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MOBILE6 Inspection/ Maintenance Benefits Methodology for 1981 through 1993 Model Year Light Vehicles

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NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data which are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position, or regulatory action.

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- Draft -

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Report Number M6.IM.001

Last Revised February 22, 1999

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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 1981-93 model year cars and light-duty trucks, and 1994 and 1995 model year cars and trucks which were not certified to Tier1 or later standards. It calculates separate 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. It is modeled using a mathematical model which resembles a 'sawtooth'. The bottom of the "teeth" are the after repair emission levels immediately following I/M, and the top of the "teeth" are the levels to which the fleet deteriorates after one periodic inspection cycle, or a six month RSD / change of ownership cycle.

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

New Features:

1. Internal operation - 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.

4. Annual, Biennial, Triennial, and Change of Ownership I/M testing frequency can now be modeled.

5. Ability to model up to five different I/M programs simultaneously.

6. Remote Sensing of High emitters can now be modeled.

7. 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 20 model years / ages.

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

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

10. Ability to model RSD Clean Screening and High Emitter Profiling exemptions from an I/M program.

Development of Important Parameters

1. The I/M methodology and associated parameters presented in this document are heavily based on two 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. The reader is encouraged to obtain these documents from the EPA Web site and review them.

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.

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

5. Average emissions of Normals and Highs for start and running emissions - FTP data were 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 - It is from MOBILE5. It assumes that vehicles repaired as part of the I/M process deteriorate at the same rate as a fleet which does not have an I/M program. However, unlike previous MOBILE models, the deterioration varies over the entire mileage range of 0 to 300,000 miles.

10. 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 change between draft and final versions, if real data provides another value. Stakeholders are encouraged to comment on this assumption, and provide any data or rational for an alternative default value.

11. High Emitter Non-Compliance Rate - Set to a default value of 15 percent. MOBILE6 will offer users the ability to enter alternative values. This is a generous default which is based on extensive analysis of Arizona and Ohio I/M vehicles. The analysis suggested higher rates (> 20 percent). It also includes high emitters which do not show up for the initial I/M test. The fact that 15 percent has been selected for use in the absence of user input does not constitute a policy by EPA to allow the use of this value for SIP purposes. EPA will propose a policy on this issue separately from this document. Stakeholders are encouraged to comment on this assumption, and provide any data or rational for an alternative default value.

12. High Emitter Waiver Rate - Selected to be 15 percent of failures, and loosely based on analysis of Arizona and Ohio I/M vehicles. The user will also have the ability to enter an alternative value into MOBILE6. Also, the fact that 15 percent

has been selected for use in the absence of user input does not constitute a policy by EPA to allow the use of this value for SIP purposes. EPA will propose a policy on this issue separately from this document. Stakeholders are encouraged to comment on this assumption, and provide any data or rational for an alternative default value.

13. Remote Sensing Parameters - These are based on two reports published by EPA. One report was on RSD identification of high emitters and the other was on RSD clean screening effectiveness. RSD and Change of Ownership modeling is new to the MOBILE model series, and requires several new inputs. However, its impact is relatively minimal on the overall I/M credits or basic emission level rates.

14. Assume **on average** for the fleet that one RSD inspection to identify high emitters is done per year on each vehicle in the I/M program. Field experience with RSD suggests that this is an ambitious goal, and may require many vehicles to get dozens of RSD tests per year; however, programs which manage to test more frequently than this rate will not get additional credit. The user will also be allowed to enter a specific RSD fleet coverage fractions for RSD high emitter identification and RSD clean screening. The range of these fractions will be from 0 percent to 100 percent.

15. The default RSD or High Emitter Profile clean screening loss of credit is five percent. However, the user of MOBILE6 is strongly encouraged to develop their own estimate and use it as an input to the model. Stakeholders are encouraged to comment on this assumption, and provide any data or rational for an alternative default value.

16. Change of Ownership - Data from Wisconsin suggests that roughly 16 percent of the testing annually is change of ownership testing. This translates into 8 percent every six months, and is built into the change of ownership "sawtooth" algorithm.

17. 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.

18. Both the ASM and Idle tests assume the same after I/M repair emission levels as the IM240 tests. Only the IDR rates are changed. This assumption is currently under review for the Idle and Idle/2500 RPM tests. The most likely change will be to adopt the MOBILE5 repair effects for Idle tests rather than assume the Idle test has the same repair reduction as the IM240 test. The ASM test will continue to use the same repair effect as the IM240 test.

General Statement

This document and the important parameters mentioned in it are currently in **DRAFT** status, and will likely remain in that status until mid-1999. This document will also likely receive some revision following peer review and stakeholder review. As a result, the I/M model, the basic emission rates, and the underlying parameters are all subject to possible future revision. Comments regarding the modeling approach, important parameters and assumptions are encouraged from stakeholders and other interested parties.

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 1993, and for non-Tier1 cars and trucks for model years 1994 and 1995. The I/M credit methodology for the pre-1996 model year will also be used for 1996 and later model years which receive only exhaust I/M tests. This document also describes how credits and debits for the remote sensing device (RSD) testing will be incorporated into MOBILE6. 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 document M6.EXH.007, 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 five 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 methodology - "sawtooth methodology", Section 5 describes the methodology for development of the start exhaust I/M credits based on the IM240 test. Section 6 describes the methodology for the development of credits for the other types of I/M tests (Idle, 2500/Idle, and ASM). The document also contains an extensive Appendix section which is listed A through H. Appendices A and C contain illustrative examples of the modeling approach. Appendix C contains some sample calculations. Appendix D contains the programmer's explanation and adoption for coding purposes of the algorithm described in this document. Appendices E through H 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 in generating the basic emission rates. 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, EPA concluded that these benefits outweighed the slight increase in uncertainty caused by using lab IM240 data.

The third database was the Arizona IM240 database 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.

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. It is documented in EPA document M6.IM.002.

The RSD credits and coverage parameters described in this document are based on extensive RSD testing at many locations. Details regarding the RSD data, and the analysis performed to determine the RSD credits can be found in EPA documents: "User Guide and Description for Interim Remote Sensing Program Credit Utility - EPA420-R-96-004", and "Draft Description and Documentation for Interim Vehicle Clean Screening Credit Utility - EPA420-P-98-008".

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), 1986-89 (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.

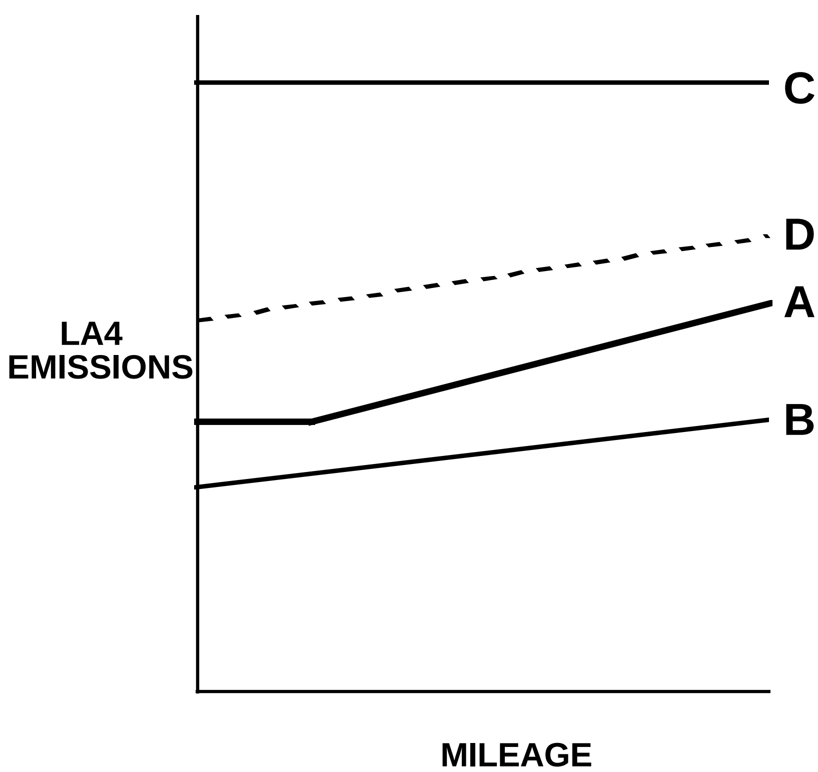
The selection of twice or thrice FTP certification standards for the boundary level between normals and highs is an engineering choice based on the literature on I/M and repair. Other reasonable boundary levels could also have been chosen. No formal analysis was done to prove that these levels were optimum. 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 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

FIGURE 1
GENERAL I/M CREDITS SCHEMATIC



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.

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	0.0001
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 is a flat horizontal line because the emissions of a high emitter is not likely to be a strong function of mileage. Regressions of the high emitter emissions versus mileage were done. However, the relatively small sample sizes of high emitters make regression determined mileage coefficients unreliable indicators of actual behavior. Various analyzes of failing cars in I/M programs also support the use of a flat emission rate for high emitters.

Instead, on many new vehicles, if something goes seriously wrong with the emission control system that is likely to immediately lead to high emissions, it is likely to be fairly random in 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). However, one weakness of this simplified approach is 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.

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 an overall mean was computed for the combined group. 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, all of 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. For this group it was thought that the average high emitter emission level was too low because it caused the average high emitter level to be lower than the normal emitter level at fairly low mileages. It was increased from 1.10 g/mi HC to 1.74 g/mi HC by adding one very high emitting 1987 model year vehicle to the 1988-93 model year PFI group.

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 non-I/M running emission estimates because the normal and high emitter split is not used to calculate the 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 emission impact because it simultaneously increases the average high emitter average, but decreases the fraction of high emitters in the fleet. This change will also impact 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. 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. However, the process will allow an I/M program to claim full credit for fixing vehicles with definitive problems such as a bad oxygen sensor.

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.

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.

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 <u>Discussion of the After Repair Adjustment Factors</u>

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.

Thus, it is proposed for MOBILE6 that the default after repair emission levels 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 <u>increasing</u> 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.

Overall, the two factors discussed above might tend to cancel each other out. However, because of these problems, the MOBILE6 program will allow optional user input of 'w/o technician training' emission increase percentages. These will be for users who do not have or plan to have a technician training program as part of their I/M program, but can nevertheless estimate the detrimental impact of not having one through engineering judgement, use of data from other I/M programs or other methods.

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. The user will also have the option of providing their own value(s) separately for each pollutant based on program data. If EPA completes such an analysis between draft and final versions of this portion of MOBILE6, or receives one in the comment period, the default value may be changed to another number.

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

Highs + Normals = 1 Eqn 5

and

LA4 = High_ave * Highs + Norm_ave * Normals 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: 0.50 to 5.0 grams/mile; CO: 5.0 to 100.0 grams/mile; and NOx: 1.0 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 C).

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:

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

3.10 I/M Non-Compliance Rates

One potential problem in I/M is that of non-compliant vehicles. By definition, these are the high emitting vehicles which fail the initial test, but drop out of the I/M process prior to receiving a passing test or a cost waiver. This type of non-compliant vehicle is assumed to remain a high emitter at the average high emitter emission level (no reduction is given like in the case of cost waived vehicles). In the MOBILE6 model, the non-compliant vehicles will be represented as a fraction of the identified high emitters that did not pass or receive a cost waiver. A default value of 15 percent will be built into the model for the non-compliance rate. It is based on studies where large samples of I/M vehicles were tracked as they passed through I/M programs. Optional user inputs will also be available that permit any number from 0 percent to 100 percent to be used if supported by data.

The other type of non-compliant vehicle is one which does not show up for its initial test (owner ignores I/M). 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, it is assumed that the 15 percent non-compliance rate (from above) includes the effect of high emitters which did not show up for their first test. Similarly a user defined input for non-compliance should take these vehicles into account.

3.11 Average Emissions After I/M

An important step in calculating the I/M credits is to calculate the average emissions of the fleet after a cycle of I/M testing and repair. The average is calculated for each vehicle type / pollutant / model year group/ technology group at many odometer points during the life of the group. Conceptually, the average emissions of the fleet after I/M is a weighted sum of (1) the normal emitters which were unaffected by I/M, (2) the high emitters which were not identified by I/M and which keep the same high emissions, (3) the high emitters which were non-compliant and which keep the same high emissions, (4) the high emitters which were identified and cost waived, and (5) the high emitters which were identified and successfully repaired by the I/M process. The last type drops down to the after repair levels (FIX in Equation 12) calculated in Section 3.6 (Line D).

Equation 12 is used to calculate the average emissions of the fleet after a cycle of I/M.

$$EIM = N*(1-X) + H*X*(1-IDR) + X*IDR*W*H*RW + N*R*X*IDR*FIX + H*X*IDR*NC \quad \text{Eqn 12a}$$

Where:

N*(1-X) = Normal Emitters emission effect

H*X*(1-IDR) = High Emitters not identified emission effect

X*IDR*W*H*RW = High Emitters identified and Waived emission effect

N*R*X*IDR*FIX = High Emitters identified and Repaired emission effect

H*X*IDR*NC = High Emitters identified and Non-Compliant vehicles emission effect

Variables:

N	Emission Level of Normal Emitters (g/mi).
H	Emission Level of High Emitters (g/mi).
X	Fraction of High Emitters in the fleet before the cycle of I/M.
IDR	Fraction of Total Fleet High Emitters Identified by an I/M test.
W	Fraction of Identified High Emitters which get a repair cost waiver.
NC	Fraction of Identified High Emitters which are in non-compliance of the I/M program.
FIX	Fraction of Identified High Emitters which get repaired to pass the test.
R	Fraction of the normal emitter level that high emitters are repaired after I/M (value is > 1.0).
RW	Fraction of the high emitter level that waived high emitters are repaired after I/M.

The fractions W, NC, and FIX are all applied to the IDR fraction. An identified vehicle is either waived, in non-compliance, or is properly repaired. Thus,

$$W + NC + FIX = 1.0 \quad \text{Eqn 12b}$$

4.0 Periodic I/M Credit Algorithm (Sawtooth Methodology)

This section describes the methodology for the periodic I/M credit algorithm over time or the "sawtooth" methodology. The first few sections describe the algorithm and equations for the "sawtooth" when neither a remote sensing program that identifies high emitters, nor a change of ownership testing requirement is present. The remaining sections describe the "sawtooth" algorithm for a combined program of periodic I/M (I/M), change of ownership I/M (COIM), and remote sensing. Both algorithms are essentially the same, except the I/M + RSD + COIM algorithm works on a bi-annual (every six months) basis, and the I/M only algorithm works on an annual or biennial basis. MOBILE6 will also compute benefits for other variations of I/M, RSD, and COIM. These include: I/M+RSD, I/M+COIM, and COIM only. The algorithm for these variations is essentially the same as for the base I/M+RSD+COIM case.

4.1 Discrete Points

The MOBILE6 program will not use "continuous" regression lines of emissions versus mileage to represent the before and after I/M emission rates, but instead will use discrete points on these lines. Each point on the line will represent a particular vehicle age that ranges from 1 to 26 years. Table 3 shows the correspondence of age and cumulative mileage for cars. Each particular age and mileage corresponds to a January 1st reference. The six month mileage points needed for RSD and COIM will be generated from the mileages on this table by averaging the two surrounding points. For example, age = 1.5 years (18 months) is obtained by averaging the points at age = 1 and age = 2.

The text describing the I/M credits with NO RSD or COIM will use the index variable 'ii' to represent yearly intervals. The text describing the I/M credits with RSD and/or COIM will use the index variable 'i' to represent six month intervals.

Table 3 January 1st Mileage and Age Correspondence for Cars in MOBILE6			
Age	Cumulative Mileage (in 1000's)	Age	Cumulative Mileage (in 1000's)
1	2.142	14	165.960
2	12.823	15	175.077
3	29.335	16	183.753
4	45.050	17	192.010
5	60.006	18	199.869
6	74.239	19	207.349
7	87.786	20	214.466
8	100.678	21	221.241
9	112.948	22	227.688
10	124.625	23	233.823
11	135.738	24	239.663
12	146.315	25	245.220
13	156.380	26	250.509

4.2 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.

MOBILE6 will be able to account for consecutive age / model year exemptions starting with age = 1. For example, most programs exempt the youngest fleet age or the newest model year in the fleet. This means that vehicles which are one year old are not tested. Because it is so common, a one year exemption is the default pattern shown for the annual and 1-3-5 biennial I/M algorithms. A two year exemption is the default pattern for the 2-4-6 biennial algorithm. MOBILE6 will also have the ability to exempt the first of any consecutive new model years (i.e., exempt vehicles 2, 3, 4, 5, ... n years old). The effect of this is to shift the 'sawtooth' curve to the right. Exempting older model year / age vehicles (i.e., all of the vehicle 15 years or older) will also be available in MOBILE6. Mechanically, this will be done by computing the credits using the standard algorithm, and then setting them to zero for the exempted model years.

