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# I/M Costs, Benefits, and Impacts Analysis

## Draft

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## 1.0 INTRODUCTION

Despite having the best vehicle control program in the world, many areas in the United States continue to measure unhealthful levels of air pollution, approximately half of which can be attributed to motor vehicles. As a result, in addition to tighter standards on new vehicles and their fuels, the Clean Air Act Amendments of 1990 (Act) require the implementation of vehicle Inspection and Maintenance (I/M) programs in areas that have been designated as nonattainment for ozone or carbon monoxide. A total of 162 such areas currently exist in the United States, 52 of which do not presently operate I/M programs. Depending upon the severity of the nonattainment problem, these areas will have to implement either a basic I/M program (required in areas with moderate ozone nonattainment, and in marginal areas with existing I/M programs) or an enhanced I/M program (required in most serious, severe, and extreme ozone areas, as well as most carbon monoxide (CO) areas registering levels greater than 12.7 parts per million (ppm)). Seventy-four of the 162 nonattainment areas currently designated will require the implementation of an enhanced I/M program.

The Environmental Protection Agency (EPA) has had oversight and policy development responsibility for I/M programs since the passage of the Clean Air Act in 1970, which included I/M as an option for improving air quality. The first such I/M program in the United States was begun in New Jersey in 1974, and the program elements which made up this program's design (i.e., a centralized, annual, idle test of all light-duty gasoline vehicles, with no waivers or tampering checks) still constitute those design features upon which the basic I/M performance standard is based. However, many advances have been made in vehicle technology since the time of that first I/M program, and while the idle test in use in many current programs works well enough when it comes to detecting emission problems in older, low-tech vehicles, its effectiveness as a testing strategy rapidly drops off as we begin testing newer, more sophisticated, computer-controlled vehicles. High-tech vehicles need high-tech testing which more closely simulates real-world driving conditions and the sort of test to which vehicles are originally certified - a loaded, transient test, which requires driving the vehicle through a prescribed pattern of accelerations and decelerations on a dynamometer.

Much has also been learned since 1974 about the many ways vehicles contribute to the problem of air pollution. Previously, it was thought that the majority of the air pollution problem attributable to mobile sources was the result of exhaust emissions; it is now understood that emissions in the form of evaporative and running losses are also major contributors. The gasoline evaporating in the tank of a vehicle and escaping into the environment is as much a source of volatile organic compound (VOC) emissions as are the exhaust gases emitted from the

tailpipe. Vapor recovery and recirculation mechanisms have been installed on vehicles since 1971, but these systems can deteriorate with time and are often rendered useless as a result of wear, tampering, and design defects. Cost effective tests have been developed to detect evaporative system failures of this sort, including the evaporative system purge test and the evaporative system pressure test.

Under the terms of the Clean Air Act Amendments of 1990, EPA is required to establish minimum performance standards for I/M programs. The Act further specifies that the standard for enhanced I/M shall be based upon a program that employs an annual cycle of automated emissions analysis, performed at a centralized site, and enforced through the denial of registration. EPA is currently in the process of developing and formalizing these standards in the form of a rulemaking.

In the past, the model program used to establish the performance standard assumed a basic program along the lines of the original New Jersey program - a standard which remains essentially unchanged for basic I/M programs. For the enhanced I/M performance standard, however, EPA is evaluating potential low, medium, and high options, the last of which would be based on loaded, transient testing, in conjunction with evaporative system purge and pressure tests (see section 3.0 for a more detailed discussion of these potential options). Using EPA's MOBILE4.1 computer model, a high-tech I/M program, such as the one proposed by EPA's high option, is expected to achieve emission reductions from mobile sources on the order of approximately 31% for ozone-forming hydrocarbons (HC) and 34% for CO (compared to a 5% HC and 16% CO emission reductions from the basic I/M performance standard program design).

Given the potentially significant economic impact of this decision, it is necessary to assess the costs and benefits of enhanced I/M performance standards. This report provides the technical background information supporting EPA's cost and benefit projections.

In assessing the costs and benefits of enhanced I/M, we will detail the findings of recent research and development on test procedures and vehicle emissions, the basis for the computer models used to establish emission benefits and program cost effectiveness, the differences in cost effectiveness among programs based upon network and test types, as well as projections of the average per vehicle cost for inspection and repairs, and the cost offset of the fuel economy benefit achieved by making such repairs. The full program listings for the computer models used to assess the costs and benefits of I/M program design options, as well as other graphic and tabular support data, are attached to this report as appendices.

## 2.0 GLOSSARY OF KEY TERMINOLOGY

Throughout this report several key terms will be used with which the reader may not be immediately familiar. To facilitate a better understanding of the issues involved, the following glossary is provided.

"Concentration" Versus "Mass Emissions" Tests: Mass emissions tests provide a much better indication of vehicle emission levels than concentration tests. A concentration reading of 200 parts per million (ppm) HC from a subcompact car and the same 200 ppm reading from a large truck (which is entirely possible) suggest that the two vehicles pollute equally. However, this is incorrect. The truck will have a much higher volume of exhaust. So, over a given one-mile drive, the subcompact car may only emit 50 cubic feet of exhaust gases, whereas the truck may emit 500 cubic feet. With both vehicles emitting 200 ppm HC over the mile, the total amount of HC emitted by the truck will be 10 times greater than the amount emitted by the small car. A mass emissions test allows the total emissions per mile to be measured; a concentration test does not. All currently approved I/M tests are concentration tests. The Federal Test Procedure and the IM240 test, however, are mass emissions tests.

Error-of-Commission (Ec): On the basis of an emissions test, the false failure of a vehicle as "dirty" (i.e., emitting high enough that repair and a retest are required) when the vehicle, in fact, meets EPA new car standards, based upon the Federal Test Procedure (see definition below). Usually, HC and CO Ec's are defined without regard to $NO_x$ emissions, and vice versa.

Error-of-Omission: To falsely pass as clean a vehicle which, in fact, exceeds EPA new car standards, based upon the results of the Federal Test Procedure.

Federal Test Procedure (FTP): The Federal Test Procedure (FTP) is a mass emissions test created to determine whether prototype vehicles comply with EPA standards, thus allowing production vehicles to be certified for sale in the United States. The FTP has become the "golden standard" for determining vehicle emission levels, so it is also used to determine the emission levels of "in-use" vehicles. The FTP is too costly to use for I/M because vehicles must be maintained in a closely controlled environment for over 13 hours. The FTP is based on a 20 minute trip, driven once when the engine is cold, and again when it is hot.

High-Tech Vehicles: Vehicles with computerized control of the engine and emission control system, especially 1983 or newer vehicles employing fuel injection (either port fuel injection or throttle-body injection) as opposed to carburetion as a fuel metering methodology.

Idle Test: A concentration-type emission test to measure the percentage of CO and ppm HC in the exhaust stream of a gasoline-powered vehicle operating at idle. The nondispersive infrared detector (NDIR) equipment normally used gives a less accurate measure of HC than does the flame ionization detector (FID) equipment used in the FTP and IM240 tests.

