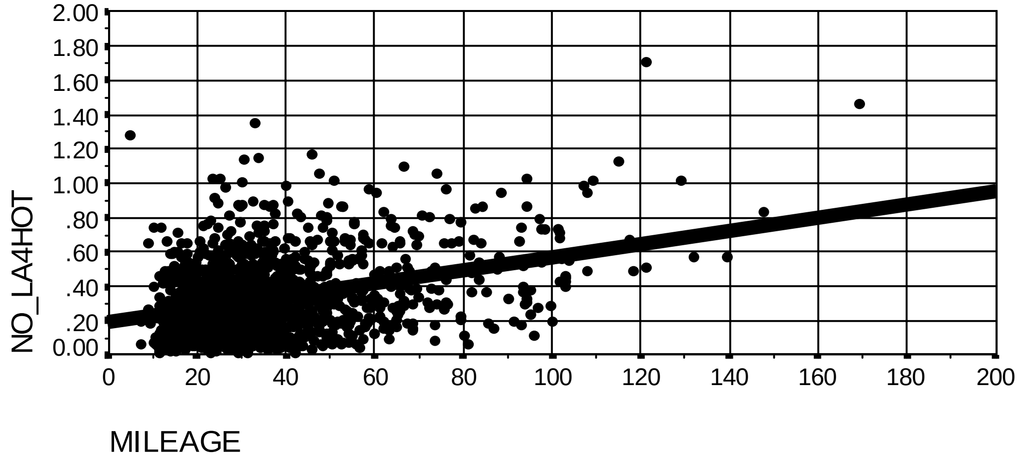


Figure A-3

NOx Emissions from Normals



APPENDIX B

<u>Sample Calculations for Fleet High Emitter Rate</u>

This sample calculation shows the steps for determining the percentage of High Emitters in the fleet for HC running emissions at an age of 5 for 1988-1993 PFI technology passenger cars.

Calculating the average emission rate (A) for HC:

mileage <21,270	A = 0.05158 + 0.0013 * M
21,270<mileage<100,000	A = 0.05158 + 0.0013 * 21.27 + (X - 21.27) * 0.0036
mileage > 100,000	A= 0.05158 + 0.0013 * 21.27 + (100.0 - 21.27) * 0.0036 + (M - 100.0) * 0.0036

Where 'M' is the mileage divided by 1000. See the document "Determination of Running Emissions as a Function of Mileage for 1981-1993 Model Year Light-Duty Vehicles" for the derivation of this equation.

From Table 3, the average mileage of passenger cars 5 years old is 67,547 miles.

A = 0.05158 + 0.0013 * 21.27 + (67.547 - 21.27) * 0.0036

A = 0.249 g/mi HC

Calculating the average normal emitter rate (B) for HC using the coefficients from Table 1a and using the mileage from Table 3:

B = 0.0214 + 0.001385 * 67.547

B = 0.115 g/mi HC

Choosing the high emitter rate (C) using the values from Table 2a:

C = 1.740 g/mi HC

Calculating percentage of Highs using Equation 7 in Section 3.8.

High Fraction = (A - B) / © - B)
High Fraction = (0.249 - 0.115) / (1.740 - 0.115) = 0.0823 or 8.23

Appendix C

Statistical Detail: Standard Errors, P values and Standard Deviations

Table C-1
Standard Deviations of Means
RUNNING Emissions of High Emitter CARS

MY Group	Tech Group	HC Sample Size	CO Sample Size	HC Standard Deviation	CO Standard Deviation	NOX Standard Deviation
1988-93	PFI*	58	44	4.049	47.350	1.069 / 11
1988-93	TBI	38	43	6.487	53.284	1.012 / 15
1983-87	FI	118	97	4.832	51.883	0.895 / 44*
1986-89	Carb	212	233	4.530	41.593	0.768 / 60*
1983-85	Carb	212	233	4.530	41.593	0.768 / 60*
1981-82	FI	118	97	4.832	51.883	0.895 / 44*
1981-82	Carb	118	97	4.832	51.883	0.895 / 44*