4.3 Annual I/M Credits with NO Remote Sensing

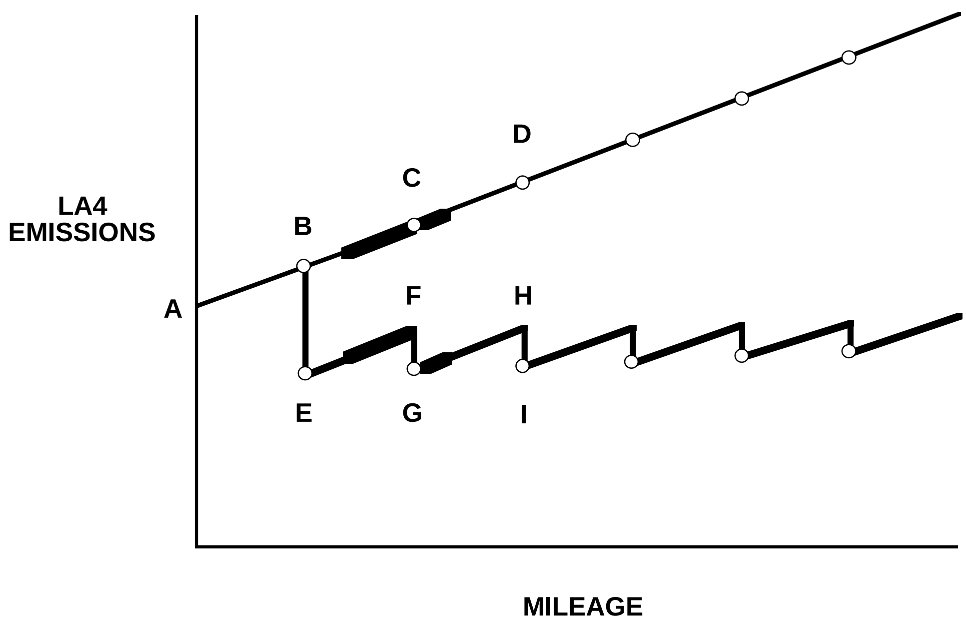
The MOBILE6 model will generate separate I/M credits for each combination of vehicle type / pollutant / model year group / technology class. In concept, these credits could be generated by comparing the basic emission rate line - (see Section 3.3) with the average emissions after I/M line - (see Section 3.9). However, because of a number of complications these lines cannot be used directly. Instead EPA developed the 'sawtooth' algorithm shown conceptually in Figure 2a.

One of the problems with a linear approach is the distribution of ages within a model year group. For purposes of modeling, all vehicles are assumed to be inspected on the first anniversary of their purchase and periodically thereafter, always on that same date. It is also assumed that sales occur exactly in the 12 month period from October of the calendar year previous to the model year through September of the next calendar year. For example, in January, 1999, the age distribution of the 1997 model year vehicles will range from 2.25 years to 1.25 years. With an annual inspection program, vehicles between one-and-two-years-old have only been inspected once. Any vehicles two years and older should have received their second inspection. In this example, 25 percent of the emissions on the evaluation date come from vehicles recently completing their second inspection and 75 percent of the emissions come from vehicles which have been inspected only once.

Another factor which must be taken into account is the deterioration of the vehicles in between their yearly inspections and repairs. Existing evidence suggests that the type of problems which cause I/M failures can re-occur as often in the repaired vehicles as they do in the unrepaired fleet. Thus, it is assumed that the fleet, after repair, will have the same emission deterioration as before repairs.

Figure 2a graphically shows the I/M credit methodology. The top set of 26 (ages) points (only 6 are shown) is the basic emission rate for a given group (vehicle type / pollutant / model year group / technology). For instance, Points B, C, and D show the non I/M line for vehicle ages of 1, 2, and 3 years. The lower 'sawtooth' figure is the I/M line. The 'sawtooth' illustrates the effect of I/M inspection and repair and the subsequent

FIGURE 2A
ANNUAL I/M CREDITS SAWTOOTH



deterioration of the fleet. All deterioration slopes are parallel (i.e., segment B-C is parallel to segment E-F). The repair effect is represented by the sudden drop in emission level at each inspection interval (i.e, from Point F to Point G). The heavy shaded portions of the lines illustrate how an I/M credit for the given group at age X is produced. MOBILE6 always chooses January 1st as the evaluation date. The vehicles sold from October through December are represented by the short line segment to the right of the two year anniversary point. These are vehicles which are older than X years. The longer line segment to the left of the anniversary point represents the vehicles sold from January through September, which are still less than X years old at the January evaluation date. The weighted average of each segment is calculated and the percent difference between the two weighted averages is computed. This percent difference is the I/M credit for a given age.

Mathematically, this process is shown for the Non I/M (top line) and the I/M (sawtooth line) as:

<u>Non I/M</u>

```
NOIM(ii) =  0.75 * (E(ii) - 0.375*(E(ii) - E(ii-1)) ) +
            0.25 * ( E(ii) + 0.125*(E(ii) - E(ii+1)) )      Eqn 14
```

Where NOIM is the average Non I/M value at age = ii in the equations above. It is the average of the two segments. Note “ii” means the “ii th” point. It should not be confused with Point I on the Figure 2B.

E(ii) is the basic emission rate at point ii. E(0) is the value at Point A.

The values of E(ii), E(ii-1), and E(ii+1) take into account the slope of the line between age = ii and age = ii + 1 and age = ii - 1. Figure 2a is an idealized drawing using a straight line. In the MOBILE6 model, the lines have some slight curvature due to the high emitter correction factor; thus, the slope is generally not the same between all segments.

Also, the weighting factor values of 0.375 and 0.125 shown throughout these equations represent the average of the heavy shaded segments in Figure 2A. For example, the 0.375 represents the average weighting of the highlighted segment between points B and C, and the 0.125 represents the average weighting of the highlighted segment between points C and D.

<u>I/M</u> <u>Special Case age = ii = 1</u>

```
IM(1)  =     0.75 * ( E(ii)   - 0.375*(E(ii) - E(ii-1) ) +
             0.25 * ( EIM(ii) + 0.125*(E(ii+1) - E(ii)) )   Eqn 15
```

<u>General Case age > 1</u>

```
IM(ii)  =   0.75 * [ EIM(ii) - 0.375*(E(ii) - E(ii-1) ] +
            0.25 * [ EIM(ii) + 0.125*(E(ii+1) - E(ii)) ]    Eqn 15
```

Where IM(ii) is the I/M line. Where EIM(i) is the average I/M emission line after repair, waiver, and non-compliance factors from Section 3.9.

The I/M credits are computed by dividing the difference between the NOIM emission value and the IM emission value by the NOIM emission value. An I/M credit is obtained for the ages 1 through 25.

```
IMCRED(ii)  =    [NOIM(ii) - IM(ii)]  /  NOIM(ii)           Eqn 15
```

4.4 Biennial I/M Credits with NO Remote Sensing

The values of E(ii) and EIM(ii) used in Equations 13 through 16 are also used to compute biennial I/M credits using a 'sawtooth' algorithm. The only difference between the annual and the biennial I/M credits is that the biennial values are applied every other year and that there is consequently a longer period of deterioration between I/M inspections and repairs. Figures 2b and 2c are analogous to Figure 2a. Figure 2b is an example of a 1-3-5 biennial program in which a vehicle is first inspected when it is one year old and then every two years thereafter. Figure 2c illustrates a 2-4-6 biennial program which first inspects a vehicle when it is two years old and then does an inspection every other year. The differences are small for a fleet that has a full complement of vehicle ages. The "Mixed" Biennial credits (Mix Bien IMCRED) are an average of these two program types. "Mixed Biennial" was the default for MOBILE5. This is an average of the 1-3-5 and 2-4-6 plans, or any mixed biennial program in which half of each model year or half of the fleet is inspected during each calendar year.

FIGURE 2B
1-3-5 BIENNIAL I/M CREDITS SAWTOOTH

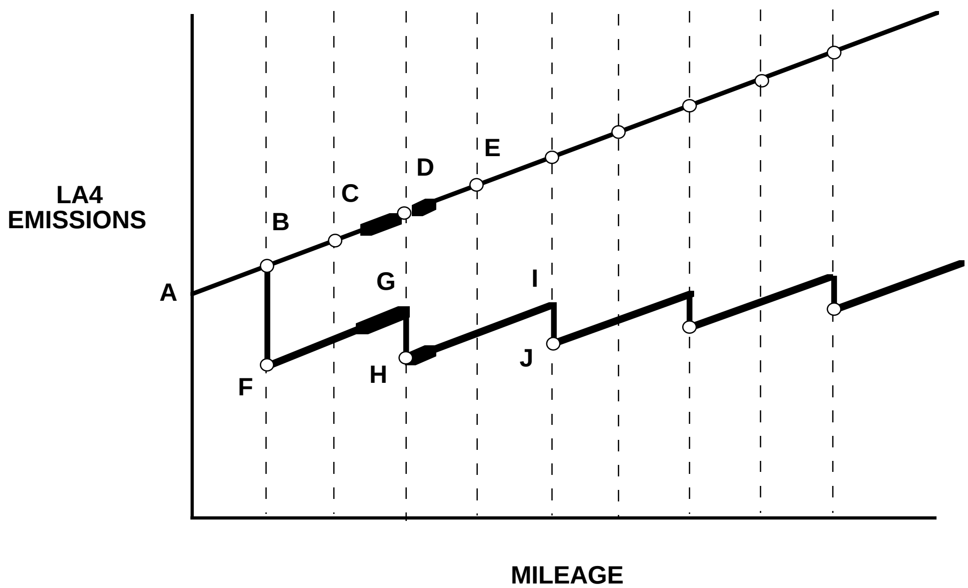
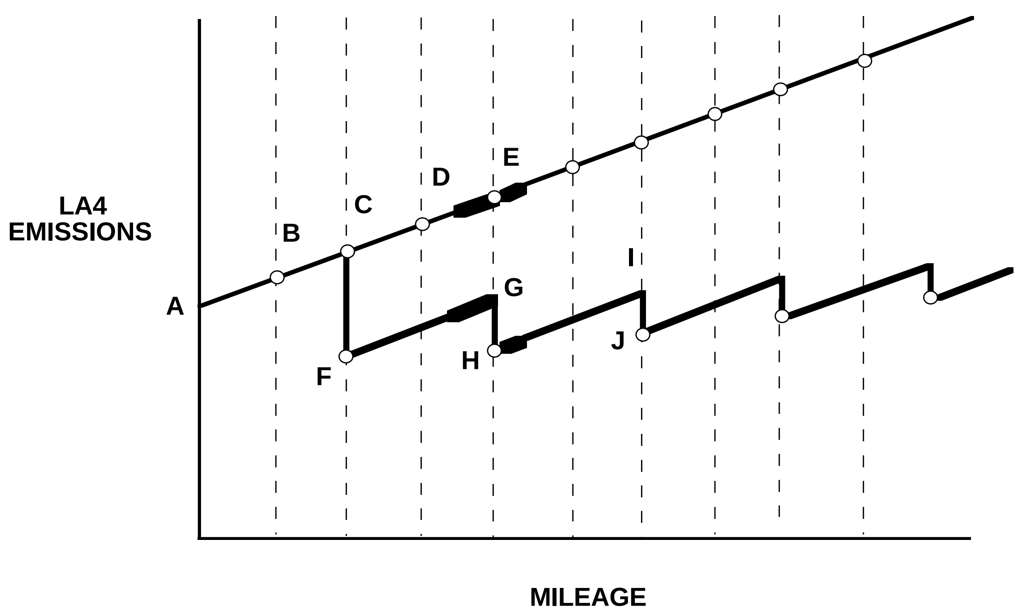


FIGURE 2C
2-4-6 BIENNIAL I/M CREDITS SAWTOOTH



Years of exemption = X. The Biennial 1-3-5 pattern and the Biennial 2-4-6 pattern have the same general equations except i starts at i=1 (X=1) for the first and i=2 for the second (X=2).

Non I/M

```
NOIM(ii) =  0.75 * [E(ii) - 0.375*(E(ii) - E(ii-1)) ] +
            0.25 * [E(ii) + 0.125*(E(ii) - E(ii+1)) ]      Eqn 14
```

I/M Special Case ii = 1 for 1-3-5 Case or ii = 2 for 2-4-6 Case

```
IM(1)  =     0.75 * [ E(ii)   - 0.375*(E(ii) - E(ii-1) ] +
             0.25 * [ EIM(ii) + 0.125*(E(ii+1) - E(ii)) ]   Eqn 15
```

General Case ii > 2*X

```
IM(ii) =    0.75*[EIM(ii-2)+E(ii-1)-E(ii-2) + 0.625*(E(ii)-E(ii-1))]
            0.25*[EIM(ii) + 0.125*(E(ii+1)-E(ii)) ]               Eqn 20
```

```
IMCRED(ii)  =     [NOIM(ii) - IM(ii)]  /  NOIM(ii)                Eqn 21
```

```
MixBien IMCRED  =  [(1-3-5 Bien Credit+ 2-4-6 Bien Credit] / 2    Eqn 22
```

4.5 I/M Credits with Remote Sensing and Change of Ownership

The MOBILE6 program will be able to calculate I/M credits for programs which conduct periodic I/M tests, RSD testing to identify high emitters, and change of ownership (COIM) I/M credits. The methodology in Sections 4.3 and 4.4 was for periodic I/M only type programs. Since RSD and COIM are non-periodic in nature, it is assumed that they identify and repair vehicles in a continuous distribution throughout a calendar year (i.e., all of the RSD testing or change of ownership testing is not conducted in June). Based on this assumption, this testing pattern is equivalent to a periodic test every six months. The RSD factor used in Equations in Sections 4.5.1 through 4.5.3 is computed as a product of the

RSD effectiveness parameter (Effectiveness), and the RSD Fleet coverage (Coverage). These two basic parameters account for the RSD's ability to individually identify high emitters, and its ability to test the entire fleet.

Also, the RSD and COIM credits are computed at each six month interval between the regular periodic inspections. Thus, there is one RSD / COIM interval (sawtooth pattern) between each periodic inspection in an annual program, and three RSD / COIM intervals between each biennial inspection. This assumes that on average the entire I/M fleet will not be inspected by RSD more than once during a year.

4.5.1 RSD Effectiveness Values

Table 4 shows the RSD effectiveness for HC, CO and NOx pollutants versus RSD percent CO readings. The individual values in the table represent the emissions identified by RSD at particular cutpoints ranging from 0.5% CO to 7.5% CO. The effectiveness values are based on studies done by EPA in Arizona, and by CARB in Sacramento. These values will be used as the RSD Effectiveness parameters in the MOBILE6 model. For more details on how these values were derived see "EPA420-R-96-004 - "User Guide and Description for Interim Remote Sensing Program Credit Utility".

Table 4
Remote Sensing Effectiveness Versus CO Cutpoint for 1981-93 Model Year Vehicles

RSD CO Cutpoint	HC Effectiveness	CO Effectiveness	NOx Effectiveness
0.5%	0.570	0.596	0.283
1.0%	0.433	0.499	0.178
1.5%	0.387	0.442	0.122
2.0%	0.348	0.396	0.091
2.5%	0.319	0.352	0.059
3.0%	0.262	0.278	0.054
3.5%	0.217	0.213	0.042
4.0%	0.182	0.178	0.018
4.5%	0.150	0.133	0.015
5.0%	0.109	0.107	0.009
5.5%	0.071	0.072	0.006
6.0%	0.060	0.053	0.003
6.5%	0.046	0.044	0.003
7.0%	0.039	0.034	0.003
7.5%	0.028	0.017	0.003

4.5.2 RSD Coverage Options

Three basic RSD program options will be available to the MOBILE6 user. Option 1 is the “Level of Effort Commitment”, Option 2 is the “Specific Level of Fleet Coverage Commitment”, and Option 3 is the “Number of Failures Commitment”. All three of these options utilize the coverage and effectiveness parameters. However, different methods are used to calculate the two parameters, and different user inputs are required.
(See RSD references for more details).

<u>Option 1 - Level of Effort Commitment</u>

In this option, the user enters the number of vehicle RSD tests which are to be done on an annual basis, and the total size of the fleet (in number of vehicles) which is subject to inspection. A modified Poisson algorithm is used to estimate the number of vehicles seen by remote sensing in order to calculate the fraction of the fleet tested by RSD (Coverage). This is necessary, since the fraction of all vehicles in the fleet which are measured by remote sensing is a function of the total number of RSD readings since some vehicles are seen multiple times by RSD. A Poisson algorithm is a standard method to model such a situation. The coverage fraction is also a function of the annual average VMT of a vehicle model year at a given age compared to its VMT when new. The equations which are used are:

P(X) = Lambda**X * exp(-Lambda) / X!