IM240 Exhaust Test: A mass emissions (as opposed to concentration), transient short test run on an inertial and power-absorbing dynamometer using a 240 second driving cycle loosely based upon the LA-4 cycle used in the FTP. EPA has usually divided the driving cycle into 2 parts or "bags" with separate emissions determinations, but other treatments are possible. Unlike the idle test which is conducted at a single speed and expresses emissions in terms of percentages and ppm, the IM240 is conducted at a range of accelerations and decelerations and provides emissions measurements in terms of grams per mile (gpm). The IM240 has proved particularly effective in accurately identifying high emitting, newer technology vehicles.

Multiple Independent Supplier Test-Only Network: A hybrid program design with elements of both centralized and decentralized networks in which multiple participants are licensed to perform I/M testing (as opposed to a single contractor). To establish equivalency with traditional centralized programs and to avoid the decentralized discount incorporated in EPA's MOBILE model, participants must operate test-only facilities and are barred from making repairs, selling replacement parts, making referrals, or otherwise engaging in activities that would violate the intention of the test-only requirement (i.e., the avoidance of conflict-of-interest).

Pressure Test: A test whereby inert gas is injected into a vehicle's evaporative system to establish the system's integrity by indicating the presence of a leak(s) or by confirming the system's ability to hold pressure.

Purge Test: A test to determine whether a vehicle's evaporative emissions system recycles the gasoline vapors adsorbed on the charcoal in the canister (i.e., whether or not the canister purges vapors to the engine to be combusted). To provide representative operation and opportunity for the purge control system to demonstrate its proper working order, the purge test is conducted on a dynamometer using the same 240-second transient driving cycle as the IM240 exhaust gas test.

2500 rpm/Idle Test: A two-speed, steady-state concentration-type test in which emissions are sampled at both idle and 2500 rpm. To be considered a pass, a vehicle must pass at both speeds. The two-speed test has a better identification rate for high emitting vehicles than does the standard idle test.

## 3.0 PROPOSED I/M PERFORMANCE STANDARDS

### 3.1 Enhanced I/M Performance Standard

Under the Act, EPA is required to establish a performance standard for enhanced I/M programs including, at a minimum, centralized, annual, automated emission testing of light-duty vehicles and trucks, including a tampering check for emission control devices, a misfueling check, and provisions for including on-road emission testing and inspection of onboard diagnostic devices (OBD). The performance standard is defined by completely specifying the design of a model or benchmark I/M program. While enhanced I/M programs need not match the performance standard's model program element by element, such programs must be designed and implemented to meet or exceed the minimum emission reductions achieved by the performance standard. Any deviations from the performance standard's program design that may lead to emission reduction losses must be made up by strengthening other aspects of the program. For example, while the Act constrains the performance standard for enhanced I/M programs to be based on an annual program, it is clear that a biennial program is more cost effective and results in relatively minor emission reduction losses over those achieved by an annual program. The emission reduction losses resulting from a decision to test vehicles biennially as opposed to annually can be made up, for example, by extending transient exhaust testing and purge testing to cover earlier model years than those specified in the performance standard. This specific example will be discussed in more detail in section 3.2 of this report, "Recommended Enhanced I/M Program Design."

In its draft guidance document issued in April 1991, EPA proposed four potential enhanced I/M performance standards for comment. More recently, in discussion with interested parties and for purposes of this document, these four options have been reduced to three: a low, a medium, and a high option. Although EPA's proposed performance standard most closely resembles the high option proposed in EPA's April 1991 draft guidance, the Agency is still soliciting public comment on the low and medium options. The low, medium, and high options take an incremental approach to advanced technology testing. These options are presented below. Computer modeling runs for these options are included in Appendix K, while a detailed listing of program elements is provided in Table 6-1.

#### 3.1.1 Low Option

The Low Option is similar to the better programs currently operating, and, by the year 2000, under conditions of temperature, fleet composition, etc. that are reasonably typical of an average nonattainment area, is projected to yield a 10% reduction in

highway vehicle VOCs and a 25% reduction in CO over a non-I/M scenario. This option includes annual, centralized idle testing of model year 1968 and later light-duty vehicles and trucks to 8,500 Gross Vehicle Weight Rating (GVWR), including a visual inspection for the catalyst and fuel inlet restrictor on 1981 and newer vehicles. The option further assumes a pre-1981 failure rate of 20%, a waiver rate of 1%, and an overall compliance rate of 98%.

### 3.1.2 Medium Option

The Medium Option is identical to the above Low Option with the exception that it includes pressure testing of the evaporative system on 1971 and newer vehicles. This option is estimated to yield a 20% reduction in VOCs and a 25% reduction in CO over a non-I/M scenario (note that pressure testing is a VOC strategy that yields no CO benefit, making the low and medium options identical for CO purposes).

### 3.1.3 High Option

The High Option includes a transient IM240 exhaust test incorporating $NO_x$ cutpoints, and purge testing of the evaporative control system of 1986 and later vehicles (using cutpoints of 0.8 gpm HC, 15 gpm CO, and 2.0 gpm $NO_x$ for emissions during the the entire 240-second test, but with an additional opportunity to pass for HC and CO by demonstrating emissions less than 0.5 gpm and 12 gpm, respectively, during the final 147 seconds). Two-speed testing is to be performed on 1981-1985 model year vehicles (using cutpoints of 1.2% CO, 6% $CO_2$, and 220 ppm HC) while idle testing is to be used on pre-1981 vehicles. Idle test cutpoints for older vehicles must yield a 20% failure rate. The performance standard also includes visual inspection of the catalyst and fuel inlet restrictor on all 1984 and later vehicles (as opposed to 1981 in the low option) and evaporative system integrity (pressure) testing of 1983 and later vehicles. The High Option is estimated to yield a 28% reduction in VOCs, a 31% reduction in CO, and a 9% reduction in $NO_x$ over a non-I/M scenario.

## 3.2 Recommended Enhanced I/M Program Design

The Act requires EPA to establish a performance standard based on an annual test program. States, however, are free to perform a biennial program under such a requirement if a demonstration can be made that such a program (in combination with other features) would be equally effective. This demonstration is made using EPA's mobile source emission model which includes biennial and annual program credits. For example, using the current version of the model, MOBILE4.1, a biennial high option can achieve the same VOC reduction achieved by the annual high option performance standard by doing transient/purge testing on

1984 and later vehicles and pressure testing on 1971 and later vehicles. Given the added convenience and cost effectiveness of a biennial program, EPA recommends that states adopt the biennial high option since it can achieve reductions equal to that of the proposed annual model program which defines the performance standard. In addition, EPA recommends that initial testing of new vehicles be delayed until the vehicle is two or three years old, as the percentage of high emitting vehicles among newer cars is relatively small.

### 3.4 Basic I/M Performance Standard

The basic I/M performance standard is based upon the program design of the original New Jersey program and remains essentially unchanged as a result of EPA's proposed action. The basic I/M performance standard is estimated to yield a 5% reduction in mobile source VOC emissions and a 16% reduction in CO. The performance standard includes annual, centralized idle testing of model year 1968 and later light duty vehicles. The pre-1981 failure rate is assumed to be 20%, with 0% waivers and 100% compliance. Unlike the low option for enhanced I/M, the basic I/M performance standard does not include testing of light-duty trucks; neither does it include visual inspections of any emission control components.