* Second number is the NOX high emitter sample size

Table C-2
Standard Deviations of Means
RUNNING Emissions of High Emitter TRUCKS

MY Group	Tech Group	HC Sampl e Size	CO Sampl e Size	HC Standard Deviation	CO Standard Deviation	NOX Standard Deviation
1988-93	PFI	2	3	0.966	18.498	NA / 1*
1988-93	TBI	2	3	2.259	18.498	NA / 1
1981-87	FI	17	3	1.1776	3.502	NA / 1
1984-93	Carb	18	11	1.244	25.000	NA / 1
1981-83	Carb	10	4	1.482	21.314	NA / 1

* Truck sample had only one high emitter in each group.

Table C-3 Regression Statistics from Normal Emitting Cars - CO EMISSIONS						
MY Group	Tech Group	Sample Size	S.E Slope	SE ZML	Sig T Slope	Sig T ZML
		CO	CO	CO	CO	CO
1988-93	PFI	1590	0.00119	0.05662	0.0000	0.0000
1988-93	TBI	431	0.00233	0.13169	0.0000	0.8301
1983-87	FI	640	0.00212	0.13010	0.0000	0.0000
1986-89	Carb	93	0.00340	0.21690	0.0001	0.0105
1983-85	Carb	233	0.00446	0.17510	0.0002	0.0000
1981-82	FI	107	0.00612	0.30090	0.0007	0.0000
1981-82	Carb	815	0.00231	0.09617	0.0000	0.0000

Table C-4 Regression Statistics from Normal Emitting Cars - HC EMISSIONS						
MY Group	Tech Group	Sample Size	S.E Slope	SE ZML	Sig T Slope	Sig T ZML
		HC	HC	HC	HC	HC
1988-93	PFI	1582	7.066e-5	0.00335	0.0000	0.0000
1988-93	TBI	435	1.254e-4	0.00708	0.0000	0.5540
1983-87	FI	622	1.564e-4	0.00919	0.0000	0.0000
1986-89	Carb	91	3.306e-4	0.02050	0.0159	0.0000
1983-85	Carb	233	3.825e-4	0.01490	0.0017	0.0000
1981-82	FI	104	3.786e-4	0.01887	0.0000	0.0000
1981-82	Carb	838	1.492e-4	0.00628	0.0000	0.0000

Table C-5
Regression Statistics from Normal Emitting Cars - NOX EMISSIONS

MY Group	Tech Group	Sample Size	S.E Slope	SE ZML	Sig T Slope	Sig T ZML
		NOX	NOX	NOX	NOX	NOX
1988-93	PFI	1610	2.210e-4	0.0106	0.0000	0.0000
1988-93	TBI	440	3.608e-4	0.0203	0.0000	0.0000
1983-87	FI	693	3.777e-4	0.0235	0.0000	0.0000
1986-89	Carb	94	0.00106	0.0680	0.1120	0.0000
1983-85	Carb	247	0.00107	0.0442	0.0119	0.0000
1981-82	FI	107	0.00136	0.0669	0.0000	0.0000
1981-82	Carb	973	4.281e-4	0.0193	0.0000	0.0000

Table C-6
Regression Statistics from Normal Emitting TRUCKS - CO EMISSIONS

MY Group	Tech Group	Sample Size	S.E Slope	SE ZML	Sig T Slope	Sig T ZML
		CO	CO	CO	CO	CO
1988-93	PFI	329	0.00421	0.2045	0.0000	0.0166
1988-93	TBI	465	0.00298	0.1274	0.0000	0.0000
1981-87	FI	90	0.01184	0.8112	0.0005	0.0486
1984-93	Carb	122	0.01802	0.9354	0.0003	0.1500
1981-83	Carb	163	0.0274	1.2391	0.2319	0.0000

Table C-7
Regression Statistics from Normal Emitting TRUCKS - HC EMISSIONS

MY Group	Tech Group	Sample Size	S.E Slope	SE ZML	Sig T Slope	Sig T ZML
		HC	HC	HC	HC	HC
1988-93	PFI	330	3.479e-4	0.01689	0.0000	0.0778
1988-93	TBI	464	2.486e-4	0.01061	0.0000	0.0000
1981-87	FI	76	8.651e-4	0.05490	0.0003	0.0172
1984-93	Carb	115	8.258e-4	0.0407	0.0014	0.0000
1981-83	Carb	157	0.00150	0.06656	0.0000	0.0000