Where,

X Is an integer number starting at zero that represents the number of RSD tests which a vehicle receives before it is called in for a confirmatory test. Most programs will require at least two failing tests (X=2) prior to the confirmatory test.

i The vehicle age under evaluation.

P(X) The Poisson distribution function

Lambda Is the mean number of RSD tests during a given year. For example, if half of the fleet is inspected on average then Lambda would be 0.50. Mathematically, it is represented as:

Lambda = # RSD tests/yr * VMT(i) / ((# Veh in Fleet)*VMT(1))

Coverage(X) = 1.0 - SUM(P(X-1))

"No RSD" is the default option, However, if RSD is to modeled then Option 1 is recommended.

Option 2 - Specific Level of Fleet Coverage Commitment

In this option, the user specifies the fraction of the fleet in each model year that is seen using remote sensing. This fraction should only be the fraction of the fleet which has had sufficient valid remote sensing measurements to be identified as remote sensing failures for purposes of further I/M inspection. For example, if the RSD program is designed so that three RSD failures are needed before a vehicle is sent for off-cycle I/M testing (confirmatory testing), the fraction of the fleet used as the coverage commitment should represent the portion of the fleet that has received three RSD readings.

Thus,

Coverage = User Input

Option 3 - Number of Failures Commitment

In this option, the user specifies the fleet size by model year (in units of number of vehicles), and number of confirmed I/M failures by model year which the RSD will identify. Only vehicles identified for inspection by remote sensing and which fail the I/M inspection are to be included. In the MOBILE6 model, this option effectively combines the Effectiveness and the Coverage into one parameter - the fraction of high emitters identified by RSD. This value is then normalized to the entire fleet fraction of high emitters. The variable "Highs" from Equation 7 in Section 3.8 is used to normalize the RSD failure rate. The normalized value becomes the RSD parameter used in the equations in Sections 4.5.2 and 4.5.3.

RSD Fail Rate = # RSD Failures / Fleet Size

RSD = RSD Fail Rate / Highs

4.5.3 RSD Effective and Coverage Together

The final RSD value used in the I/M + RSD credit equations in Equations 4.5.2 and 4.5.3 is the product of the RSD Effectiveness and the RSD Coverage. For Coverage Options 1 and 2, the values are calculated separately and multiplied together. For Coverage Option 3, the RSD effectiveness and coverage are implied in the RSD Fail Rate. To assure consistency between all three coverage methods, MOBILE6 will prompt the user if unreasonable values for "RSD" or RSD Coverage parameters are used.

RSD = RSD Coverage * RSD Effectiveness

4.5.4 Change of Ownership Parameters

The change of ownership testing frequency is assumed to be quite random, and will be modeled for simplicity by the same six month interval as RSD. This effectively assumes that the change of ownership vehicles are representative of the overall fleet, and that this fraction of the fleet receives an additional I/M test every six months. Based on IM240 data from Wisconsin, this fraction was determined to be 16 percent annually. A default value of 8 percent will be applied for each six month interval. The 16 percent value was estimated from the Wisconsin change of ownership versus periodic test volume data shown in Table 5. The numbers are test vehicle counts, and are based on a quasi-random sample of full IM240 initial tests conducted either at Station #12 in Wisconsin or at other Wisconsin test stations on Saturdays. The Wisconsin I/M program is biennial and the periodic tests for the 1996 calendar year are on the odd model years only whereas the change of ownership testing is on all model years.

In addition, anecdotal evidence from Wisconsin suggests that this model may be a simplistic, and under predict the benefits of change of ownership. For example, analysis of change of ownership vehicles suggests that they (1) often contain a higher percentage of high emitters than the overall fleet, (2) that the high emitters change ownership more frequently than the more normal emitters, and (3) that a percentage of the change of ownership vehicles change owners more than once during a year. Therefore, to help balance these possible effects, the effect of waivers and non-compliance will not be assessed on change of ownership I/M testing.

Because of the uncertainty in estimating change of ownership parameters, the user will be allowed to input their own value into the MOBILE6 model. The COIM factor used in Equations in Sections 4.5.1 through 4.5.3 is computed as a product of the change of ownership fraction and the high emitter identification rate (IDR). These two factors account for how many change of ownership tests are done, and the effectiveness of each test.

Table 5 **Wisconsin Change-of-Owner Test Volumes** **in a 1996 Calendar Year Data Sample**			
Model Year	**Periodic Testing**	**Change Owner Testing**	**% Change of Owner**
1981	100	31	24.0%
1982		48	
1983	275	62	18.4%
1984		201	
1985	679	147	17.8%
1986		250	
1987	943	212	18.4%
1988		280	
1989	1231	209	14.5%
1990		250	
1991	1238	181	12.8%
ALL	**4,466**	**842**	**15.9%**

The RSD / COIM credits are computed as a fraction of the maximum possible periodic I/M credit at that given age. This has the effect of producing smaller "sawteeth" for six month intervals which do not coincide with a periodic inspection (smaller means that the bottom of the "sawtooth" is higher than the bottom of the periodic inspection "sawtooth"). There is no additional credit given, when the RSD / COIM intervals coincide with the periodic inspection interval. See Figures 3a and 3b.

4.5.1 Special Case for Year 1 of Program

Exemption = 1 Year (Annual I/M or 1-3-5 Biennial) then i = 2
Exemption = 2 Years (2-4-6 Biennial) then i = 4

Exemption = X Years then i = 2*X
Index variable 'i' represents six month intervals; thus, 2*i = ii

Non I/M

$$NOIM(i) = 0.75 * (E(i) - 0.375*(E(i) - E(i-1))) + 0.25 * (E(i) + 0.125*(E(i) - E(i+1))) \quad \text{Eqn 14}$$

I/M

(a) Points E(i) and EIM(i) are all known.
(b) I/M and non-I/M lines are parallel

$$E(½) = \frac{(E(i-2)+ E(i-1))}{2}$$

E(i-2), E(i-1), E(i), and E(i+1) are Known Values
EIM(i), EIM(i+1) are Known Values

$$TOP(i+1) = EIM(i) + (E(i+1) - E(i))$$

$$SEGMENT1A = \frac{(E(½) + E(i))}{2}$$

$$SEGMENT2A = \frac{(EIM(i) +[EIM(i) + (E(i+1) - E(i))/2])}{2}$$

$$IM(i) = 0.75 * SEGMENT1A + 0.25 * SEGMENT\ 2A$$

$$IMCRED(i) = \frac{(NOIM(i) - IM(i))}{NOIM(i)}$$

4.5.2 Annual I/M Credits

General Case #1: Annual I/M for Year 2 through 25;

General algorithm is i + n

RSD = RSD Coverage * RSD Effectiveness
COIM = Change of Ownership Fraction * IDR

RSD + COIM <= 1.0

E (i - 2)....E (i + 1) are derived from the basic emission factors
EIM (i - 2)....EIM(i + 1) are calculated in Section 3.11.

TOP (i - 1) = EIM(i - 2) + (E (i-1) - E(i - 2))
MID (i - 1) = TOP(i-1) - [TOP(i - 1) - EIM(i - 1)] * RSD
TOP(i) = MID(i - 1) + (E(i) - E (i - 1))
MID(i) = EIM(i)
TOP(i + 1) = MID(i) + (E (i + 1) - E(i))

$$\text{SEGMENT 1B} = \left(\left(\text{EIM}(i-2) + \frac{E(i-1) - E(i-2)}{2} + \text{TOP}(i-1) \right) \right) \Big/ 2$$

$$\text{SEGMENT 2B} = \left(\frac{\text{MID}(i-1) + \text{TOP}(i)}{2} \right)$$

$$\text{SEGMENT 3B} = \left[\text{MID}(i) + \left[\text{MID}(i) + \frac{E(i+1) - E(i)}{2} \right] \right] \Big/ 2$$

IM(i) = 0.25 * SEGMENT 1B + 0.50 * SEGMENT 2B + 0.25 * SEGMENT 3B

$$\text{IMCRED}(i) = \frac{(\text{NOIM}(i) - \text{IM}(i))}{\text{NOIM}(i)}$$

4.5.3 Biennial I/M Credits

General Case #1: Biennial I/M for Year i through 25;

General algorithm is i + n
i = 2 for the 1-3-5 Biennial
i = 4 for the 2-4-6 Biennial

CHART

General	Example
i - 4	2
i - 3	3
i - 2	4
i - 1	5
i	6
i + 1	7

RSD = RSD Coverage * RSD Effectiveness

COIM = Change of Ownership Fraction * IDR

RSD + COIM <= 1.0

E (i - 2)....E (i + 1) are derived from the basic emission factors

EIM (i - 2)....EIM(i + 1) are calculated in Section 3.11.

EIM(i-4)	=	MID(i-4)
TOP(i-3)	=	MID(i-4) + (E(i-3) - E(i-4))
MID(i-3)	=	TOP(i-3) - [TOP(i-3) - EIM(i-3)] * RSD
TOP(i-2)	=	MID(i-3) + (E(i-2) - E (i-3))
MID(i-2)	=	TOP(i-2) - [TOP(i-2) - EIM(i-2)] * RSD
TOP(i-1)	=	MID(i-2) + (E(i-1) - E(i-2))
MID(i-1)	=	TOP(i-1) - [TOP(i-1) - EIM(i-1)] * RSD
TOP(i)	=	MID(i-1) + (E(i) - E(i-1))
EIM(i) =	MID(i)	
TOP(i+1)	=	MID(i) + (E(i+1) - E(i-1))

$$\text{SEGMENT 1B} = \Big(\big(\text{EIM}(i-4) + (E(i-3) - E(i-4))/2 + \text{TOP}(i-3)\Big)\Big/ 2$$

$$\text{SEGMENT 2B} = \left(\frac{\text{MID}(i-3) + \text{TOP}(i-2)}{2}\right)$$

$$\text{SEGMENT 3B} = \Big[\text{MID}(i-2) + \big[\text{MID}(i-2) + (E(i-1) - E(i-2))/2\big]\Big]\Big/ 2$$

$$\text{IM}(i) = 0.25 * \text{SEGMENT 1B} + 0.50 * \text{SEGMENT 2B} + 0.25 * \text{SEGMENT 3B}$$

$$\text{IMCRED}(i) = \frac{(\text{NOIM}(i) - \text{IM}(i))}{\text{NOIM}(i)}$$

$$\text{SEGMENT 1C} = \Big(\big(\text{MID}(i-2) + (E(i-1) - E(i-2))/2 + \text{TOP}(i-1)\Big)\Big/ 2$$

$$\text{SEGMENT 2C} = \left(\frac{\text{MID}(i-1) + \text{TOP}(i)}{2}\right)$$

$$\text{SEGMENT 3C} = \Big[\text{MID}(i) + \big[\text{MID}(i) + (E(i+1) - E(i))/2\big]\Big]\Big/ 2$$

$$\text{IM}(i+1) = 0.25 * \text{SEGMENT 1C} + 0.50 * \text{SEGMENT 2C} + 0.25 * \text{SEGMENT 3C}$$

$$\text{IMCRED}(i+1) = \frac{(\text{NOIM}(i) - \text{IM}(i))}{\text{NOIM}(i)}$$

4.6 RSD / Vehicle Profiling Exemptions

4.6.1 RSD Exemptions

An important use of the RSD test in the context of I/M may be to use it as a method of screening out 'normal' emitting vehicles, and exempting them from regular I/M. The motivation for such a program might be to reduce the inspection cost by exempting a fraction of the fleet which is very likely to pass anyway. Also, since the test is largely unknown to the vehicle owner, and rather automatic, it might help build public support for an I/M program by inconveniencing fewer motorists.

The RSD clean screening logic is similar to that used in the high emitter identification algorithm. Both involve the terms RSD fleet coverage and RSD effectiveness. However, clean screening is attempting to properly identify low emitting vehicles for exemption from further program requirements while RSD high emitter identification is concerned with identifying high emitters for further testing and repair.

Clean Screening Coverage Options

Options 1 and 2 presented in Section 4.5.2 will be used for the clean screening coverage. These two options are the "Level of Effort Commitment", and the "Specific Level of Fleet Coverage Commitment". The same equations and algorithms will be used to model clean screening coverage as were used to model high emitter identification coverage (i.e., Poisson distribution equations). Option 3 will not be used because it only applies to high emitters.

Clean Screening Effectiveness Values

The RSD clean screening effectiveness values are shown in Tables 6a and 6b. They are shown as a percentage of the I/M credit which is lost through clean screening. They are a function of the RSD cutpoint combination, and the stringency of the underlying I/M test from which a clean screened vehicle is exempted. Also shown in the table is the percentage of the fleet which is exempted (clean screened). For example, if the RSD cutpoints of 200 ppm HC and 0.5% CO are used for clean screening, and the less stringent (phase-in) IM240 cutpoints are used, then 51 percent of the RSD tested fleet is exempted, 2 percent of the HC IDR is lost, 7 percent of the CO IDR is lost and 23 percent of the NOx IDR is lost.

<u>RSD Clean Screening Effectiveness and Coverage Together</u>

The RSD clean screening effectiveness and RSD coverage are multiplied together to produce an overall RSD clean screening effect. Mathematically, this is:

RSD_Loss = RSD Coverage * RSD Clean Screening Effectiveness

The resulting value for the RSD_Loss is applied by subtracting it from the I/M IDR (IDR) obtained in the previous I/M credit equations in Section 3.8. This produces the final IDR_RSD. For example, if the original I/M IDR (IDR) is 80 percent, the RSD coverage is 50 percent, and the losses from falsely exempting high emitters using RSD is 2 percent, then the I/M credit with RSD (IDR_RSD) is 79 percent.

A simplified mathematical equation is:

IDR_RSD = IDR - RSD_Loss

Table 6a
Remote Sensing Clean Screening Effectiveness
Interim (Less Stringent) I/M Standards

Clean Screening Cutpoints	Vehicles Tested	% Vehicles Passing Clean Screening	% HC IDR Credit **LOST**	% CO IDR Credit **LOST**	% NOx IDR Credit **LOST**
HC 200 ppm CO 0.5% NOx - None	594	51 %	2 %	7 %	23 %
HC 200 ppm CO 0.5% NOx - 2000 ppm	594	40 %	2 %	7 %	12 %
HC 200 ppm CO 0.5% NOx - 1500 ppm	594	37 %	1 %	0 %	11 %
HC 200 ppm CO 0.5% NOx - 1000 ppm	594	29 %	1 %	0 %	7 %

The default RSD exemptions used in the MOBILE6 model are based on an extensive study of RSD data and I/M data collected in various cities. The full methodology and numbers used in the MOBILE6 model are fully documented in the EPA document "Draft Description and Documentation for Interim Vehicle Clean Screening Credit Utility - EPA420-P-98-008".

Table 6b
Remote Sensing Clean Screening Effectiveness
Final (More Stringent) I/M Standards

Clean Screening Cutpoints	Vehicles Tested	% Vehicles Passing Clean Screening	% HC IDR Credit **LOST**	% CO IDR Credit **LOST**	% NOx IDR Credit **LOST**
HC 200 ppm CO 0.5% NOx - None	594	51 %	9 %	7 %	28 %
HC 200 ppm CO 0.5% NOx - 2000 ppm	594	40 %	6 %	5 %	15 %
HC 200 ppm CO 0.5% NOx - 1500 ppm	594	37 %	5 %	1 %	12 %
HC 200 ppm CO 0.5% NOx - 1000 ppm	594	29 %	4 %	1 %	7 %

4.6.2 High Emitter Profiling

High emitter profiling is similar to RSD in that it seeks to screen out low emitting vehicles and exempt them from the regular I/M inspection. The benefit is a saving of testing resources, and less inconveniencing of motorists. Like RSD the drawback is the loss of I/M benefits from exempting high emitters which should not be exempted. The equations which are used (shown below) are completely analogous to the RSD equations in terms of form and use.

Profile_High = Function [%fleet Profiled, Error Rate of Profile]

IDR_Prof = IDR - Profile_High

A user of MOBILE6 may want to model an I/M program which does both RSD and high emitter profile exemptions. In that case, both the RSD_High and the Profile_High losses are subtracted from the based IDR to produce a new IDR.

IDR_RSD_Prof = IDR - RSD_High - Profile_High

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 grams 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 eight technology and model year groups. Table 5 contains the average start emissions 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. 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. The analysis of the start emissions before and after repair is discussed in detail in EPA document M6.IM.002 "Determining Repair Effects of IM240 Cold Start Emissions for 1981 and Later Light-duty Vehicles".

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		CO Coefficients		NOx Coefficients	
		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 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 0.50 g/mi to 5.0 g/mi and CO ranges from 5.0 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). The variable S_RLEV is used in place of the variables N*R (normal emission level times the after repair emission level percentage) used in the running emissions calculation.