## 4.0 EMISSION REDUCTIONS FROM I/M PROGRAMS

### 4.1 Recent I/M Test Programs (Maryland and Indiana)

The data used by EPA to assess the benefits of high-tech I/M testing concepts, including the IM240[1], and evaporative system purge and pressure testing, have been obtained as a result of two special testing programs performed under contract to EPA. The first testing program - an IM240 transient test pilot study - was conducted as part of a cooperative project with the State of Maryland in 1989, and utilized one of the state's I/M stations for testing and recruiting vehicles. This was the first attempt to perform transient emissions tests on consumer vehicles in a high throughput system. A more extensive program is currently being run in Indiana. The Maryland pilot study began testing in August 1989, and continued through December of that year, testing a total of approximately 600 vehicles for an average of approximately 120 vehicles per month. The larger-scale Indiana program began testing in February 1990. As of November 1, 1991, approximately 8,300 vehicles had been tested as part of the Indiana program, with an average of approximately 120 vehicles per week. As such, the database produced by this test program is the largest of its kind ever assembled to assess I/M testing.

The Indiana testing contracts include two test facilities, a laboratory in New Carlisle (a few miles west of South Bend), and an I/M station in Hammond. The laboratory is owned by Automotive Testing Laboratories, Inc. (ATL), a contractor to EPA, and the I/M station is owned by the Indiana Vocational-Technical College, which operates the I/M program for the State of Indiana. The I/M station includes four lanes, with ATL running one of the four.

EPA has three separate testing contracts in Indiana that utilize the two facilities: Emission factor (EF), I/M, and running loss testing. Reformulated fuels testing is being performed under the EF contract. The three contracts use vehicles that are selected at the I/M station. The selection criteria for follow-up laboratory testing include model year, fuel metering type, and results from the following tests: The IM240, canister purge flow measurement, and evaporative control system pressure tests.

The goal at the I/M station originally was to test a random sample of 1976 and newer light duty vehicles. On May 15, 1991, the recruitment goal changed to randomly sample 1983 and newer vehicles, to increase the number of fuel-injected vehicles represented in the database. This change was made to reflect the fact that fuel injection is rapidly replacing carburetion as the

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1 Pidgeon, W. and Dobie, N., "The IM240 Transient I/M Dynamometer Driving Schedule and The Composite I/M Test Procedure," U.S. EPA Technical Report Number EPA-AA-TSS-91-1, January 1991.

preferred fuel-metering method for new vehicles, and the percentage of carbureted vehicles in the in-use fleet will become insignificant in the future.

Choosing cars for further laboratory testing is driven by the overriding importance of testing and assessing emissions from - and the impact of repair on - dirty in-use vehicles. A random sample of vehicles visiting the I/M station would result in the contractor recruiting mostly clean vehicles, given that the majority of excess emissions comes from a relatively small percentage of vehicles known as high to super emitters. To avoid the problem and cost of evaluating a majority of vehicles that will ultimately be assessed as clean, a stratified recruitment plan is employed to deliberately over-recruit dirty cars, based on the results of IM240, purge and pressure tests. Actually, two recruitment and lab testing programs operate simultaneously. In one, a nominally 50/50 mix of IM240-clean and IM240-dirty vehicles is recruited for FTP exhaust testing. In actual practice, more clean cars than dirty have been recruited rather than allow lab testing slots to be idle while waiting for a dirty car to be recruited. The Hammond I/M lane vehicles were categorized as clean or dirty using the IM240 standards listed in Table 4-1. In the other lab-testing recruitment effort, a sample even more heavily weighted toward purge and pressure test failures is recruited for evaporative and running loss emissions testing.

Table 4-1

IM240 Selection Standards for Stratified FTP Recruitment

| | Selection Standards (grams per mile) | |
|---|---|---|
| Model Years | HC | CO |
| 1986+ * | >1.10 | >15.0 |
| 1983-85 | >1.20 | >16.0 |

* The 1986+ standards were set to be more stringent than 1983-1985 standards to improve recruitment of high emitters and to balance the failure rates between model year groups.

The FTP database that results from EPA's recruitment targets must be corrected to represent the clean/dirty vehicle ratio in the in-use fleet to correctly determine excess emission identification rates (IDR), error-of-commission rates (Ec) and failure rates (all important criteria for assessing the overall effectiveness of I/M testing strategies). The database was corrected using the weighting factors presented in Table 4-2.

Table 4-2

Weighting Factors for Correcting Recruitment Biases

| Fuel Metering System | Lane IM240 Results | Lane Count | Lab Sample Count | Weighting Factor | # Lab Veh Passing FTP | # Normals Failing FTP |
|---|---|---|---|---|---|---|
| PFI | Clean | 1505 | 55 | 27.36 | 23 | 24 |
| | Dirty | 97 | 19 | 5.11 | 1 | 2 |
| | Total | 1602 | 74 | | 24 | 26 |
| TBI | Clean | 1555 | 73 | 21.30 | 25 | 32 |
| | Dirty | 166 | 35 | 4.74 | 4 | 6 |
| | Total | 1721 | 108 | | 29 | 38 |

Weighting factors are used as follows: If the 19 dirty vehicles that received FTP tests in the Port Fuel Injected (PFI) vehicle sample had excess HC emissions which totaled 100 gpm, the database would be corrected in this case by multiplying 100 by the 5.11 weighting factor, resulting in a corrected excess emission rate of 511 gpm for the dirty vehicles (excess emissions are those FTP-measured emissions that exceed the certification emission standards for the vehicle under consideration; an I/M test's identification rate for excess emissions represents one of the important criteria for assessing an I/M test's effectiveness, as detailed in section 4.2 of this report). In comparison, the excess emissions of the IM240 clean vehicles have to be multiplied by 27.36 to make their excess emissions representative. The total simulated excess emissions are the sum of the simulated excess emissions from the clean and dirty vehicles in the I/M lane sample. The number of vehicles tested was similarly adjusted with the factors for the purpose of calculating failure rates. The large sample of 55 clean cars in this sample provides confidence in conclusions about a test's relative tendency to avoid failing clean cars.

Appendix H provides additional information on adjustments to make the FTP database representative of the Hammond lane fleet's ratio of clean and dirty vehicles. Appendix H also includes tables that allow a comparison of cutpoint effects on IDR, I/M failure rates, Ec rates, and I/M failure rates for FTP-passing vehicles.

At the Hammond I/M station, in addition to the IM240, technicians perform the official Indiana I/M test (2500 rpm/Idle) and an additional second-chance 2500 rpm/Idle test for those that fail the first chance test. Vehicles that require a second-chance test first receive 3 minutes of preconditioning. The combination

of this "enhanced" steady-state testing, along with the IM240 and purge/pressure tests allows for direct comparison of these alternative I/M procedures. section 4.2 of this report provides a more detailed discussion of the results of comparing the degree to which the IM240 and the second-chance 2500 rpm/Idle test correlate with the FTP.