Table C-8 Regression Statistics from Normal Emitting TRUCKS - NOX EMISSIONS						
MY Group	Tech Group	Sample Size	S.E Slope	SE ZML	Sig T Slope	Sig T ZML
		NOX	NOX	NOX	NOX	NOX
1988-93	PFI	331	9.091e-4	0.0441	0.0000	0.0000
1988-93	TBI	466	6.508e-4	0.0279	0.0000	0.0000
1981-87	FI	93	0.00263	0.1825	0.0032	0.0478
1984-93	Carb	132	0.00205	0.1134	0.2511	0.0000
1981-83	Carb	166	0.00210	0.0960	0.9910	0.0000

Appendix D
Statistical Diagnostics for Running and Start Emission I/M Identification Rate Effectiveness (IDR) Determination

```
-> REGRESSION
->   /DESCRIPTIVES MEAN STDDEV CORR SIG N
->   /MISSING LISTWISE
->   /STATISTICS COEFF OUTS CI R ANOVA
->   /CRITERIA=PIN(.05) POUT(.10)
->   /NOORIGIN
->   /DEPENDENT hcrun_id
->   /METHOD=ENTER ln_hccut ln_cocut  .


           * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Equation Number 1    Dependent Variable..   HCRUN_ID   HCRun ID

  Descriptive Statistics are printed on Page    2

Block Number  1.  Method:  Enter      LN_HCCUT LN_COCUT


Variable(s) Entered on Step Number
   1..    LN_COCUT
   2..    LN_HCCUT


Multiple R           .90947
R Square             .82713
Adjusted R Square    .82246
Standard Error       .06411

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           2             1.45516           .72758
Residual            74              .30413           .00411

F =     177.03226       Signif F =  .0000


---------------------- Variables in the Equation -----------------------

Variable              B        SE B     95% Confdnce Intrvl B       Beta

LN_HCCUT       -.136503     .010483     -.157390     -.115615   -.629362
LN_COCUT       -.106888     .007869     -.122568     -.091209   -.656531
(Constant)     1.145095     .026063     1.093164     1.197027

----------- in ------------

Variable           T  Sig T

LN_HCCUT     -13.021  .0000
LN_COCUT     -13.583  .0000
(Constant)    43.936  .0000


-> REGRESSION
->   /DESCRIPTIVES MEAN STDDEV CORR SIG N
->   /MISSING LISTWISE
->   /STATISTICS COEFF OUTS CI R ANOVA
->   /CRITERIA=PIN(.05) POUT(.10)
->   /NOORIGIN
->   /DEPENDENT corun_id
->   /METHOD=ENTER ln_hccut ln_cocut  .


           * * * *   M U L T I P L E   R E G R E S S I O N   * * * *

Equation Number 1    Dependent Variable..   CORUN_ID   CORun ID
```

```
Block Number  1.  Method:  Enter      LN_HCCUT LN_COCUT


Variable(s) Entered on Step Number
   1..    LN_COCUT
   2..    LN_HCCUT


Multiple R           .90658
R Square             .82188
Adjusted R Square    .81707
Standard Error       .06736

Analysis of Variance
                   DF      Sum of Squares      Mean Square
Regression          2             1.54920           .77460
Residual           74              .33574           .00454

F =     170.72789       Signif F =  .0000


---------------------- Variables in the Equation -----------------------

Variable              B        SE B     95% Confdnce Intrvl B       Beta

LN_HCCUT       -.107306     .011014     -.129253     -.085360   -.477976
LN_COCUT       -.129819     .008268     -.146293     -.113344   -.770339
(Constant)     1.188020     .027384     1.133456     1.242584


----------- in ------------

Variable           T  Sig T

LN_HCCUT      -9.742  .0000
LN_COCUT     -15.702  .0000
(Constant)    43.384  .0000

-> * Curve Estimation.
-> TSET NEWVAR=NONE .
-> CURVEFIT /VARIABLES=noid  WITH nocut
->   /CONSTANT
->   /MODEL=CUBIC
->   /PRINT ANOVA
->   /PLOT FIT.

Dependent variable.. NOID              Method.. CUBIC