Equation 34 is used to calculate the average emissions of the fleet after I/M, and is used in the “sawtooth” methodology for I/M start emissions.

```
S_EIM =     N*(1-X) +   H*X*(1-S_IDR) +   X*S_IDR*W*H*RW +
            S_RLEV*X*S_IDR*FIX   +   H*X*S_IDR*NC
```
Eqn 34

5.6 I/M "Sawtooth"

The I/M credits for start emissions will also utilize the 'sawtooth' algorithm in the final calculation steps. This algorithm is virtually identical in structure to the ones presented in Section 4 for the running emissions. The structures used to model change of ownership and RSD are the same. Because the structure is the same, the methodology will not be repeated in this section. The only difference between the start and running algorithms are the actual emission rate parameters and values which are described in the previous sections. These include the normal and high emission levels, the IDRs, and the repair effects.

5.7 Remote Sensing and High Emitter Profile Start Emissions Parameters

Currently, the same remote sensing and high emitter profile parameters will be used for the start emissions as were used for the running emissions. In the case of RSD this may introduce some error since RSD is defined to be a warm emission test, and is not designed to identify high start emitters or screen out low start emitters. Presumably a high emitter profile which correctly profiles high and low start emissions can also be developed. However, it is likely to differ from the one used for running emissions.

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, (3) ASM tests, and (4) On-board Diagnostic (OBD) I/M tests. In addition, MOBILE6 will have the flexibility to model user defined test(s), or future test(s) which are currently unspecified.

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. Biennial Two-Mode ASM 2525/5015 with Phase-in Cutpoints
10. Biennial Two-Mode ASM 2525/5015 with Final Cutpoints
11. Biennial Single-Mode ASM 5015 with Phase-in Cutpoints
12. Biennial Single-Mode ASM 5015 with Final Cutpoints
13. Biennial Single-Mode ASM 2525 with Phase-in Cutpoints
14. Biennial Single-Mode ASM 2525 with Final Cutpoints
15. Biennial Idle Test
16. Biennial 2500 RPM / Idle Test

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). Rather than store all those ratios in the MOBILE6 program, the ratio data were reduced by fitting it to a linear-quadratic equations using least squares regression. The independent variables in the regression were age and model year. The age range is from 1 to 25 and the model year range is from 81 through 98. The 98 model year credits will be used to represent all subsequent model years. The equation form is:

$$ASM = A * age + B * age^2 + C * model\ year + D \qquad \text{Eqn 35}$$

Separate equation coefficients (A, B, C and D) were developed for each ASM test, cutpoint group, and pollutant. They are shown in Tables 7a and 7b below. Table 7a provides the coefficients for the Final ASM cutpoints and Table 7b shows the Phase-in ASM coefficients. Within each of these tables different coefficients were also developed for vehicle ages which are less than or equal to 10 years, and greater than 10 years. These ratios are then multiplied by the MOBILE6 IM240 IDR at the 0.80 HC / 15 CO / 2.0 NOx cutpoints to compute the MOBILE6 ASM IDR. This is done for both running and start IDRs. After computation, the ASM IDR is used in Equation 12a to compute the ASM After I/M line, and the I/M credits. Typically, the ASM ratioes which are applied to the IM240 credits are in the range of 0.60 to 1.30. This may lower or boost the IM240 credits by 0.30 times or raise by 0.40 times. The lower ratios prevail for HC and CO emissions, and the higher ratios are occasionally seen for NOx emissions at the lower ages. Also, the ratios are typically very similar to each other within a given ASM test type and pollutant - generally ranging from 0 to 10 percent different within a model year group.

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.

Table 7a **ASM I/M IDR Coefficients for Final ASM Cutpoints**						
Description			**For AGE <= 10**			
Test	**Cutpoint**	**Pollutant**	**Coeff A**	**Coeff B**	**Coeff C**	**Coeff D**
ASM 2525	Phase-in	HC	0.001759	1.588e-04	-0.001383	0.9655
ASM 2525	Phase-in	CO	0.007035	-1.826e-04	0.001893	0.6641
ASM 2525	Phase-in	NOx	-0.05733	0.002875	-0.03234	4.1179
ASM 5015	Phase-in	HC	-0.00494	5.766e-04	-0.002577	1.0894
ASM 5015	Phase-in	CO	0.003682	5.1103e-05	0.001625	0.6787
ASM 5015	Phase-in	NOx	-0.12004	0.006165	-0.02997	4.1908
ASM 2mod	Phase-in	HC	-0.006005	6.0291e-04	-0.001904	1.0791
ASM 2mod	Phase-in	CO	9.809e-04	1.5345e-04	0.002478	0.6573
ASM 2mod	Phase-in	NOx	-0.1461	0.007589	-0.036311	4.9515
			For AGE > 10			
Test	**Cutpoint**	**Pollutant**	**Coeff A**	**Coeff B**	**Coeff C**	**Coeff D**
ASM 2525	Phase-in	HC	-0.005209	1.161e-04	-0.001458	1.0459
ASM 2525	Phase-in	CO	-0.002926	6.517e-05	0.001498	0.7751
ASM 2525	Phase-in	NOx	-0.001853	3.9017e-05	-0.006412	1.5271
ASM 5015	Phase-in	HC	-0.005936	1.3247e-04	-0.002217	1.1102
ASM 5015	Phase-in	CO	-0.003783	8.5342e-05	0.001490	0.7627
ASM 5015	Phase-in	NOx	-0.004784	1.1196e-04	5.749e-04	0.9120
ASM 2mod	Phase-in	HC	-0.004063	9.1144e-05	-0.001374	1.0614
ASM 2mod	Phase-in	CO	-0.002706	6.0543e-05	0.002150	0.7326
ASM 2mod	Phase-in	NOx	-0.005176	1.1762e-04	-0.002785	1.2899

Table 7b
ASM I/M IDR Coefficients for Phase-in ASM Cutpoints

Description			For AGE <= 10			
Test	**Cutpoint**	**Pollutant**	**Coeff A**	**Coeff B**	**Coeff C**	**Coeff D**
ASM 2525	Phase-in	HC	-0.0301	0.002811	-9.764e-04	0.7324
ASM 2525	Phase-in	CO	0.00171	6.151e-04	0.00390	0.2676
ASM 2525	Phase-in	NOx	0.0289	-0.001775	0.015844	-1.0368
ASM 5015	Phase-in	HC	-0.03507	0.003147	0.002789	0.4213
ASM 5015	Phase-in	CO	1.775e-05	7.131e-04	0.006458	0.05215
ASM 5015	Phase-in	NOx	-0.07537	0.003535	5.805e-04	0.9142
ASM 2mod	Phase-in	HC	-0.03397	0.003077	-2.039e-04	0.6986
ASM 2mod	Phase-in	CO	-3.874e-04	7.258e-04	0.004660	0.2228
ASM 2mod	Phase-in	NOx	-0.3024	0.01462	-0.10688	11.890
			For AGE > 10			
Test	**Cutpoint**	**Pollutant**	**Coeff A**	**Coeff B**	**Coeff C**	**Coeff D**
ASM 2525	Phase-in	HC	-0.01390	3.1742e-04	-0.001254	0.8387
ASM 2525	Phase-in	CO	-0.00747	1.698e-04	0.00331	0.4557
ASM 2525	Phase-in	NOx	-0.00118	7.0546e-05	0.00833	-0.2571
ASM 5015	Phase-in	HC	-0.01281	2.945e-04	0.003960	0.3707
ASM 5015	Phase-in	CO	-0.007068	1.6312e-04	0.005987	0.2188
ASM 5015	Phase-in	NOx	-0.005603	1.7994e-04	0.01033	-0.3290
ASM 2mod	Phase-in	HC	-0.01242	2.8523e-04	6.932e-04	0.6740
ASM 2mod	Phase-in	CO	-0.00714	1.6475e-04	0.004418	0.3669
ASM 2mod	Phase-in	NOx	-0.01342	3.5207e-04	-0.02177	2.8099

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. Although, they could have been developed this way. 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.

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.

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

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 19.49 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	=	1.50
CO Ratio:	19.49 g/mi / 13.46 g/mi	=	1.45

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".

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 90 percent (fraction 0.90). 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.

APPENDIX A

Running LA4 Emissions from 1990-93 MY PFI Normal Emitters

Figure A-1

HC Emissions from Normals

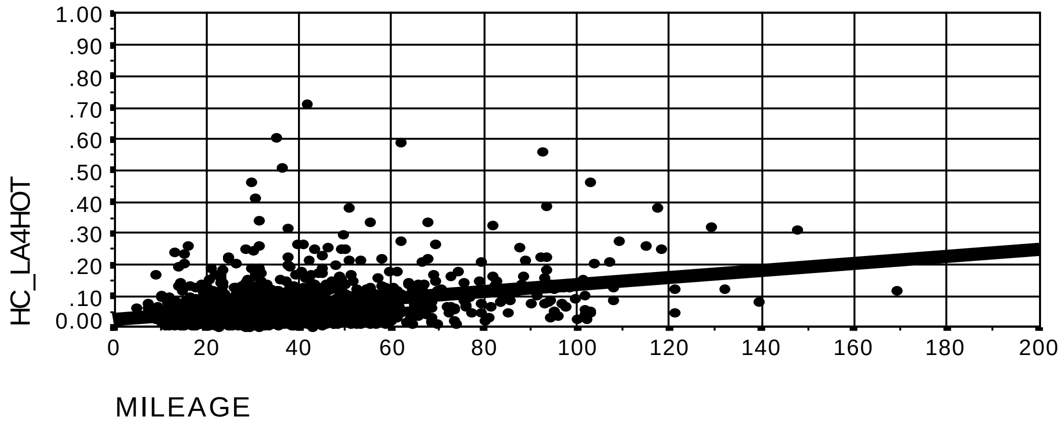


Figure A-2

CO Emissions from Normals

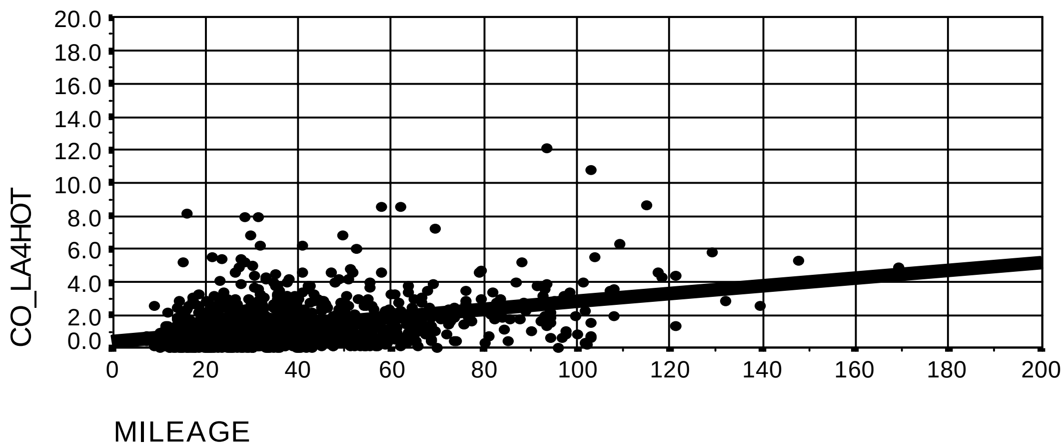
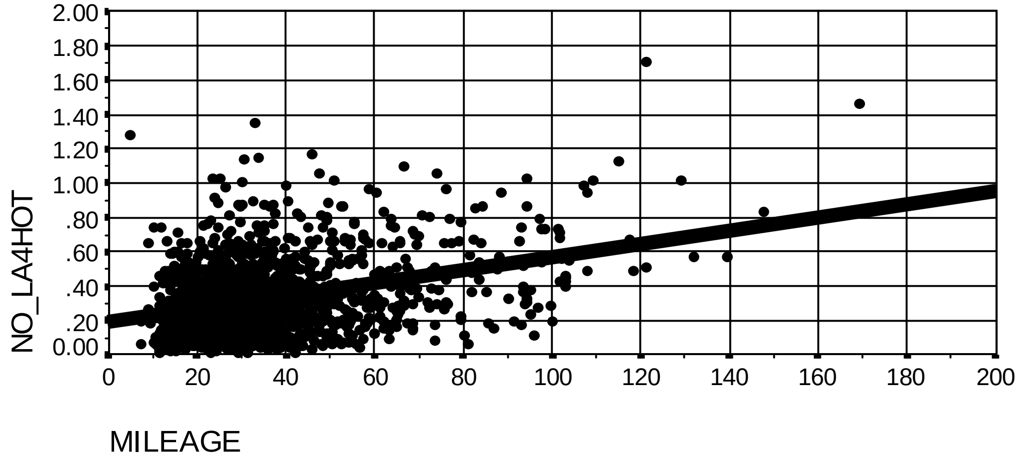


Figure A-3

NOx Emissions from Normals



APPENDIX B

Sample Calculations

Sample calculation for determining percentage of HC running emission Highs in the fleet at age = 5 for 1990-1993 PFI technology.

Calculating Line A in Figure 1 (basic emission rate)

X < 21.27 A = 0.0508 + 0.0013 * mile

X > 21.27 A = 0.0508 + 0.0013 * mile + (mile - 21.27) * 0.0023

from Table 3, mile = 49.835

X is the inflection point of the basic emission rate (thousand mile units).
See the document "Determination of Running Emissions as a Function of Mileage for 1981-1993 Model Year Light-Duty Vehicles."

A = 0.181 g/mi HC

Calculating Line B in Figure 1 (normal emitter rate)

B = 0.0249 + 0.00113 * mile

B = 0.081 g/mi HC

Calculating Line C in Figure 1 (high emitter rate)

C = 1.367 g/mi HC

Calculating Line D in Figure 1 (After I/M repair emission rate)

D = (2.24 - 0.07595 * Age) * B

D = 1.86 * 0.081 = 0.151

Calculating percentage of Highs from equation 7.

Highs = (A - B) / © - B)

Highs = 0.078 = (0.181 - 0.081) / (1.367 - 0.081)