In addition to assessing the IM240 for correlation with the FTP, several other issues are addressed as part of the Hammond study. Since dirty vehicles are repaired at the lab, the repair effectiveness can be evaluated. The running loss tests allow EPA to characterize the air quality impact of vehicles failing pressure and purge tests and the effectiveness of repairing these vehicles. The transient short test developed by the Colorado Department of Health (CDH-226) as well as a variety of steady-state tests are performed at the lab and can be evaluated as potential I/M tests. Additionally, one of the IM240s performed at the lab was restricted to inertia weight settings of 2,500 pounds or 3,500 pounds. This restriction allowed EPA to evaluate the FTP correlation effect of a more economical dynamometer (with fewer inertia weight settings). We found that an inertia weight range of 2,000 to 5,500 pounds using four inertia wheels (500, 1,000, and 2,000 pounds with a fixed wheel of 2,000 pounds) is worth the moderate additional cost.

The evidence displayed in section 4.2 (see below) and Appendices E and G of this report graphically and quantitatively shows the advantage of the high-tech IM240 test for the sample of vehicles tested in Indiana in 1990 and 1991. The actual calculations of the exhaust emission reductions of the several short tests are more detailed in order to best reflect the actual characteristics of the fleet as it ages and changes in technology mix. A computer model called Tech4.1 is used to calculate technology- and age-specific adjustment factors that represent the effect of I/M programs of different types (the so-called "I/M credit"), and these factors are built into the mobile source emissions model MOBILE4.1. Section 4.3 of this document contains details on the Tech4.1 model, while Appendix B lists the source code for the model.

Finally, the Indiana testing program has revealed the true seriousness of evaporative emission control system malfunctions that develop during real world operation. Previous EPA testing programs (i.e., those conducted during the last 10 years or so) that did not make use of an operating I/M lane to screen and recruit vehicles for more thorough laboratory testing have focused mostly on vehicles that were about 5 years old or younger, in order to most quickly obtain information on the latest generation of new technology vehicles. When special efforts were made to recruit high mileage vehicles, they tended to be vehicles that had accumulated unusually high mileage for their age, for example vehicles from owners with long commutes or who used their vehicles for business during the day. EPA staff have been concerned for

some time that testing such vehicles was not giving a true picture of evaporative emission problems, which may develop more as a function of passing time than of miles driven; for example, deterioration of rubber and plastic components would be more time- than mileage-based. Also, the recruitment practices in the test programs prior to the Indiana I/M lane program relied on owner response to letters and phone calls. There has been concern that this resulted in a different sample of vehicles, probably a sample biased towards better maintenance condition than would be found if owners could be solicited face-to-face, as they are in the Hammond study (where the level of motorist participation has been sufficiently high to ameliorate these concerns). These differences in study design explain why the Indiana program has produced results very different from previous estimates of in-use evaporative emissions. EPA's interest in the high-tech evaporative purge and pressure tests has been in response to these findings.

Because of the extensive detail of the evaporative emissions findings from Indiana, the results of the testing are presented in Appendix C, rather than illustrated with figures and tables here. Briefly stated, the Indiana program showed that by 13 years of age, nearly one-half of all vehicles will experience an evaporative system failure that renders the control system virtually ineffective, causing evaporative and running loss emissions to increase by factors of up to 10 times. Nearly all of these failures can be detected by the combination of the pressure and purge tests. Use of only one of these tests finds at least some of the problem vehicles. The problems can be repaired, and vehicles will then pass a re-inspection using the pressure and/or purge test. Appropriate repairs reduce emissions back to normal levels. Of course, the purge and pressure tests cannot overcome the limited control capacity designed into vehicles by their manufacturers, so under certain conditions of temperature and fuel volatility, both passing and repaired vehicles will fail to meet the certification emission standard.

## 4.2 FTP HC/CO Correlation Comparison Between the IM240 and the Second-chance 2500 rpm/Idle Test

This section focuses on the comparison of the IM240 transient test (using cutpoints of 0.8 gpm HC and 15 gpm CO for the results over the full 240 seconds, with a provision that a vehicle also may pass by having emissions during the last 147 seconds of the test less than or equal to 0.5 gpm HC and 12 gpm CO - see section 4.2.3 for a more detailed explanation of the two-ways-to-pass criteria) to EPA's currently recommended second-chance 2500 rpm/Idle test procedure[2], and details the evaluation criteria upon

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2 Tierney, E., Herzog, E. and Snapp, L. "Recommended I/M Short Test Procedures For the 1990s: Six Alternatives", U.S. EPA Technical Report Number EPA-AA-TSS-90-3, January 1991.

which the comparison is based. This comparison shows how an I/M program based on one of the better currently used (non-dynamometer) I/M tests (second-chance 2500 rpm/Idle) can be improved upon by changing to the IM240 test, which has a much better classical correlation with the FTP than the idle or 2500 rpm/Idle test for matched pollutants (see the regression analyses including R-squared values and scatter plots in Appendix E for an illustration of this better correlation).

For the sake of the correlation analysis illustrated in Appendix E, only 1983 and newer vehicles equipped with fuel injection were considered[3]. The vehicles in this sample received both the second-chance 2500 rpm/Idle test and the IM240 at the Hammond test site. At this time, most I/M programs have not adopted second-chance testing and the test algorithms recommended in EPA's Alternative Test Procedure report, which calls for an immediate second-chance test for vehicles that initially fail the emission standards. Under the recommended procedures, vehicles are preconditioned in a non-loaded state for three minutes at 2500 rpm prior to the second test. Second-chance testing was devised to reduce, to the extent possible, the problem of falsely failing vehicles. For the purposes of this comparison and to enable analyses of the effectiveness of more stringent standards, second-chance tests were performed on 1983 and newer fuel-injected vehicles if their emissions exceeded 100 ppm HC or 0.5% CO on their initial 2500 rpm/Idle tests. Note that these standards are substantially tighter than the standards of 220 ppm HC and 1.2% CO used in nearly all I/M programs on 1981 and later vehicles.

One of the central concerns in developing a new I/M short test was to devise a test that would pass vehicles that would pass the FTP and fail those that would fail the FTP. With that in mind, the IM240 was devised by truncating, splicing, and otherwise augmenting the first two hills of the FTP driving cycle. One of the goals of the pilot program was to assess how well the IM240 correlates with the FTP. Since performing the FTP in the Indiana lane was not a practical alternative, both IM240s and FTPs were conducted in the lab after the vehicles were recruited in the I/M lane. The lab results of the IM240 and the FTP showed excellent correlation. One can conclude that the IM240 is an excellent measurement of the true emissions of the vehicle at the time and place it is performed, given the fuel being used at the time.