Listwise Deletion of Missing Data

Multiple R           .99902
R Square             .99805
Adjusted R Square    .99658
Standard Error       .01860

            Analysis of Variance:

              DF   Sum of Squares      Mean Square

Regression     3        .70707598        .23569199
Residuals      4        .00138343        .00034586

F =     681.46957       Signif F =  .0000

-------------------- Variables in the Equation --------------------

Variable                  B        SE B       Beta         T  Sig T

NOCUT               .756842     .102036   3.175112     7.417  .0018
NOCUT**2          -.368671     .037175  -9.352562    -9.917  .0006
NOCUT**3            .040631     .004083   5.358327     9.951  .0006
(Constant)          .545291     .082060                6.645  .0027
```

```
-> REGRESSION
->   /MISSING LISTWISE
->   /STATISTICS COEFF OUTS CI R ANOVA
->   /CRITERIA=PIN(.05) POUT(.10)
->   /NOORIGIN
->   /DEPENDENT hc_strt_
->   /METHOD=ENTER ln_hccut ln_cocut  .


           * * * *   M U L T I P L E   R E G R E S S I O N   * * * *


Listwise Deletion of Missing Data

Equation Number 1    Dependent Variable..   HC_STRT_   HC Strt ID

Block Number  1.  Method:  Enter      LN_HCCUT LN_COCUT


Variable(s) Entered on Step Number
   1..    LN_COCUT
   2..    LN_HCCUT


Multiple R           .85506
R Square             .73113
Adjusted R Square    .70669
Standard Error       .11633

Analysis of Variance
                   DF      Sum of Squares      Mean Square
Regression          2             .80951           .40476
Residual           22             .29769           .01353

F =      29.91216       Signif F =  .0000


---------------------- Variables in the Equation -----------------------

Variable              B        SE B     95% Confdnce Intrvl B       Beta

LN_HCCUT       -.158962     .028853     -.218799     -.099126   -.609838
LN_COCUT       -.140941     .024734     -.192237     -.089645   -.630732
(Constant)      .981406     .084067      .807061     1.155752


----------- in ------------

Variable           T  Sig T

LN_HCCUT      -5.509  .0000
LN_COCUT      -5.698  .0000
(Constant)    11.674  .0000

-> REGRESSION
->   /MISSING LISTWISE
->   /STATISTICS COEFF OUTS CI R ANOVA
->   /CRITERIA=PIN(.05) POUT(.10)
->   /NOORIGIN
->   /DEPENDENT co_strt_
->   /METHOD=ENTER ln_hccut ln_cocut  .


           * * * *   M U L T I P L E   R E G R E S S I O N   * * * *


Listwise Deletion of Missing Data

Equation Number 1    Dependent Variable..   CO_STRT_   CO Strt ID

Block Number  1.  Method:  Enter      LN_HCCUT LN_COCUT


Variable(s) Entered on Step Number
   1..    LN_COCUT
   2..    LN_HCCUT
```

```
Multiple R           .84999
R Square             .72249
Adjusted R Square    .69726
Standard Error       .13266

Analysis of Variance
                   DF      Sum of Squares      Mean Square
Regression          2            1.00799           .50399
Residual           22             .38718           .01760

F =      28.63762       Signif F =  .0000


--------------------- Variables in the Equation ----------------------

Variable              B        SE B     95% Confdnce Intrvl B       Beta

LN_HCCUT       -.159301     .032905     -.227541     -.091061   -.544428
LN_COCUT       -.170728     .028208     -.229228     -.112229   -.680635
(Constant)     1.145947     .095873      .947118     1.344777


----------- in ------------

Variable           T  Sig T

LN_HCCUT      -4.841  .0001
LN_COCUT      -6.053  .0000
(Constant)    11.953  .0000
```