% Highs = 7.8 percent

APPENDIX C

<u>Periodic I/M and RSD / Change of Ownership Sawtooth Illustrations</u>

Figure 1 - Annual I/M with RSD

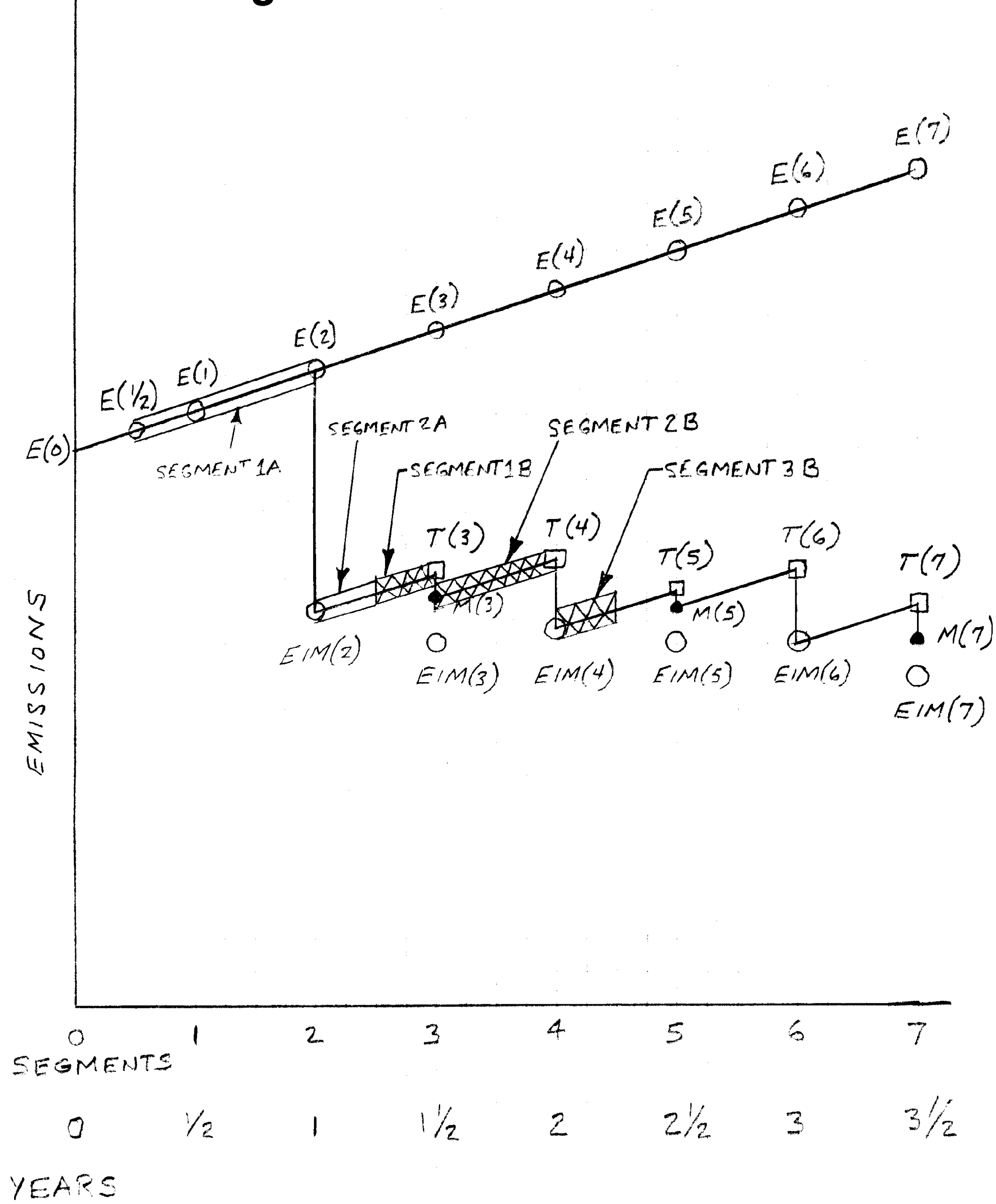
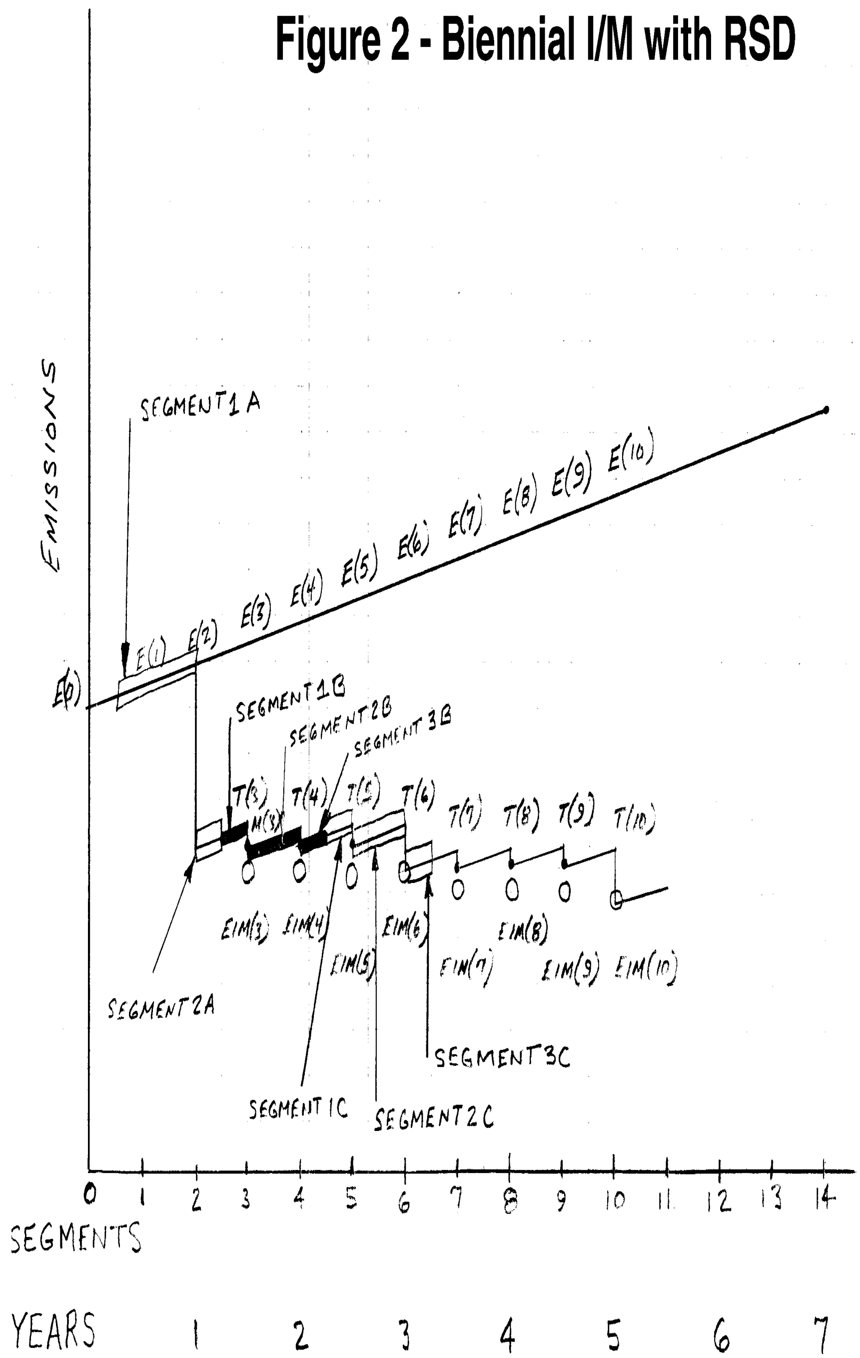


Figure 2 - Biennial I/M with RSD



Appendix D

Description of the FORTRAN Algorithm Adopted from EPA Document M6.IM.001 Used to Code the I/M Methodology in MOBILE6

TASK:2-663 DRAFT: 12/01/99

DynTel Report:
Mobile 6 IM Benefits Methodology for 1981 through 1993 Model Year Light Vehicles

Employee: Robert Ducharme

1. Introduction

In most inspection and maintenance programs vehicles are inspected annually or biennially. However, some inspections are prompted by special events such as change of ownership (COIM) or identification of high emitting vehicles using a remote sensing device (RSD). The objective of this report is to derive an equation for the emissions from a fleet of vehicles that is subject to both periodic and selective (RSD+COIM) IM programs. The most general form of this equation allows for an arbitrary period N between inspections and an arbitrary grace period GPRD before each vehicle receives its first test. However, both N and GPRD must be an integer number of years.

For the purposes of modeling, light duty gasoline vehicles and trucks are classed either as normal or high emitters. High emitters are the vehicles with broken emission control systems. The influence of inspection and maintenance programs is to reduce the basic exhaust emission levels from high emitting vehicles compared to what they would be if no IM program were in force. No IM correction is required for normal emitting vehicles.

This report is based on the inspection and maintenance methodology described in the US EPA draft report M6.IM.001 though there are some differences. One such point of departure is that the IM sawtooth methodology from Mobile 5 is replaced using an algebraic approach for calculating the benefits of IM programs that does not require the use of sawtooth diagrams. This has led to two refinements of the EPA model. Firstly, the basic emission factor lines drawn straight in the sawtooth diagrams are slightly curved in reality.

This curvature has now been taken into account. Secondly the sawtooth method applies the benefits of periodic IM testing on a single day (October 1) during each relevant twelve month test period preceding the emissions evaluation date. Here, a continuous model is used that assumes vehicles are always tested on the anniversaries of their sales. It is further assumed that new vehicle sales are uniform throughout each model year so that the distribution of the anniversaries of those sales is also uniform in future model years. The notation used in this report is not month specific so that the mathematical formulation is equally applicable for both January 1 and July 1 calculations.

2. IM240 tests

EPA have worked out an explicit equation for the quantity that must be subtracted from the basic emission factor of any high emitting 1981-1993 model year light duty gasoline vehicles and trucks in order to take into account the benefits of having an IM240 program in force. There is no IM correction for normal emitting vehicles. The form of this correction factor is readily deduced from eqn 12a and eqn 34 (ref: M6.IM.001) to be:

$$IMCF(JDX, AIM) = XIM(JDX, AIM) * IDR * \left[HIM(JDX, AIM) * (W * RW + NC - 1) + A * FIX\right] \tag{1}$$

where the symbols have the following meaning

AIM: Integer age of a vehicle in years on the date of its IM test previous to the emissions evaluation date. It is assumed that vehicles are always tested on their anniversaries of their sales.
JDX: Integer model year index of a vehicle referred to the year ICY and month MEVAL of the emission factor calculations.
XIM: Fraction of the fleet composed of high emitters on the date of the IM test.
HIM: High average emission factor on the date of the IM test.
IDR: Fraction of all the high emitters in a target group identified by an IM test.
W: Fraction of all the identified high emitters that get a repair cost waiver.
RW: Fraction of the high emitter level that waived vehicles are repaired after IM.
NC: Fraction of identified high emitters which are in non-compliance of the IM program.
FIX: Fraction of identified high emitters which get repaired to pass the test.
A: Average emission level from vehicles after they have been repaired and passed an IM test.

Eqn (1) normally has a negative value and applies for both running (ISR=1) and start (ISR=2) emissions. However, the calculation of the after repair level A and the identification rate IDR is different depending on the value of ISR. The details of these calculations can be found in M6.IM.001 together with default values for R, RW and NC. The value of FIX is 1-W-NC. The calculation of XIM and HIM are discussed in section 4.

3. Other IM Tests Types

Eq. (1) is valid for the following additional IM test types.

1. Two-Mode ASM 2525/5015 with phase-in cutpoints
2. Two-Mode ASM 2525/5015 with final cutpoints
3. Single-Mode ASM 5015 with phase-in cutpoints
4. Single-Mode ASM 5015 with final cutpoints
5. Single-Mode ASM 2525 with phase-in cutpoints
6. Single-Mode ASM 2525 with final cutpoints
7. Idle test
8. 2500 RPM/Idle test

The test type affects the benefit through the high emitter identification rate IDR and the after repairs emission level A. IDR is also corrected for RSD clean screening and high emitter profiling. The maximum allowable value of IDR is 0.9. The after repairs emission level A includes a correction for technician training. It cannot be higher than the high emission factor or lower than the normal emission factor.

4. IM Emission Factors

The EPA IM methodology for periodic (annual, biennial, triennial etc.) IM programs makes two simplifying assumptions.

17. All vehicles are tested on the anniversaries of their sales.
18. Vehicle sales are uniform throughout each model year.

The assumption that IM tests always tested on the anniversaries of their sales will have to be revised when COIM and RSD prompted testing is considered later.

The normal (INH=1) and high (INH=2) basic emission factors for a vehicle of model year MY on the date of an IM test is

$$BIM(INH,MY,AIM)=ZML(INH,MY)+KIM(AIM)*DR(INH,MY) \qquad (2)$$

where ZML is the zero mile level, DR is the deterioration rate, KIM is the vehicle miles traveled in units of thousands of miles for a vehicle of age AIM. Note, MY=ICY-JDX+1 where JDX has previously been defined as the model year index referred to the evaluation year ICY. Default values for ZML and DR are stored in the mobile model. The value of KIM for AIM>0 is readily calculated from the expression

$$KIM\,(AIM) = \sum_{I=1}^{AIM} AMAR(I) \tag{3}$$

where AMAR(I) is the annual mileage accrual rate also stored in Mobile. It is a reasonable approximation to assume the vehicle has traveled zero miles when its first owner aquires it so KIM(0)=0.0.

The HIM variable defined in section 2 is:

HIM =BIM(INH=2,MY,AIM)

The default value of the deterioration rate for highs emitters in Mobile is zero but the user can override this default.

The probability that a vehicle of age AIM will be a high emitter is XIM(MY,AGE). This quantity like BIM can also be expressed exclusively as a function of MOBILE 6 regression coefficients and KIM.

5. The NO IM case

Mobile 6 calculates emissions on January 1 or July 1. The existing method of evaluating the uncorrected (FTP) basic emission factors on these dates is through the equation

Normals: *NOIM(INH=1,MY,JDX)=BEV(INH=1,MY,JDX)*(1-XEV(MY,JDX))*

Highs: *NOIM(INH=2,MY,JDX)=BEV(INH=2,MY,JDX)*XEV(MY,JDX)*

(4)

where

*BEV(INH,MY,JDX) =ZML(INH,MY)+KMILES(JDX)*DR(INH,MY)* (5)

and XEV is the fraction of high emitters in the fleet on the evaluation date. Expression (5) is identical to (2) except the model year index is now calculated from the evaluation date and KMILES has replaced KIM where KMILES is the average vehicle mileage on the evaluation date. Similar arguments apply to XEV and its XIM counterpart. The method of adjusting vehicle mileage for the month of evaluation is described in AP42 for the special case of January 1 emissions. This method has since been extended to treat the July 1 case

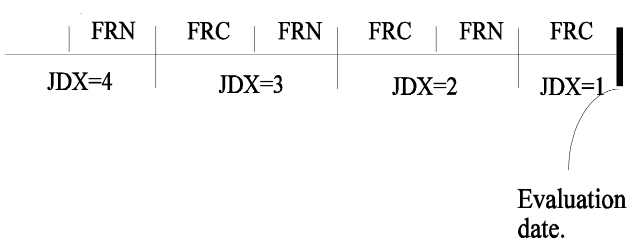


Figure 10 Shows the partitioning of each model year into segments.

as well. The general formula for KMILES expressed in terms of KIM is

$$KMILES(1) = \frac{1}{2} FRC * KIM(1)$$

$$KMILES(JDX) = KIM(JDX) + \frac{1}{2} FRC^2 * \left[KIM(JDX+1) - KIM(JDX)\right]$$
$$- \frac{1}{2} FRN^2 * \left[KIM(JDX) - KIM(JDX-1)\right] \quad ....(6)$$

where FRC is the elapsed fraction of a year since the model year changed on October 1 and FRN=1-FRC. The fraction FRC is readily calculated in terms of the month of evaluation MEVAL using the algorithm

$$DIFF = MEVAL - 10$$
$$FRC(DIFF \geq 0) = DIFF / 12$$
$$FRC(DIFF < 0) = 1 - DIFF / 12$$

Thus, FRC=0.25 on January 1 and FRC=0.75 on July 1.

6.0 Annual I/M Inspection

In annual IM programs vehicles are inspected every year on the anniversary of the sale to their first owner. For generality, it will be assumed that vehicles do not receive their first inspection until they have been in operation for GRPD years. Consequently, all vehicles with model year index greater than GRPD+1 should receive one inspection in the twelve month period preceding the date when the emissions are to be evaluated.

An essential concept in analyzing periodic IM programs is the fact that the age of a vehicle AIM on the date of its previous IM test is not a unique function of its model year index. However, it is possible to partition each model year into two segments in such a manner that a unique value of AIM can be assigned to each segment. This breakdown is done next for the case of an annual IM inspection program with a grace period of 1 year. The value of AIM can be determined for each model year and model year segment with the help of figure 1. For example, if emissions are to be evaluated in 1990 from a 1988 model year vehicle then JDX=3 will be the model year index of the vehicle. The JDX=3 model year can be divided, as can any other year, into FRC and FRN segments. Therefore, suppose that the vehicle was purchased new in the FRC model year segment. The choice of JDX=3 and the FRC segment give the starting point in the diagram. It is then simply a question of counting forward an integer number of years (AIM) until the date of the previous IM test before the evaluation date is found. The result is AIM=2. Table 1 shows the value of AIM for other values of JDX.

JDX	SEGMENT	AIM
1	FRC	0
2	FRN	0
2	FRC	1
3	FRN	1
3	FRC	2
4	FRN	2
4	FRC	3
JDX	FRN	JDX-2
JDX	FRN	JDX-1

Table 1. Vehicle ages in annual IM programs.

The above table gives sufficient information to calculate periodic IM corrections for any model year. For example, for JDX=3 it can be seen that the correction is

$$PIMCF(JDX=3)=FRN*IMCF(JDX=3,AIM=1)+FRC*IMCF(JDX=3,AIM=2) \qquad (7)$$

In completion of the annual IM program problem it is necessary to treat arbitrary values of the grace period. The JDX<GPRD+1 case is trivial since the maximum age of any vehicle in this group is too young (<GPRD) for any IM tests to have been carried out. Consequently,

$$PIMCF(JDX<GPRD+1)=0.0$$

In the JDX=GPRD+1 case, a fraction FRC of the vehicles will be older than GPRD years and the rest will be younger. Thus, the additive IM correction factor must include the FRC weighting factor so that

$$PIMCF(JDX=GRPD+1)=FRC* IMCF(JDX,AIM=JDX-1) \qquad (8)$$

The M6.IM.001 report also finds this result.

7. N-ennial IM programs.

In N-ennial IM programs vehicles are inspected every N years on the anniversaries of the sale to their first owner. In this general case, all vehicles with model year index greater than GRPD+1 should receive one inspection in the 12*N month period preceding the date when the emissions are to be evaluated.

The principle that a unique value of AIM can be calculated for each model year segment holds true for arbitrary values of N and GPRD. The general form of the additive correction factor PIMCF is thus:

$$PIMCF(JDX)=FRN*IMCF(JDX,AIM1)+FRC*IMCF(JDX,AIM2) \qquad (9)$$

where AIM1 and AIM2 denote the integer ages in years of vehicles on the date of their previous IM test that were purchased new in the respective first and second segments of the JDXth model year.
Referring to figure 1 the algorithm for calculating AIM1 is as follows.