Comparing lab FTP and lane IM240 results is problematic for several reasons, but still shows good correlation. Since the lab tests are performed at a different time from the lane IM240s, intervening factors, such as intermittent problems or changes in

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[3] The emission reduction benefits presented in Section 6, however, do reflect the application of the IM240 to carbureted vehicles as well as fuel-injected vehicles; the comparisons of IDR, Ec rate, and failure rate for the various I/M tests presented in Appendices G and H also address carbureted vehicles.

the vehicle, may affect the results. For example, exhaust systems are repaired, when needed, prior to the lab tests. Another major problem making lab and lane comparisons difficult is the fact that FTP tests are all done on Indolene fuel[4] while lane tests are done on the fuel in the tank of the vehicle as received. Also, the equipment used in the lanes measured a lower maximum emission value than the lab equipment; for example, a car would have pegged the lane instrument for hydrocarbons at 13 gpm while in the lab it actually measured 25 gpm. Temperature and preconditioning at the lane were also often different than at the lab. For these reasons, lab/lane comparisons say less about the actual performance of the test and more about the influence real world differences make on vehicle emissions. Nevertheless, both sets of comparisons are presented in Appendix E of this report.

One of the conclusions evident from the data collected as part of the Hammond study is that for fuel injected vehicles in particular, the high-tech IM240 test has a better correlation with the FTP than the conventional idle or 2500 rpm/Idle test. This section and Appendix E present some illustrations of this better correlation.

For example, one indication of better correlation is demonstrated by higher R-squared values from least-squares regressions with FTP emissions as the dependent variable and short test emissions as the independent variable. Statistics for these regressions are given in the regression analyses tables in Appendix E.

The better correlation of the IM240 test also can be seen visually in the scatter plots of emissions results from vehicles which received all four tests (Appendix E). Separate plots of FTP versus short test results are included for each type of fuel injection (whether PFI or Throttle Body Injection (TBI)), pollutant (HC, CO, and $NO_x$), and each short test type (except for idle and 2500 rpm/Idle for $NO_x$, since representative in-use $NO_x$ emissions cannot be measured on these tests). Because of the wide range of the data, the graphs showing all the data contain a lump of points near the origin. To allow examination of the correlation for vehicles emitting in this range, an enlargement of the data in this range is also provided for each of the graphs in Appendix E.

The above two indications (R-squared values and scatter plots) of better correlation do not directly enter the calculation of the emission reduction advantages of the IM240. In an I/M program, predicting the absolute level of a vehicle's FTP

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[4] Indolene is a special test fuel whose properties are held constant. This is necessary because the normal changes in fuel properties of commercial fuel can change a car's emissions results even if all of the other test procedure variables and vehicle variables did not change between tests.

emissions is not as important as identifying a large majority of the vehicles whose emissions are likely to be high enough to merit repair (which are, themselves, a minority of the overall in-use fleet). Also, the short test should pass vehicles that are not malfunctioning, in order to avoid impacting owners of vehicles which have emissions low enough to not merit repair. The figures in Appendix G, which are discussed in the following sections, graphically demonstrate the differences between the second-chance 2500 rpm/Idle test and IM240 in regard to these objectives.

The I/M test must also do a good job of ensuring that vehicles that have shown emission reductions from repairs large enough to pass re-inspection on the short test have also achieved sizeable FTP reductions. Better performance of one short test versus another in identifying vehicles as generally clean or dirty will also ensure that fewer vehicles can pass reinspection without achieving real FTP reductions. Therefore, it is clear that the IM240 test will be the better enforcer of good repairs. Analysis of data from vehicles in Indiana that were repaired at the laboratory and retested on both the FTP and IM240 shows that reductions measured by the two tests are highly correlated, even better than the correlation discussed above. Figures and statistics to illustrate this are also included in Appendix E.

### 4.2.1 I/M Test Assessment Criteria Overview

In assessing the overall effectiveness of an I/M testing procedure, it is important to determine the test's effectiveness in measuring and determining a variety of factors, including the IDR, the failure rate, the error-of-commission rate, the failure rate among vehicles that pass FTP standards, and the failure rate for so-called "normal emitters," which may fail an FTP standard but are clean enough to make it an issue whether they will benefit much from normal repair procedures. Each of these is discussed, in turn, below. Section 4.2.2 provides a more detailed discussion of the same topics.

#### 4.2.1.1 Excess Emission Identification Rate (IDR)

EPA commonly uses the rate of excess emissions identified during an I/M test to objectively and quantitatively compare I/M test procedures. As mentioned earlier, excess emissions are those FTP-measured emissions that exceed the certification emission standards for the vehicle under consideration. For example, a vehicle certified to the 0.41 gpm HC standard that failed the second-chance 2500 rpm/Idle I/M test with an FTP result of 2.00 gpm, would have excess emissions equalling 1.59 gpm (i.e., 2.00 - 0.41 = 1.59).

The excess emissions identification rate (IDR) equals the sum of the excess emissions for the vehicles failing the I/M test divided by the total excess emissions (because of imperfect

correlation between I/M tests and the FTP, some I/M passing vehicles also have excess emissions which are used for calculating the total excess emissions). Thus, assuming an I/M area that tests 1000 vehicles, 100 of which are emitting 1.59 gpm excess emissions each, while the I/M test fails (identifies) 80 of the excess emitting vehicles, the excess emission identification rate can be calculated as follows:

$$\frac{\text{80 failing vehicles * 1.59 gpm excess per vehicle}}{\text{100 vehicles * 1.59 gpm excess per vehicle}} * 100 = 80\% \text{ IDR}$$

As can be seen in Figures 1 and 4 in Appendix G, the IM240 using two-mode criteria has been shown to identify more excess emissions among the cars tested at the Indiana lane than the second-chance 2500 rpm/Idle test with current I/M program cutpoints.

4.2.1.2 Failure Rate

As the IDR increases, the opportunity to identify vehicles for emission repairs also increases. However, this measure is not sufficient for determining which is the more efficient and cost-effective I/M test. Other criteria must also be addressed before such an assessment can be made. One such criterion is the failure rate, which is calculated by dividing the number of failing vehicles by the number of vehicles tested. For example:

$$\frac{\text{50 vehicles failed I/M}}{\text{1000 vehicles tested}} * 100 = 5\% \text{ I/M failure rate}$$

The ideal I/M test is one that fails all of the dirtiest vehicles while passing those below the FTP standard or close to it, but still above it. The potential emission reduction benefit decreases as emission levels from a vehicle approach the standard, because the prospect for effective repair diminishes. Thus, achieving a high IDR in conjunction with a low failure rate (as a result of identifying fewer vehicles passing or close to the standard) efficiently utilizes resources. As the figures in Appendix G show, tightening the cutpoints on the idle test to achieve IDRs comparable to the IM240's results in increasing the failure rate well beyond that of the IM240. For example, for 1983 and newer, PFI vehicles, the failure rate rose from 12% to 38% when second-chance, two-speed cutpoints were tightened to 100 ppm for HC and 0.5% for CO, even though the two-speed test's IDRs for HC and CO were only 77% and 82% respectively (compared to the IM240's 82% and 85% IDRs for HC and CO, and its 14% failure rate). The remaining figures in Appendix G illustrate a similar relationship between IDR and failure rate for tighter two-speed cutpoints for both TBI and carbureted vehicles. For a more specific, model year breakdown of failure rates among the vehicles in the Hammond lane sample, by test type, see the Appendix M,."Model Year Failure Rates by Test Type."