1. Begin in the FRN segment of the JDXth model year.

2. Move forward an integer number of years equal to the grace period.
3. If you have moved beyond the emissions evaluation date set AIM1=0.
4. Else move move forward in steps of N years until the date of the previous IM test. In this case, AIM1 is equal to the total number of years between the purchase date and previous IM test date for the vehicle.

The algorithm for calculating AIM2 is identical except that step 1 begins in the FRC segment of the JDXth model year. The complication of vehicles that are too young to have received their first test is readily handled using the convention IMCF(JDX,AIM=0)=0. One simple test of this algorithm is to reproduce the results in section 6 for an annual IM program. It is also of interest to calculate the vehicle ages for biennial programs with grace period of 1 and 2 years. These results are given in table 2.

JDX	SEGMENT	AIM	
		GPRD=1	GPRD=2
1	FRC	0	0
2	FRN	0	0
2	FRC	1	0
3	FRN	1	0
3	FRC	1	2
4	FRN	1	2
4	FRC	3	2
5	FRN	3	2
5	FRC	3	4
6	FRN	3	4
6	FRC	5	4

Table 2. Vehicle ages in biennial IM programs.

8. Selective IM programs

In periodic IM programs all vehicles are tested every N years following an initial grace period GPRD years after they were first bought into the fleet. In selective IM programs, vehicles are only tested if they meet certain criteria such as a recent change of ownership (COIM) or detection as a high emitter using a remote sensing device (RSD). Selective IM testing is usually done in areas where a periodic program is also in operation. One important difference between selective and periodic programs is that a vehicle can be tested at any time during the year rather than just on the anniversary of its purchase. However, for modeling purposes it will be assumed that selective IM tests only affect vehicles of integer and half-integer ages.

Let PSTE(JDX,AGE) and PSTL(JDX,AGE) denote the respective probabilities that a FRC and FRN segment vehicle with model year index JDX and age AGE (=0.5,1.0,1.5....) will have an IM test as a result of identification in the previous six months by either a COIM or RSD program. These quantities can be defined more precisely as

$$PSTE(JDX,AGE)=FSTE(JDX,AGE)*STR(JDX,AGE) \qquad (10)$$

$$PSTL(JDX,AGE)=FSTL(JDX,AGE)*STR(JDX,AGE) \qquad (11)$$

where FSTL and FSTE are the FRC and FRN segment fractions of all the JDX model year vehicles eligible by virtue of having reached the age AGE for a selective IM test and

$$STR(JDX,AGE)=RSD(JDX,AGE)+COIM\ (JDX,AGE) \qquad (12)$$

is the normalized probability that an eligible vehicle will be selected for a test as a result of change of ownership or detection by a remote sensing device. For example, if PSTE(JDX=3,AGE=1.5)=0.01
then 1% of all the JDX=3 vehicles will receive an IM benefit IMCF(JDX=3,AGE=1.5) as a result of the fact they were all purchased new in the same FRC model year segment and tested at the same age of 1.5 years.

Selective IM tests only benefit vehicle emissions if they take place after the vehicles previous periodic IM test. All FRC segment vehicles

$$FSTE(JDX,AGE) = FRC \qquad (13)$$

will be eligible for selective IM tests for integer and half integer values of AGE in the range

$$AIM + 0.5 \leq AGE \leq JDX - 1 \qquad (14)$$

providing AIM<JDX-1. This result can be deduced from figure 1. If FRC>0.5 then a fraction

$$FSTE(JDX,AGE) = FRC-0.5 \qquad (15)$$

of the JDX model year vehicles will also be eligible for one additional test at age JDX-0.5. Eqns (13) and (15) give the only nonzero values of FSTE. The arguments pertaining to the FRN segment vehicles are similar. In particular, all FRN segment vehicles

$$FSTL(JDX,AGE) = FRN \qquad (16)$$

will be eligible for selective IM tests for integer and half integer values of AGE in the range

$$AIM + 0.5 \leq AGE \leq JDX - 2 \qquad (17)$$

providing AIM<JDX-2. If FRN<0.5 then all FRN segment vehicles will also be eligible for an additional test at age JDX-1.5. Otherwise if FRN>0.5 then only a fraction

$$FSTL(JDX,AGE)=0.5 \qquad (18)$$

of the JDX model year vehicles will be eligible.

The probability CPSIME(JDX,AIM) that a vehicle purchased new in the FRC segment of the JDX model year receiving a selective IM test between its previous periodic IM test date at age AIM and the emissions evaluation date at the end of the FRC segment of the JDX=1 model year is equal to the sum over PSTE(JDX,AGE) for all the values of AGE satisfying equations (14) and (15). This is given by

$$CPSIME(JDX, AIM) = \sum_{M=1}^{M_E} \left[PSTE(JDX, AGE = AIM + 0.5 * M) \right] \qquad (19)$$

where M_E=2*(JDX-AIM-0.5) is the maximum number of possible selective IM test dates. The arguments for vehicles in the FRN model year segment are similar with all the possible values of the AGE variable calculable from eqns. (17) and (18). This leads to the probability

$$CPSIML(JDX, AIM) = \sum_{M=1}^{M_L} \left[PSTL(JDX, AGE = AIM + 0.5 * M) \right] \qquad (20)$$

with M_L=2*(JDX-AIM-1.5). It is a further requirement that vehicles cannot receive the benefits from more than one IM test. Consequently, the values of CPSIME and CPSIML cannot exceed FRC and FRN respectively.

The arguments in this section up to here have been quite formal. It is therefore instructive to once again consider an example. Consider the case of a biennial IM program with selective IM testing and a grace period of one year. Let us set JDX=4 and select a vehicle that was bought new in the FRN model year segment. Table 2 indicates that this vehicle will have received its previous periodic IM test at age AIM=1 year. From eqn (20) the probability that this vehicle will be tested as a result of the selective IM program is

CPSIML(JDX=4,AIM=1) = PSTL(JDX=4, AGE=1.5) + PSTL(JDX=4, AGE=2.0) + PSTL(JDX=4, AGE=2.5)

By contrast, the vehicles belonging to the FRC segment of the JDX=4 model year segment are all old enough to have received their second periodic IM test at age AIM=3. In this case eqn (19) gives

CPSIME(JDX=4,AIM=3) = PSTE(JDX=4,AGE=3.5)

where this expression contains only one term because a relatively short period elapses between the date when the vehicles receive their periodic IM test and the emissions evaluation date.

Each PSTE(JDX,AGE) term in eqn (19) gives the probability that a vehicle bought new in the FRC segment of the JDX model year will receive a selective IM test at age AGE. The benefit that arises from such a test is therefore PSTE(JDX,AGE)*IMCF(JDX,AGE). These benefits can therefore be summed over all the possible selective IM test dates to give the total benefit from all the selective IM tests carried out on the FRC segment vehicles to be

$$SIMCFE(JDX, AIM) = \sum_{M=1}^{M_E} \left[PSTE(JDX, AGE = AIM + 0.5*M) * IMCF(JDX, AGE = AIM + 0.5*M) \right] \tag{21}$$

The total benefit from all the selective IM tests carried out on the FRN segment vehicles is then similarly

$$SIMCFL(JDX, AIM) = \sum_{M=1}^{M_L} \left[PSTL(JDX, AGE = AIM + 0.5*M) * IMCF(JDX, AGE = AIM + 0.5*M) \right] \tag{22}$$

Here, IMCF is evaluated using the vehicle mileage equation

$$KIM(J+0.5) = 0.5 * AMAR(J+1) + \sum_{I=1}^{J} AMAR(I) \qquad (23)$$

for all half-integer ages.

9. Calculation of IM Benefits

Suppose a selective IM program is operating alongside the annual program. The generalization of eqn. (9) to include the effect of the selective testing is then

*PIMCF(JDX)=(FRN-CPSIML(JDX,AIM1))*IMCF(JDX,AIM1)*
+ SIMCFL(JDX,AIM1)
*+ (FRC-CPSIME(JDX,AIM2))*IMCF(JDX,AIM2)*
+ SIMCFE(JDX,AIM) (24)

There are two points to note. Firstly, the earlier and later SIMCF terms are included to account for the benefits of the selective IM tests that take place after the periodic IM tests. Secondly, the CPSIM terms are subtracted from the FRC and FRN fractions so that the selectively tested vehicles do not also receive a benefit for their earlier periodic test.

It is instructive to evaluate eqn. (24) for the correction to July 1 emissions arising from an annual IM program with COIM. Let JDX=3. Annual I/M programs are treated in section 6 where the values AIM1=1 and AIM2=2 can be read from table 1. With this information, the arguments in section 8 then give the cumulative probabilities and selective I/M correction factors for this problem to be

*CPSIME(JDX=3,AIM=2)=0.25*STR(JDX=3,AGE=2.5)*

*CPSIML(JDX=3,AIM=1)=0.25*STR(JDX=3,AGE=1.5)*

SIMCFE(JDX=3,AIM=2)=CPSIME(JDX=3,AIM=2) IMCF(JDX=3,AGE=2.5)*

SIMCFL(JDX=3,AIM=2)=CPSIML(JDX=3,AIM=1) IMCF(JDX=3,AGE=1.5)*

having set FRC=0.75 and FRN=0.25. Here, the value of STR depends on the rate of selective testing. For example, if a COIM program is in operation in an area with 16% per annum change of ownership then STR=0.08. In this case, eqn (24) simplifies to

*PIMCF(JDX=3)=0.23*IMCF(JDX=3,AGE=1)*

+ 0.02 IMCF(JDX=3,AGE=1.5)*
*+ 0.73*IMCF(JDX=3,AGE=2)*
+ 0.02 IMCF(JDX=3,AGE=2.5)*

where IMCF can be calculated directly from eqn (1) for each of the 4 vehicle ages.

APPENDIX E
Statistical Diagnostics for Running Emissions 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
```

APPENDIX F
Statistical Diagnostics for Start Emissions IDR Determination

```
-> 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
```

APPENDIX G

Statistical Diagnostics for Running and Start High Emitter Levels

```
-> USE ALL.
-> COMPUTE filter_$=(vehicle = 1 & hc_2x = 2 & (grp88 = 3 | grp88 = 6 )).
-> VARIABLE LABEL filter_$ 'vehicle = 1 & hc_2x = 2 & (grp88 = 3 | grp88 = 6 )'+
->  ' (FILTER)'.
-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.
-> FORMAT filter_$ (f1.0).
-> FILTER BY filter_$.

-> EXECUTE .

-> EXAMINE
->   VARIABLES=hc_cs hc_la4ho BY filter_$
->   /PLOT NONE
->   /STATISTICS DESCRIPTIVES
->   /CINTERVAL 95
->   /MISSING LISTWISE
->   /NOTOTAL.


     HC_CS
 By  FILTER_$  1         Selected

 Valid cases:       118.0   Missing cases:        .0   Percent missing:      .0


 Mean        5.3127  Std Err      .9562  Min       -23.3000  Skewness    6.7474
 Median      3.8660  Variance  107.8864  Max       100.5300  S E Skew     .2227
 5% Trim     4.3032  Std Dev    10.3868  Range     123.8300  Kurtosis   61.6924
 95% CI for Mean (3.4190, 7.2064)        IQR         2.8755  S E Kurt     .4419


     HC_LA4HO  HC_LA4HOT
 By  FILTER_$  1         Selected

 Valid cases:       118.0   Missing cases:        .0   Percent missing:      .0


 Mean        2.3725  Std Err      .4448  Min          .2690  Skewness    5.1217
 Median      1.0085  Variance   23.3486  Max        34.8100  S E Skew     .2227
 5% Trim     1.4788  Std Dev     4.8320  Range      34.5410  Kurtosis   28.7006
 95% CI for Mean (1.4916, 3.2535)        IQR         1.3385  S E Kurt     .4419


-> USE ALL.
-> COMPUTE filter_$=(vehicle = 1 & co_3x = 2 & (grp88 = 3 | grp88 = 6 )).
-> VARIABLE LABEL filter_$ 'vehicle = 1 & co_3x = 2 & (grp88 = 3 | grp88 = 6 )'+
->  ' (FILTER)'.
-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.
-> FORMAT filter_$ (f1.0).
-> FILTER BY filter_$.

-> EXAMINE
->   VARIABLES=co_cs co_la4ho BY filter_$
->   /PLOT NONE
->   /STATISTICS DESCRIPTIVES
->   /CINTERVAL 95
->   /MISSING LISTWISE
->   /NOTOTAL.


     CO_CS
 By  FILTER_$  1         Selected
```

```
 Valid cases:        97.0   Missing cases:        .0   Percent missing:      .0


 Mean       65.3116  Std Err     9.4172  Min       -181.100  Skewness     .7955
 Median     41.1230  Variance  8602.238  Max       441.8000  S E Skew     .2450
 5% Trim    63.1510  Std Dev    92.7483  Range     622.9000  Kurtosis    2.4172
 95% CI for Mean (46.6187, 84.0045)      IQR        95.2160  S E Kurt     .4853


     CO_LA4HO  CO_LA4HOT
 By  FILTER_$  1         Selected

 Valid cases:        97.0   Missing cases:        .0   Percent missing:      .0


 Mean       37.9327  Std Err     5.2679  Min          .2920  Skewness    2.4569
 Median     14.1360  Variance  2691.801  Max       288.6300  S E Skew     .2450
 5% Trim    30.7305  Std Dev    51.8826  Range     288.3380  Kurtosis    6.7550
 95% CI for Mean (27.4761, 48.3894)      IQR        33.8540  S E Kurt     .4853


-> USE ALL.
-> COMPUTE filter_$=(vehicle = 1 & no_2x = 2 & (grp88 = 3 | grp88 = 6 )).
-> VARIABLE LABEL filter_$ 'vehicle = 1 & no_2x = 2 & (grp88 = 3 | grp88 = 6 )'+
->  ' (FILTER)'.
-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.
-> FORMAT filter_$ (f1.0).
-> FILTER BY filter_$.

-> EXECUTE .

-> EXAMINE
->   VARIABLES=no_la4ho BY filter_$
->   /PLOT NONE
->   /STATISTICS DESCRIPTIVES
->   /CINTERVAL 95
->   /MISSING LISTWISE
->   /NOTOTAL.


     NO_LA4HO  NO_LA4HOT
 By  FILTER_$  1         Selected

 Valid cases:        44.0   Missing cases:        .0   Percent missing:      .0


 Mean        2.9513  Std Err      .1349  Min         1.9530  Skewness    1.2149
 Median      2.5785  Variance     .8006  Max         5.6660  S E Skew     .3575
 5% Trim     2.8761  Std Dev      .8948  Range       3.7130  Kurtosis     .9399
 95% CI for Mean (2.6793, 3.2233)        IQR         1.2920  S E Kurt     .7017


-> USE ALL.
-> COMPUTE filter_$=(vehicle = 1 & hc_2x = 2 & (grp88 = 4 | grp88 = 5 | grp88 =
->   7 )).
-> VARIABLE LABEL filter_$ 'vehicle = 1 & hc_2x = 2 & (grp88 = 4 | grp88 = 5 |'+
->  ' grp88 = 7 ) (FILTER)'.
-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.
-> FORMAT filter_$ (f1.0).
-> FILTER BY filter_$.

-> EXECUTE .

-> EXAMINE
->   VARIABLES=hc_cs hc_la4ho BY filter_$
->   /PLOT NONE
->   /STATISTICS DESCRIPTIVES
->   /CINTERVAL 95
->   /MISSING LISTWISE
```

```
->   /NOTOTAL.


     HC_CS
 By  FILTER_$  1         Selected

 Valid cases:       212.0   Missing cases:        .0   Percent missing:      .0


 Mean       10.5195  Std Err     1.6407  Min        -5.3850  Skewness   11.1465
 Median      5.8390  Variance  570.6977  Max       326.0100  S E Skew     .1671
 5% Trim     7.8954  Std Dev    23.8893  Range     331.3950  Kurtosis  145.4885
 95% CI for Mean (7.2852, 13.7538)       IQR         6.8020  S E Kurt     .3326


     HC_LA4HO  HC_LA4HOT
 By  FILTER_$  1         Selected

 Valid cases:       212.0   Missing cases:        .0   Percent missing:      .0


 Mean        1.8447  Std Err      .3111  Min          .1390  Skewness   10.4292
 Median       .7975  Variance   20.5202  Max        59.8590  S E Skew     .1671
 5% Trim     1.2606  Std Dev     4.5299  Range      59.7200  Kurtosis  129.3009
 95% CI for Mean (1.2314, 2.4580)        IQR         1.3962  S E Kurt     .3326


-> USE ALL.
-> COMPUTE filter_$=(vehicle = 1 & co_3x = 2 & (grp88 = 4 | grp88 = 5 | grp88 =
->   7 )).
-> VARIABLE LABEL filter_$ 'vehicle = 1 & co_3x = 2 & (grp88 = 4 | grp88 = 5 |'+
->  ' grp88 = 7 ) (FILTER)'.
-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.
-> FORMAT filter_$ (f1.0).
-> FILTER BY filter_$.

-> EXECUTE .

-> EXAMINE
->   VARIABLES=co_cs co_la4ho BY filter_$
->   /PLOT NONE
->   /STATISTICS DESCRIPTIVES
->   /CINTERVAL 95
->   /MISSING LISTWISE
->   /NOTOTAL.


     CO_CS
 By  FILTER_$  1         Selected

 Valid cases:       233.0   Missing cases:        .0   Percent missing:      .0


 Mean       92.8206  Std Err     5.4515  Min       -145.000  Skewness     .8815
 Median     78.5740  Variance  6924.600  Max       401.0900  S E Skew     .1595
 5% Trim    88.8831  Std Dev    83.2142  Range     546.0900  Kurtosis    1.8693
 95% CI for Mean (82.0797, 103.5614)     IQR        88.6325  S E Kurt     .3176


     CO_LA4HO  CO_LA4HOT
 By  FILTER_$  1         Selected

 Valid cases:       233.0   Missing cases:        .0   Percent missing:      .0


 Mean       27.6531  Std Err     2.7249  Min          .1330  Skewness    3.2284
 Median     11.4820  Variance  1729.998  Max       298.0400  S E Skew     .1595
 5% Trim    21.1470  Std Dev    41.5932  Range     297.9070  Kurtosis   12.9400
 95% CI for Mean (22.2845, 33.0217)      IQR        21.1570  S E Kurt     .3176
```

```
-> USE ALL.
-> COMPUTE filter_$=(vehicle = 1 & no_2x = 2 & (grp88 = 4 | grp88 = 5 | grp88 =
->   7 )).
-> VARIABLE LABEL filter_$ 'vehicle = 1 & no_2x = 2 & (grp88 = 4 | grp88 = 5 |'+
->  ' grp88 = 7 ) (FILTER)'.
-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.
-> FORMAT filter_$ (f1.0).
-> FILTER BY filter_$.

-> EXECUTE .

-> EXAMINE
->   VARIABLES=no_la4ho BY filter_$
->   /PLOT NONE
->   /STATISTICS DESCRIPTIVES
->   /CINTERVAL 95
->   /MISSING LISTWISE
->   /NOTOTAL.


     NO_LA4HO  NO_LA4HOT
 By  FILTER_$  1         Selected

 Valid cases:        60.0   Missing cases:        .0   Percent missing:      .0


 Mean        2.8719  Std Err      .0991  Min         1.8730  Skewness    1.2166
 Median      2.6320  Variance     .5898  Max         5.8210  S E Skew     .3087
 5% Trim     2.8139  Std Dev      .7680  Range       3.9480  Kurtosis    2.2562
 95% CI for Mean (2.6735, 3.0703)        IQR         1.1900  S E Kurt     .6085


-> USE ALL.
-> COMPUTE filter_$=(vehicle = 1 & hc_2x = 2 & (n_group = 1 )).
-> VARIABLE LABEL filter_$ 'vehicle = 1 & hc_2x = 2 & (n_group = 1 ) (FILTER)'.
-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.
-> FORMAT filter_$ (f1.0).
-> FILTER BY filter_$.

-> EXECUTE .

-> EXAMINE
->   VARIABLES=hc_cs hc_la4ho BY filter_$
->   /PLOT NONE
->   /STATISTICS DESCRIPTIVES
->   /CINTERVAL 95
->   /MISSING LISTWISE
->   /NOTOTAL.




     HC_CS
 By  FILTER_$  1         Selected

 Valid cases:        58.0   Missing cases:        .0   Percent missing:      .0


 Mean        4.8290  Std Err      .7673  Min       -23.3000  Skewness    -.7800
 Median      3.9220  Variance   34.1484  Max        24.2470  S E Skew     .3137
 5% Trim     4.6639  Std Dev     5.8437  Range      47.5470  Kurtosis   11.2352
 95% CI for Mean (3.2925, 6.3655)        IQR         3.3150  S E Kurt     .6181


     HC_LA4HO  HC_LA4HOT
 By  FILTER_$  1         Selected
```

```
 Valid cases:        58.0   Missing cases:        .0   Percent missing:      .0


 Mean        1.7400  Std Err      .5316  Min          .1450  Skewness    6.9800
 Median       .8790  Variance   16.3917  Max        31.1790  S E Skew     .3137
 5% Trim     1.1879  Std Dev     4.0487  Range      31.0340  Kurtosis   51.3330
 95% CI for Mean (.6754, 2.8045)         IQR        1.0667  S E Kurt     .6181


-> USE ALL.
-> COMPUTE filter_$=(vehicle = 1 & hc_2x = 2 & (n_group = 2 )).
-> VARIABLE LABEL filter_$ 'vehicle = 1 & hc_2x = 2 & (n_group = 2 ) (FILTER)'.
-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.
-> FORMAT filter_$ (f1.0).
-> FILTER BY filter_$.

-> EXECUTE .

-> EXAMINE
->   VARIABLES=hc_cs hc_la4ho BY filter_$
->   /PLOT NONE
->   /STATISTICS DESCRIPTIVES
->   /CINTERVAL 95
->   /MISSING LISTWISE
->   /NOTOTAL.


     HC_CS
 By  FILTER_$  1         Selected

 Valid cases:        38.0   Missing cases:        .0   Percent missing:      .0


 Mean        3.2927  Std Err      .4646  Min        -3.2350  Skewness    -.0333
 Median      3.1575  Variance    8.2028  Max        10.4150  S E Skew     .3828
 5% Trim     3.2990  Std Dev     2.8640  Range      13.6500  Kurtosis     .7728
 95% CI for Mean (2.3513, 4.2341)        IQR        3.0717  S E Kurt     .7497


     HC_LA4HO  HC_LA4HOT
 By  FILTER_$  1         Selected

 Valid cases:        38.0   Missing cases:        .0   Percent missing:      .0


 Mean        3.3937  Std Err     1.0523  Min          .5030  Skewness    3.8432
 Median      1.5370  Variance   42.0754  Max        34.8100  S E Skew     .3828
 5% Trim     2.2123  Std Dev     6.4866  Range      34.3070  Kurtosis   15.8588
 95% CI for Mean (1.2616, 5.5257)        IQR        1.5170  S E Kurt     .7497


-> USE ALL.
-> COMPUTE filter_$=(vehicle = 1 & co_3x = 2 & (n_group = 1 )).
-> VARIABLE LABEL filter_$ 'vehicle = 1 & co_3x = 2 & (n_group = 1 ) (FILTER)'.
-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.
-> FORMAT filter_$ (f1.0).
-> FILTER BY filter_$.

-> EXECUTE .

-> EXAMINE
->   VARIABLES=co_cs co_la4ho BY filter_$
->   /PLOT NONE
->   /STATISTICS DESCRIPTIVES
->   /CINTERVAL 95
->   /MISSING LISTWISE
->   /NOTOTAL.
```

```
    CO_CS
By  FILTER_$  1         Selected

Valid cases:        44.0   Missing cases:        .0   Percent missing:      .0


Mean       38.0579  Std Err    11.1153  Min       -134.000  Skewness     .5754
Median     33.6220  Variance  5436.158  Max       286.3600  S E Skew     .3575
5% Trim    36.5122  Std Dev    73.7303  Range     420.3600  Kurtosis    2.4815
95% CI for Mean (15.6419, 60.4740)      IQR        73.3610  S E Kurt     .7017


    CO_LA4HO  CO_LA4HOT
By  FILTER_$  1         Selected

Valid cases:        44.0   Missing cases:        .0   Percent missing:      .0


Mean       36.1057  Std Err     7.1383  Min         5.0870  Skewness    3.8473
Median     19.5880  Variance  2242.051  Max       288.6300  S E Skew     .3575
5% Trim    29.1347  Std Dev    47.3503  Range     283.5430  Kurtosis   18.8008
95% CI for Mean (21.7099, 50.5015)      IQR        30.8875  S E Kurt     .7017


-> USE ALL.
-> COMPUTE filter_$=(vehicle = 1 & co_3x = 2 & (n_group = 2 )).
-> VARIABLE LABEL filter_$ 'vehicle = 1 & co_3x = 2 & (n_group = 2 ) (FILTER)'.
-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.
-> FORMAT filter_$ (f1.0).
-> FILTER BY filter_$.

-> EXECUTE .

-> EXAMINE
->   VARIABLES=co_cs co_la4ho BY filter_$
->   /PLOT NONE
->   /STATISTICS DESCRIPTIVES
->   /CINTERVAL 95
->   /MISSING LISTWISE
->   /NOTOTAL.




    CO_CS
By  FILTER_$  1         Selected

Valid cases:        43.0   Missing cases:        .0   Percent missing:      .0


Mean       27.1649  Std Err    14.4273  Min       -280.000  Skewness   -1.3909
Median     35.0280  Variance  8950.311  Max       218.1000  S E Skew     .3614
5% Trim    33.9697  Std Dev    94.6061  Range     498.1000  Kurtosis    4.0345
95% CI for Mean (-1.9505, 56.2804)      IQR        74.8400  S E Kurt     .7090


    CO_LA4HO  CO_LA4HOT
By  FILTER_$  1         Selected

Valid cases:        43.0   Missing cases:        .0   Percent missing:      .0


Mean       46.5270  Std Err     8.1257  Min         3.9840  Skewness    1.7022
Median     21.1950  Variance  2839.142  Max       216.8700  S E Skew     .3614
5% Trim    40.2982  Std Dev    53.2836  Range     212.8860  Kurtosis    2.4073
95% CI for Mean (30.1287, 62.9252)      IQR        55.1990  S E Kurt     .7090
```

```
-> USE ALL.
-> COMPUTE filter_$=(vehicle = 1 & no_2x = 2 & (n_group = 1 )).
-> VARIABLE LABEL filter_$ 'vehicle = 1 & no_2x = 2 & (n_group = 1 ) (FILTER)'.
-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.
-> FORMAT filter_$ (f1.0).
-> FILTER BY filter_$.

-> EXECUTE .

-> EXAMINE
->   VARIABLES=no_la4ho BY filter_$
->   /PLOT NONE
->   /STATISTICS DESCRIPTIVES
->   /CINTERVAL 95
->   /MISSING LISTWISE
->   /NOTOTAL.


     NO_LA4HO  NO_LA4HOT
 By  FILTER_$  1         Selected

 Valid cases:        11.0   Missing cases:        .0   Percent missing:      .0


 Mean        2.8455  Std Err      .3223  Min         1.7130  Skewness     .9851
 Median      2.3870  Variance    1.1423  Max         5.0350  S E Skew     .6607
 5% Trim     2.7867  Std Dev     1.0688  Range       3.3220  Kurtosis     .0612
 95% CI for Mean (2.1274, 3.5635)        IQR         1.6230  S E Kurt    1.2794


-> USE ALL.
-> COMPUTE filter_$=(vehicle = 1 & no_2x = 2 & (n_group = 2 )).
-> VARIABLE LABEL filter_$ 'vehicle = 1 & no_2x = 2 & (n_group = 2 ) (FILTER)'.
-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.
-> FORMAT filter_$ (f1.0).
-> FILTER BY filter_$.

-> EXECUTE .



-> EXAMINE
->   VARIABLES=no_la4ho BY filter_$
->   /PLOT NONE
->   /STATISTICS DESCRIPTIVES
->   /CINTERVAL 95
->   /MISSING LISTWISE
->   /NOTOTAL.


     NO_LA4HO  NO_LA4HOT
 By  FILTER_$  1         Selected

 Valid cases:        15.0   Missing cases:        .0   Percent missing:      .0


 Mean        2.8723  Std Err      .2612  Min         1.9530  Skewness    1.9401
 Median      2.4130  Variance    1.0235  Max         5.6660  S E Skew     .5801
 5% Trim     2.7682  Std Dev     1.0117  Range       3.7130  Kurtosis    3.5993
 95% CI for Mean (2.3121, 3.4326)        IQR          .9110  S E Kurt    1.1209
```

APPENDIX H

Statistical Diagnostics for Running and Start Normal Emitter Levels

```
-> GET
-> FILE='D:\MOBILE6\IM\IM_CRED\NEW_CRED\EF5_DAT.SAV'.

-> COMPUTE filter_$=(vehicle = 1 & hc_2x = 1 & grp88 = 1).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & hc_2x = 1 & grp88 = 1 (FILTER)'.

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT hc_la4ho
->    /METHOD=ENTER mileage  .


           * * * *   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_LA4HO   HC_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .44218
R Square             .19552
Adjusted R Square    .19501
Standard Error       .07163

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             1.97161          1.97161
Residual          1581             8.11227           .00513

F =     384.24703       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .001385  7.0661E-05      .001247      .001524    .442178
(Constant)      .021397     .003347      .014831      .027963


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

Variable           T  Sig T

MILEAGE       19.602  .0000
(Constant)     6.392  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .18470
R Square             .03411
Adjusted R Square    .03350
Standard Error       .92659

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1            47.94271         47.94271
Residual          1581          1357.41150           .85858

F =      55.83968       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .006830  9.1404E-04      .005037      .008623    .184701
(Constant)     1.998720     .043300     1.913788     2.083652


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

Variable           T  Sig T

MILEAGE        7.473  .0000
(Constant)    46.159  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & hc_2x = 1 & grp88 = 2).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & hc_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT hc_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   HC_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE
```

```
Multiple R           .54551
R Square             .29758
Adjusted R Square    .29596
Standard Error       .07463

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             1.02400          1.02400
Residual           434             2.41708           .00557

F =     183.86531       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .001701  1.2544E-04      .001454      .001947    .545510
(Constant)      .004198     .007088     -.009733      .018128


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

Variable           T  Sig T

MILEAGE       13.560  .0000
(Constant)      .592  .5540


End Block Number   1   All requested variables entered.


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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .10853
R Square             .01178
Adjusted R Square    .00950
Standard Error       .70086

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             2.54088          2.54088
Residual           434           213.18120           .49120

F =       5.17279       Signif F =  .0234


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .002679     .001178  3.63926E-04      .004995    .108529
(Constant)     1.901893     .066564     1.771064     2.032721


----------- in ------------
```

```
Variable           T  Sig T

MILEAGE        2.274  .0234
(Constant)    28.572  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & hc_2x = 1 & grp88 = 3).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & hc_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT hc_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   HC_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .34643
R Square             .12001
Adjusted R Square    .11859
Standard Error       .12378

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             1.29756          1.29756
Residual           621             9.51443           .01532

F =      84.69051       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .001439  1.5635E-04      .001132      .001746    .346426
(Constant)      .094216     .009189      .076171      .112261


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

Variable           T  Sig T

MILEAGE        9.203  .0000
(Constant)    10.254  .0000


End Block Number   1   All requested variables entered.