#### 4.2.1.3 Error-of-Commission (Ec) Rate

Properly functioning vehicles which pass FTP standards sometimes fail the 2500 rpm/Idle test; these are referred to as false failures or as errors of commission (Ecs). When error-of-commission vehicles are sent to repair shops, no emission control system malfunctions exist. Often, the repair shop finds that the vehicle now passes the test without any changes. These false failures waste resources, annoy vehicle owners, and may lead to emissions increases as a result of unnecessary and possibly detrimental "repairs." Motor vehicle manufacturers see this as a significant problem, since it can contribute to customer dissatisfaction and increased warranty costs. An I/M program seeking larger emission reductions through more stringent emission test standards may actually increase the number of false failures. The error-of-commission rate is, therefore, an important measure for evaluating the accuracy of I/M tests.

To see how an error-of-commission rate is calculated, assume an I/M area which tests 1000 vehicles, of which 100 fail the I/M test, although only 50 of those 100 failing vehicles also exceed their FTP standard for HC or CO. The error-of-commission rate equals the number of vehicles that fail the I/M test while passing the FTP for HC and CO, divided by the total number of vehicles which were I/M tested:

$$\frac{\text{50 vehicles failed I/M but passed FTP HC and CO}}{\text{1000 vehicles tested}} * 100 = 5\% \text{ Ec}^* \text{ rate}$$

*Error-of-commission

As the error-of-commission rate decreases, vehicle owner satisfaction and acceptance of the I/M program increases. Thus, while it is relatively easy to improve the IDR by making the I/M test standards more stringent, this "improvement" comes at the cost of potential increases in the error-of-commission rate.

#### 4.2.1.4 Failure Rate Among FTP-Passing Vehicles

The risk of failing an I/M test with a clean vehicle is not expressed very clearly, however, by stating fleet error-of-commission rates. Fleet rates tend to be very low, but the impact on any individual motorist can be very significant. A more informative statistic than error-of-commission rate is the failure rate among all inspected vehicles which still pass their FTP standard. This indicates the risk to the owner of having a clean vehicle failed. For the IM240 using the two-ways-to-pass criteria, the failure rate for vehicles which pass the FTP is zero for the sample tested in Indiana (Appendix G). While the false failure rate for the second-chance two-speed test is initially comparable to the IM240 using the two-speed cutpoints in current use, tightening these cutpoints to improve IDR has the effect of

increasing the false failure for the steady-state test. For example, as illustrated in Figures 1 through 3 of Appendix G, for 1983 and newer PFI vehicles, tightening the steady-state cutpoints from 220 ppm HC and 1.2% CO (the cutpoints most commonly used in current I/M programs) to 100 ppm HC and 0.5% CO has the effect of increasing the test's false failure rate from 0% to 13% - this, even though the two-speed test's IDRs for both HC and CO still fall appreciably below that of the IM240. For 1983 and newer TBI vehicles, the same tightening of cutpoints achieves HC and CO IDRs for the steady-state test that actually exceed those of the IM240 by a percentage point or two, but this at the cost of a false failure rate of 20% compared to no false failures for the IM240 (Figures 4 - 6, Appendix G).

Even when the two-ways-to-pass criteria are not used for the IM240, the false failure rate for the vehicles in EPA's sample was only 0.8%, representing a total of 5 Ec vehicles - still much lower than the false failure rate for the steady-state test with comparable IDRs. Since even this number of full-test failures was unexpected, given the IM240's similarity to the FTP and the looseness of the 0.8/15 cutpoints compared to the 0.41/3.4 new car standards, section 4.2.3 is included to discuss these false failures in depth.

#### 4.2.1.5 "Normal Emitter" Failure Rate

The IM240 failure rate for normal emitters will also be lower. "Normal" emitters are defined, for the purposes of this discussion, as those vehicles that emit less than twice the FTP HC standard and less than three times the FTP CO standard. Normal emitters include those vehicles that pass the FTP. Repairs on such vehicles usually do not produce large emission reductions (at least short of catalyst replacement, which EPA generally avoids in its emission repair evaluations due to cost and because testing after a new catalyst is installed would not necessarily indicate what emissions will be after the catalyst "wears in"), their emissions are sometimes increased by inept repairs, and they account for little of the total excess emissions (9% of excess HC for 1983 and newer PFI vehicles [page 8, Appendix H], 6% excess HC for 1983 and newer TBI vehicles [page 21, Appendix H] and 3% excess HC for 1981 and newer carbureted vehicles [page 31, Appendix H]). Therefore, normal emitters are not the most cost effective to identify for repairs. These vehicles often lack overt defects. Those that fall above one of the FTP standards obviously have some problem, but may only have suffered catalyst deterioration (which is difficult to diagnose) or may have been either poorly designed or built in the first place. Thus, the marginal costs of identifying and effectively repairing these vehicles may not always be worth the marginal benefits that could be expected.

### 4.2.2 Detailed Discussion of Correlation and Test Assessment

The following analysis shows that the IM240 test using the two-ways-to-pass criteria is considerably more powerful as an I/M test than the second-chance 2500 rpm/Idle test for all technology type vehicles, but especially newer tech, fuel-injected vehicles. The analysis presumes that the IM240 is implemented to achieve higher IDRs. Given that rationale, IM240 standards of 0.8 gpm HC and 15 gpm CO for the full test and 0.5 gpm HC and 12 gpm CO for the last 147 seconds were selected for this analysis. These IM240 standards achieve IDRs that are significantly higher than for the present second-chance 2500 rpm/Idle standards, while maintaining a false failure rate of zero.

This discussion is limited to PFI vehicles, as this is the most commonly used fuel metering system on new vehicles. Throttle body injection, which is less sophisticated, may also be used on a significant proportion of the future fleet, though less than for PFI. Therefore, although analogous figures and tables are included in Appendices G and H for both TBI and carbureted vehicles, they are not formally discussed.

Figure 1 in Appendix G provides a comparison of the present second-chance 2500 rpm/Idle test using current standards (220 ppm HC and 1.2% CO) to the more effective, high-tech IM240 test using the two-ways-to-pass criteria. Note the following:

- The FTP excess emissions identification rates are 17% higher for HC and 12% higher for CO with the IM240 as compared to the second-chance 2500 rpm/Idle test using the 1.2%/220 ppm standards.

- Neither test failed FTP passing vehicles. (Without the two-ways-to-pass criteria, however, 5 FTP-passing fuel-injected vehicles would have failed the IM240 yielding an error-of-commission rate of 0.8% using the weighting factors (discussed in section 2.4.1) to correct the lab sample to simulate the lane sample. These vehicles are discussed in section 4.2.3.)

- The IM240 increases the failure rate to 14% from 12% for the second-chance 2500 rpm/Idle test.

Figure 2 in Appendix G illustrates the power of the IM240 test compared to the 2500 rpm/Idle test using more stringent idle standards, currently in use in California. I/M programs might consider California idle standards because the emission reduction from the program can be increased and the cost of implementation is relatively small.