-> REGRESSION
```

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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .03793
R Square             .00144
Adjusted R Square   -.00017
Standard Error      1.16208

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             1.20815          1.20815
Residual           621           838.61274          1.35042

F =        .89465       Signif F =  .3446


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .001388     .001468     -.001494      .004271    .037929
(Constant)     2.358932     .086266     2.189523     2.528341


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

Variable           T  Sig T

MILEAGE         .946  .3446
(Constant)    27.345  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & hc_2x = 1 & grp88 = 4).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & hc_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT hc_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   HC_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .25073
R Square             .06286
Adjusted R Square    .05245
Standard Error       .09393

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1              .05327           .05327
Residual            90              .79414           .00882

F =       6.03737       Signif F =  .0159


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE     8.12421E-04  3.3064E-04  1.55544E-04      .001469    .250729
(Constant)      .077383     .020471      .036713      .118053


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

Variable           T  Sig T

MILEAGE        2.457  .0159
(Constant)     3.780  .0003


End Block Number   1   All requested variables entered.


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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .48064
R Square             .23102
Adjusted R Square    .22247
Standard Error       .99649

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1            26.84774         26.84774
Residual            90            89.36862           .99298

F =      27.03742       Signif F =  .0000
```

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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .018238     .003508      .011270      .025207    .480640
(Constant)     1.493421     .217166     1.061982     1.924860


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

Variable           T  Sig T

MILEAGE        5.200  .0000
(Constant)     6.877  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & hc_2x = 1 & grp88 = 5).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & hc_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT hc_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   HC_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .20394
R Square             .04159
Adjusted R Square    .03746
Standard Error       .12495

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             .15719           .15719
Residual           232            3.62209           .01561

F =      10.06796       Signif F =  .0017


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .001214  3.8251E-04  4.60068E-04      .001967    .203940
(Constant)      .126577     .014947      .097128      .156026


----------- in ------------
```

```
Variable           T  Sig T

MILEAGE        3.173  .0017
(Constant)     8.469  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .16213
R Square             .02628
Adjusted R Square    .02209
Standard Error      1.22801

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             9.44422          9.44422
Residual           232           349.86033          1.50802

F =       6.26267       Signif F =  .0130


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .009408     .003759      .002001      .016815    .162126
(Constant)     1.589214     .146898     1.299790     1.878638


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

Variable           T  Sig T

MILEAGE        2.503  .0130
(Constant)    10.818  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & hc_2x = 1 & grp88 = 6).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & hc_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
```

```
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT hc_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   HC_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .50527
R Square             .25529
Adjusted R Square    .24806
Standard Error       .11052

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             .43130           .43130
Residual           103            1.25812           .01221

F =      35.30979       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .002250  3.7865E-04      .001499      .003001    .505267
(Constant)      .097024     .018871      .059598      .134450


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

Variable           T  Sig T

MILEAGE        5.942  .0000
(Constant)     5.141  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .21032
```

```
R Square             .04423
Adjusted R Square    .03495
Standard Error      1.14075

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             6.20337          6.20337
Residual           103           134.03607          1.30132

F =       4.76698       Signif F =  .0313


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .008533     .003908  7.81969E-04      .016284    .210319
(Constant)     2.354343     .194779     1.968044     2.740641


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

Variable           T  Sig T

MILEAGE        2.183  .0313
(Constant)    12.087  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & hc_2x = 1 & grp88 = 7).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & hc_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT hc_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   HC_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .28245
R Square             .07978
Adjusted R Square    .07868
Standard Error       .11606

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1              .97738           .97738
Residual           837            11.27372           .01347

F =      72.56441       Signif F =  .0000
```

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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .001271  1.4921E-04  9.78196E-04      .001564    .282452
(Constant)      .153943     .006278      .141621      .166266


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

Variable           T  Sig T

MILEAGE        8.518  .0000
(Constant)    24.522  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .24760
R Square             .06131
Adjusted R Square    .06019
Standard Error      1.43178

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1           112.06309        112.06309
Residual           837          1715.84167          2.04999

F =      54.66519       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .013610     .001841      .009997      .017224    .247602
(Constant)     2.121260     .077449     1.969242     2.273278


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

Variable           T  Sig T

MILEAGE        7.394  .0000
(Constant)    27.389  .0000


End Block Number   1   All requested variables entered.


->
->
->
```

```
->
-> COMPUTE filter_$=(vehicle = 1 & co_3x = 1 & grp88 = 1).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & co_3x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT co_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   CO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .43497
R Square             .18920
Adjusted R Square    .18869
Standard Error      1.21705

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1           549.21332        549.21332
Residual          1589          2353.66001          1.48122

F =     370.78421       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .022927     .001191      .020592      .025262    .434967
(Constant)      .458769     .056622      .347707      .569832


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

Variable           T  Sig T

MILEAGE       19.256  .0000
(Constant)     8.102  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .01494
R Square             .00022
Adjusted R Square   -.00041
Standard Error     12.05858

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1            51.59410         51.59410
Residual          1589        231055.54059        145.40940

F =        .35482       Signif F =  .5515


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .007027     .011797     -.016112      .030166    .014941
(Constant)    18.972536     .561015    17.872129    20.072942


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

Variable           T  Sig T

MILEAGE         .596  .5515
(Constant)    33.818  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & co_3x = 1 & grp88 = 2).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & co_3x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT co_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   CO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE
```

```
Multiple R           .57491
R Square             .33052
Adjusted R Square    .32897
Standard Error      1.39129

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1           411.88438        411.88438
Residual           431           834.28637          1.93570

F =     212.78325       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .033909     .002325      .029340      .038478    .574909
(Constant)     -.028277     .131686     -.287103      .230549


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

Variable           T  Sig T

MILEAGE       14.587  .0000
(Constant)     -.215  .8301


End Block Number   1   All requested variables entered.


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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .02245
R Square             .00050
Adjusted R Square   -.00182
Standard Error      8.95890

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1            17.43774         17.43774
Residual           431         34592.88334         80.26191

F =        .21726       Signif F =  .6414


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE        -.006977     .014969     -.036398      .022444   -.022446
(Constant)    19.232859     .847958    17.566211    20.899506


----------- in ------------
```

```
Variable           T  Sig T

MILEAGE        -.466  .6414
(Constant)    22.681  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & co_3x = 1 & grp88 = 3).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & co_3x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT co_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   CO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .34381
R Square             .11821
Adjusted R Square    .11683
Standard Error      1.80541

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1           279.20868        279.20868
Residual           639          2082.82364          3.25950

F =      85.65984       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .019588     .002116      .015432      .023744    .343812
(Constant)     1.444769     .130120     1.189254     1.700284


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

Variable           T  Sig T

MILEAGE        9.255  .0000
(Constant)    11.103  .0000


End Block Number   1   All requested variables entered.


-> REGRESSION
```

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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .01070
R Square             .00011
Adjusted R Square   -.00145
Standard Error     13.54016

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1            13.41337         13.41337
Residual           639        117151.73251        183.33604

F =        .07316       Signif F =  .7869


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE        -.004293     .015873     -.035462      .026875   -.010700
(Constant)    19.949338     .975872    18.033034    21.865642


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

Variable           T  Sig T

MILEAGE        -.270  .7869
(Constant)    20.443  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & co_3x = 1 & grp88 = 4).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & co_3x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT co_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   CO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .38730
R Square             .15000
Adjusted R Square    .14076
Standard Error      1.02382

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1           17.01790         17.01790
Residual            92           96.43454          1.04820

F =      16.23534       Signif F =  .0001


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .013709     .003402      .006952      .020467    .387299
(Constant)      .566553     .216869      .135832      .997274


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

Variable           T  Sig T

MILEAGE        4.029  .0001
(Constant)     2.612  .0105


End Block Number   1   All requested variables entered.


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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .16121
R Square             .02599
Adjusted R Square    .01540
Standard Error     21.02393

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1         1085.07366       1085.07366
Residual            92        40664.53507        442.00582

F =       2.45489       Signif F =  .1206
```

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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .109470     .069868     -.029294      .248234    .161214
(Constant)    24.697606    4.453376    15.852816    33.542395


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

Variable           T  Sig T

MILEAGE        1.567  .1206
(Constant)     5.546  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & co_3x = 1 & grp88 = 5).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & co_3x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT co_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   CO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .24144
R Square             .05829
Adjusted R Square    .05423
Standard Error      1.46214

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1            30.70190         30.70190
Residual           232           495.98217          2.13785

F =      14.36108       Signif F =  .0002


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .016908     .004462      .008118      .025699    .241439
(Constant)      .727606     .175115      .382587     1.072626


----------- in ------------
```

```
Variable           T  Sig T

MILEAGE        3.790  .0002
(Constant)     4.155  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .10909
R Square             .01190
Adjusted R Square    .00764
Standard Error     20.73715

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1          1201.49589       1201.49589
Residual           232         99766.81401        430.02937

F =       2.79399       Signif F =  .0960

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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .105775     .063281     -.018903      .230453    .109086
(Constant)    24.442451    2.483616    19.549126    29.335775


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

Variable           T  Sig T

MILEAGE        1.672  .0960
(Constant)     9.841  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & co_3x = 1 & grp88 = 6).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & co_3x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
```

```
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT co_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   CO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .32292
R Square             .10428
Adjusted R Square    .09583
Standard Error      1.75396

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1            37.96399         37.96399
Residual           106           326.09694          3.07639

F =      12.34045       Signif F =  .0007


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .021502     .006121      .009367      .033637    .322923
(Constant)     1.576249     .300873      .979739     2.172759


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

Variable           T  Sig T

MILEAGE        3.513  .0007
(Constant)     5.239  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .27648
```

```
R Square             .07644
Adjusted R Square    .06773
Standard Error     25.80196

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1          5840.81033       5840.81033
Residual           106         70568.54286        665.74097

F =       8.77340       Signif F =  .0038


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .266706     .090043      .088187      .445224    .276480
(Constant)    20.038190    4.426039    11.263137    28.813243


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

Variable           T  Sig T

MILEAGE        2.962  .0038
(Constant)     4.527  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & co_3x = 1 & grp88 = 7).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & co_3x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT co_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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_LA4HO   CO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .20587
R Square             .04238
Adjusted R Square    .04121
Standard Error      1.75821

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1           111.36702        111.36702
Residual           814          2516.33162          3.09132

F =      36.02576       Signif F =  .0000
```

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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .013887     .002314      .009346      .018429    .205869
(Constant)     1.393200     .096173     1.204424     1.581977


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

Variable           T  Sig T

MILEAGE        6.002  .0000
(Constant)    14.486  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .23702
R Square             .05618
Adjusted R Square    .05502
Standard Error     24.75160

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1         29684.08673      29684.08673
Residual           814        498690.22165        612.64155

F =      48.45262       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .226728     .032572      .162792      .290663    .237023
(Constant)    28.636627    1.353894    25.979092    31.294161


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

Variable           T  Sig T

MILEAGE        6.961  .0000
(Constant)    21.151  .0000


End Block Number   1   All requested variables entered.


->
->
->
```

```
-> COMPUTE filter_$=(vehicle = 1 & no_2x = 1 & grp88 = 1).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & no_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT no_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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..   NO_LA4HO   NO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .39011
R Square             .15219
Adjusted R Square    .15166
Standard Error       .22872

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1            15.10851         15.10851
Residual          1609            84.16805           .05231

F =     288.82214       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .003756  2.2100E-04      .003322      .004189    .390110
(Constant)      .200589     .010576      .179844      .221334


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

Variable           T  Sig T

MILEAGE       16.995  .0000
(Constant)    18.966  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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..   NO_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .05934
R Square             .00352
Adjusted R Square    .00290
Standard Error       .95537

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             5.18937          5.18937
Residual          1609          1468.57163           .91272

F =       5.68559       Signif F =  .0172


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .002201  9.2312E-04  3.90488E-04      .004012    .059340
(Constant)     1.443620     .044179     1.356966     1.530274


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

Variable           T  Sig T

MILEAGE        2.384  .0172
(Constant)    32.677  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & no_2x = 1 & grp88 = 2).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & no_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT no_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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..   NO_LA4HO   NO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE
```

```
Multiple R           .44967
R Square             .20220
Adjusted R Square    .20038
Standard Error       .21488

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             5.13724          5.13724
Residual           439            20.26926           .04617

F =     111.26452       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .003806  3.6084E-04      .003097      .004515    .449669
(Constant)      .225302     .020306      .185393      .265212


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

Variable           T  Sig T

MILEAGE       10.548  .0000
(Constant)    11.095  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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..   NO_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .10744
R Square             .01154
Adjusted R Square    .00929
Standard Error      1.17515

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             7.08035          7.08035
Residual           439           606.25000          1.38098

F =       5.12705       Signif F =  .0240


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE        -.004468     .001973     -.008347 -5.89886E-04   -.107444
(Constant)     2.300454     .111055     2.082188     2.518720


----------- in ------------
```

```
Variable           T  Sig T

MILEAGE       -2.264  .0240
(Constant)    20.715  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & no_2x = 1 & grp88 = 3).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & no_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT no_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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..   NO_LA4HO   NO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .18619
R Square             .03467
Adjusted R Square    .03327
Standard Error       .33374

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             2.76791          2.76791
Residual           692            77.07747           .11138

F =      24.85020       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .001883  3.7774E-04      .001141      .002625    .186188
(Constant)      .479830     .023534      .433623      .526037


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

Variable           T  Sig T

MILEAGE        4.985  .0000
(Constant)    20.389  .0000


End Block Number   1   All requested variables entered.


-> REGRESSION
```

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

           * * * *   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..   NO_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .04406
R Square             .00194
Adjusted R Square    .00050
Standard Error      1.07313

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             1.54972          1.54972
Residual           692           796.91339          1.15161

F =       1.34570       Signif F =  .2464


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .001409     .001215 -9.75750E-04      .003794    .044055
(Constant)     1.406422     .075673     1.257846     1.554999


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

Variable           T  Sig T

MILEAGE        1.160  .2464
(Constant)    18.586  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & no_2x = 1 & grp88 = 4).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & no_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT no_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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..   NO_LA4HO   NO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .16411
R Square             .02693
Adjusted R Square    .01647
Standard Error       .32441

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1              .27088           .27088
Residual            93             9.78756           .10524

F =       2.57391       Signif F =  .1120


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .001702     .001061 -4.04579E-04      .003808    .164107
(Constant)      .495967     .067974      .360984      .630950


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

Variable           T  Sig T

MILEAGE        1.604  .1120
(Constant)     7.296  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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..   NO_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .06506
R Square             .00423
Adjusted R Square   -.00647
Standard Error      1.05703

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1              .44169           .44169
Residual            93           103.91026          1.11731

F =        .39531       Signif F =  .5311
```

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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE        -.002173     .003456     -.009035      .004690   -.065059
(Constant)     1.404902     .221481      .965084     1.844719


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

Variable           T  Sig T

MILEAGE        -.629  .5311
(Constant)     6.343  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & no_2x = 1 & grp88 = 5).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & no_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT no_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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..   NO_LA4HO   NO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .15950
R Square             .02544
Adjusted R Square    .02148
Standard Error       .38404

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1              .94709           .94709
Residual           246            36.28266           .14749

F =       6.42139       Signif F =  .0119


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .002725     .001075  6.06968E-04      .004843    .159497
(Constant)      .555546     .044174      .468539      .642552


----------- in ------------
```

```
Variable           T  Sig T

MILEAGE        2.534  .0119
(Constant)    12.576  .0000


End Block Number   1   All requested variables entered.


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


           * * * *   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..   NO_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .10136
R Square             .01027
Adjusted R Square    .00625
Standard Error      1.17091

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             3.50127          3.50127
Residual           246           337.27551          1.37104

F =       2.55374       Signif F =  .1113


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .005240     .003279     -.001218      .011698    .101363
(Constant)      .747776     .134681      .482502     1.013050


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

Variable           T  Sig T

MILEAGE        1.598  .1113
(Constant)     5.552  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & no_2x = 1 & grp88 = 6).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & no_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
```

```
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT no_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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..   NO_LA4HO   NO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .41146
R Square             .16930
Adjusted R Square    .16146
Standard Error       .38335

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             3.17478          3.17478
Residual           106            15.57778           .14696

F =      21.60302       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .006326     .001361      .003628      .009024    .411459
(Constant)      .459727     .066906      .327079      .592376


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

Variable           T  Sig T

MILEAGE        4.648  .0000
(Constant)     6.871  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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..   NO_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .01562
```

```
R Square             .00024
Adjusted R Square   -.00919
Standard Error      1.03573

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1              .02775           .02775
Residual           106           113.71076          1.07274

F =        .02587       Signif F =  .8725


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE     5.91396E-04     .003677     -.006699      .007882    .015619
(Constant)     1.530162     .180765     1.171777     1.888547


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

Variable           T  Sig T

MILEAGE         .161  .8725
(Constant)     8.465  .0000


End Block Number   1   All requested variables entered.


->
-> COMPUTE filter_$=(vehicle = 1 & no_2x = 1 & grp88 = 7).

-> VARIABLE LABEL filter_$ 'vehicle = 1 & no_2x = 1 & grp88 = 1 (FILTER)'.

-> VALUE LABELS filter_$  0 'Not Selected' 1 'Selected'.

-> FORMAT filter_$ (f1.0).

-> FILTER BY filter_$.

-> EXECUTE .

-> REGRESSION
->    /MISSING LISTWISE
->    /STATISTICS COEFF OUTS CI R ANOVA
->    /CRITERIA=PIN(.05) POUT(.10)
->    /NOORIGIN
->    /DEPENDENT no_la4ho
->    /METHOD=ENTER mileage  .

           * * * *   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..   NO_LA4HO   NO_LA4HOT

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .17186
R Square             .02954
Adjusted R Square    .02854
Standard Error       .37012

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1             4.05244          4.05244
Residual           972           133.15445           .13699

F =      29.58196       Signif F =  .0000
```

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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE         .002328  4.2806E-04      .001488      .003168    .171858
(Constant)      .583430     .019264      .545626      .621234


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

Variable           T  Sig T

MILEAGE        5.439  .0000
(Constant)    30.286  .0000


End Block Number   1   All requested variables entered.


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

           * * * *   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..   NO_CS

Block Number  1.  Method:  Enter      MILEAGE


Variable(s) Entered on Step Number
   1..    MILEAGE


Multiple R           .17750
R Square             .03151
Adjusted R Square    .03051
Standard Error      1.36097

Analysis of Variance
                    DF      Sum of Squares      Mean Square
Regression           1            58.56677         58.56677
Residual           972          1800.38342          1.85225

F =      31.61932       Signif F =  .0000


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

Variable              B        SE B     95% Confdnce Intrvl B       Beta

MILEAGE        -.008851     .001574     -.011940     -.005762   -.177497
(Constant)     1.601358     .070836     1.462349     1.740366


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

Variable           T  Sig T

MILEAGE       -5.623  .0000
(Constant)    22.607  .0000
```

Figure 2 - Biennial I/M with RSD