California uses standards of 1.0% CO and 100 ppm HC for the idle mode, while using 1.2% CO and 220 ppm HC for the 2500 mode. In Figure 2, only the stringency of the 2500 rpm/Idle test is

increased, while the IM240 standards are the same as those used in Figure 1 (see Appendix G for both figures). Note the following:

- The IDRs are still 6% higher for HC and 3% higher for CO with the IM240 as compared to the second-chance 2500 rpm/Idle test with more stringent standards.

- The second-chance 2500 rpm/Idle test failure rate using California standards is 34% compared to only 14% for the IM240. So even with the IM240's higher IDRs, significantly fewer vehicles will need to be repaired.

- Thirteen percent of the FTP-passing vehicles fail the second-chance 2500 rpm/Idle test, while none fail the IM240. Sending this many cars for unnecessary repairs, while also identifying less excess emissions, wastes resources.

- The normal emitter failure rate is only 2.3% for the IM240 versus 22% for the second-chance 2500 rpm/Idle test. This means that the vehicles identified for repairs by the IM240 are more likely to achieve significant emission reductions.

In Appendix G, Figure 3 compares the same IM240 standard to the more stringent standards of 0.5% CO and 100 ppm HC for both modes of the second-chance 2500 rpm/Idle test for PFI vehicles, while Figures 4, 5, and 6 present data analogous to the first three figures, but this time for TBI vehicles, and Figures 7 - 9 present this information for 1981 and newer carbureted vehicles. However, second chance testing was only performed on 1983 and newer vehicles, so Figures 7, 8, and 9 only include second chance results for 1983 and newer vehicles, not for 1981 and 1982 vehicles.

### 4.2.3 Avoiding Errors of Commission

I/M test procedures and standards that cause low emitting vehicles to fail I/M tests are obviously undesirable. Using full-test IM240 standards of 0.8 gpm HC and 15 gpm CO (without incorporating 0.5/12 cutpoints for the last 147 seconds) results in five of the 182 vehicles that received FTP tests (1983 and newer with fuel injection) failing when they should have passed. EPA staff were curious to find that even this small number of FTP-passing vehicles failed the IM240 0.8/15 standards since the IM240 driving schedule is taken from the FTP and is a hot start test at the Indiana lane. This section will investigate why these vehicles falsely failed the IM240 test, and in so doing will explain how and why two-mode criteria were developed. Given that attempting to repair properly functioning vehicles wastes resources and adversely affects vehicle owners, I/M programs and vehicle manufacturers, EPA regards this as an important issue.

The causes of IM240 false failures can be categorized into those that may have occurred due to errors in performing the test

and those that occurred because of the interactions of vehicle design, fuel properties and test conditions.

In addressing these errors of commission, we will concentrate on the vehicles actually tested rather than the reweighted database discussed elsewhere. Of the 74 PFI equipped 1983 and newer vehicles receiving FTPs, 24 passed the FTP, while one of these 24 failed the IM240 standards of 0.8/15. Of the 108 TBI 1983 and newer vehicles receiving FTPs, 29 passed the FTP and 4 of these failed the IM240 0.8/15 gpm standards. Other identifying data and test results for these vehicles are listed in Table 4-3.

Table 4-3

FTP, Lane IM240, and "Tank Fuel" IM240 Results

(grams per mile)

| Veh # | Fuel Sys | Model Year | Mfr. | Carbon Monoxide | | | Hydrocarbons | | | Oxides of Nitrogen | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Lane IM240 | Tank Fuel IM240 | FTP | Lane IM240 | Tank Fuel IM240 | FTP | Lane IM240 | Tank Fuel IM240 | FTP |
| 1674 | PFI | 1989 | Suzuki | 15.3 | 1.7 | 3.1 | 0.73 | 0.1 | 0.37 | 0.8 | 0.2 | 0.2 |
| 685 | TBI | 1989 | Chry. | 16.3 | 2.7 | 2.4 | 0.4 | 0.06 | 0.12 | 1.3 | 1.1 | 0.8 |
| 1607 | TBI | 1988 | GM | 16.1 | 1.2 | 2.5 | 0.78 | 0.14 | 0.24 | 0.9 | 1.1 | 0.6 |
| 1624 | TBI | 1983 | GM | 19.1 | 11.0 | 2.2 | 1.37 | 0.64 | 0.38 | 1.4 | 1.6 | 1.4 |
| 1663 | TBI | 1986 | GM | 23.3 | 3.4 | 0.5 | 0.76 | 0.15 | 0.1 | 0.7 | 0.6 | 0.4 |

The first thing to note is that the lane IM240 HC and CO emissions are considerably higher than for the two tests performed at the laboratory. The "tank fuel" IM240 is the first test the vehicles receive at the laboratory, usually using the same fuel that was in the tank for the lane test. Since the vehicles are stored outside prior to testing, each is preconditioned before receiving the tank fuel IM240. The preconditioning consists of a 3 mile drive at 50 mph (on the road) immediately before the test. The comparison of the lane and "tank fuel" tests strongly suggests that it was some factor at the lane that resulted in these vehicles being errors of commission, not some inherent unsuitability of the IM240 test itself.

The following analysis of the test results suggests that vehicle 1674, the only PFI error-of-commission vehicle, probably failed as a result of testing errors at the lane. The four TBI error-of-commission vehicles are likely the result of interactions of vehicle design, fuel properties and test conditions.

4.2.3.1 Vehicle 1674

One possible explanation for vehicle 1674's results on the lane IM240 test is that it was run at too high an inertia weight (IW) setting on the dynamometer. This is important because the fuel metering system enrichens under heavy loads, causing CO emissions to increase, which could explain the inconsistently high CO result at the I/M lane. Also, $NO_x$ emissions typically increase in conjunction with engine load, while fuel economy (FE) decreases, suggesting one method for determining whether the dynamometer settings were, in fact, inconsistent. Table 4-4 provides fuel economy and $NO_x$ results for vehicle 1674 for the various tests conducted.

Table 4-4

Vehicle 1674 $NO_x$, FE Results Versus Dynamometer Settings

| | Lane IM240 | Tank Fuel IM240 | indolene IM240 | IW=2500# IM240 |
|---|---|---|---|---|
| $NO_x$ (gpm) | 0.83 | 0.24 | 0.12 | 0.18 |
| Fuel Economy (mpg) | 29.61 | 31.19 | 33.90 | 32.43 |
| IW Setting (lbs.) | 2125 | 2125 | 2125 | 2500 |
| Road Load (hp) | 7 | 7 | 6.5 | 6.5 |

Note that the lane IM240 $NO_x$ is about 4 times greater than any of the other $NO_x$ results, including the 2,500 pound inertia weight test that was performed at the lab to simulate an economical dynamometer with only two inertia weight settings (i.e., 2,500 or 3,500 pounds). The lane IM240 shows poorer fuel economy than for any of the other tests. Another indication suggesting that vehicle 1674 represents a unique situation is the fact that the other 4 vehicles which were errors of commission had fairly consistent $NO_x$ emissions, (see Table 4-3) even though their HC and CO emissions deviated considerably from lane to lab.

Another important consideration is the fact that the vehicle tested at the lane just before vehicle 1674 used dynamometer settings of 3,125 pounds and 7 horsepower (hp). Vehicle 1674 should have been tested at 2,125 pounds and 7 hp. The comparatively high $NO_x$ emissions and fuel consumption results in conjunction with the consistent $NO_x$ results for the other 4 vehicles suggest that 1674 was, in fact, tested at the previous vehicle's inertia weight setting of 3,125 pounds, 47% higher than the 2,125 pound setting required.

The settings at the Hammond lane are selected manually, and there is no feedback circuit to document the setting. The only record of the setting is a handwritten data sheet completed by the

lane technician, who may have recorded the correct dynamometer setting, while failing to change the actual setting on the dynamometer. Given the importance of using correct dynamometer inertia weight settings, automatic selection of the IW settings is essential to ensure that vehicles are tested correctly. EPA is developing quality control procedures to insure correct settings are chosen in I/M program lanes.

#### 4.2.3.2 Interactions of Vehicle Design, Fuel Properties, and Test Conditions

Three techniques were considered for preventing IM240 false failures caused by the interaction of vehicle design, fuel properties and test conditions.

1. Reduce the stringency of the pass/fail standard.

2. Allow second-chance testing for failing vehicles that are close to the standard and precondition vehicles prior to the second-chance IM240.

3. Since the IM240 is a 240-second test, use the latter part of the test as a separate, second chance to pass, if the vehicle fails over the entire test. For example, consider a vehicle with a composite result of 0.7 gpm HC and 16 gpm CO, with Bag-2 results of 0.4 and 11 gpm. Because it only slightly exceeds the 15 gpm CO standard, the test software could be designed to also consider the emissions in the 147-second mode of the test (i.e., Bag 2). Vehicles pass if they pass either the full-test cutpoints or the Bag-2 cutpoints. Assuming Bag-2 cutpoints of 0.5 gpm HC and 12 gpm CO, which are significantly more stringent than the composite standards, the vehicle in this example would pass because it does not fail both sets of cutpoints. The logic supporting the suitability of these pass/fail criteria will be discussed later.

Each of the three strategies for avoiding false failures will be further discussed below.

The first alternative, reducing the stringency of the pass/fail standards, is unacceptable. Although this strategy decreases errors of commission, it also unacceptably reduces IDR, as shown in the tables in Appendix H. For example, page H-24 lists a variety of potential cutpoints of varying stringency, the least stringent of which is 1.6/20 gpm. Three of the 4 error-of-commission TBI vehicles were found to pass at this standard, but a number of vehicles which were high emitters did also, lowering the HC IDR from 89% to 61% and the CO IDR from 80% to 58%. These IDR reductions would compromise the purpose of this high-tech test and reduce the benefits from an I/M program.

Second-chance testing and the two-ways-to-pass criteria are better ways of avoiding false failures. The theory behind this is as follows. Assuming that the test was correctly performed in the first place, the most likely reason that a properly functioning vehicle would fail an IM240 is that the evaporative canister was highly loaded with fuel vapors and that the vapors were being purged into the engine during the test. This has been a significant cause of false failures in existing I/M programs and it has been shown that highly loaded canisters can cause both high HC and CO emissions, even though the feedback fuel metering system is functioning properly.

Since the canister is being purged during the IM240, the fuel vapor concentration from the canister continually decreases during IM240 operation. The decreasing fuel vapor concentration results in decreasing HC and CO emissions. So, Bag-2 results should be lower than the composite results, on a gram per mile basis. On the other hand, if the vehicle is actually malfunctioning, Bag-2 emissions should remain high. For this reason, second chance tests after preconditioning, as shown for current 2500 rpm/Idle test, should be less influenced by canister purge.

Adding Bag-2 results to the pass/fail criteria completely solves the error-of-commission problem for the vehicles in our test sample. As shown in Table 4-5, all 4 of the TBI error-of-commission vehicles will pass the lane IM240 if the two-ways-to-pass criteria are applied such that a vehicle fails only by exceeding both 0.8/15 gpm for the composite IM240 and Bag-2 cutpoints of 0.5/12 gpm.

Table 4-5

Two-Ways-To-Pass Criteria Applied to Lane IM240 TBI Error-of-Commission Vehicles

(grams per mile)

| Vehicle | Lane IM240 Bag-1 | | Lane IM240 Bag-2 | | Lane IM240 Composite | |
|---|---|---|---|---|---|---|
| Number | HC | CO | HC | CO | HC | CO |
| 685 | 0.73 | 29.1 | 0.28 | 11.2 | 0.40 | 16.31 |
| 1607 | 2.01 | 44.4 | 0.30 | 4.9 | 0.78 | 16.09 |
| 1624 | 3.60 | 53.6 | 0.47 | 5.0 | 1.37 | 19.08 |
| 1663 | 1.94 | 55.0 | 0.28 | 10.5 | 0.76 | 23.28 |

Using two-ways-to-pass criteria has the added benefit of reducing the normal emitter failure rate for TBI vehicles from 5.2% to 4.1%. At the same time, the overall TBI failure rate

decreases from 22% to 21% without a perceptible reduction in the IDRs which remain at 89% and 80% for HC and CO respectively. Analogous benefits were observed for the PFI sample, where the normal emitter failure rate for PFI vehicles decreases from 2.7% to 2.3%, and the overall PFI failure rate decreases from 15% to 14% without a perceptible reduction in the IDRs which remain at 82% and 85% for HC and CO respectively.

All of the TBI error-of-commission vehicles passed 0.8/15 gpm standards on the tank fuel IM240, suggesting that performing a second-chance test after preconditioning would eliminate errors-of-commission. Second-chance testing would increase the cost of the testing process, however, so it may be best reserved as a last resort. Given the efficacy of the two-ways-to-pass criteria, the error-of-commission problem may be fully resolved. Nevertheless, second-chance tests on select vehicles during high temperature days in spring or fall would serve to insure no false failures. Since such a procedure could be used on only the small fraction of vehicles that are slightly above one or both of the standards, the impact on test costs should be minimal.

The following discusses how vehicle design, fuel properties, and test conditions can interact to cause false failures. Considering these variables can facilitate designing algorithms that determine when second-chance testing should be performed. The success of utilizing the two-ways-to-pass criteria indicates that second chance testing will not often be necessary. This discussion shows that these 4 TBI EC vehicles were tested under rather unique conditions and explains why second chance testing may be useful for some cars.

HC emissions and especially CO emissions have both been shown to vary with evaporative canister loading, so EPA investigated variables that affect canister loading such as gasoline Reid Vapor Pressure (RVP), ambient temperature, and the exhaust interaction caused by canister purge flow (see Table 4-6).

While the specific fuel RVP for the lane IM240 is unknown, the test dates do provide some information regarding RVP. The RVP at service stations in the Hammond area was regulated by EPA to a maximum 10.5 psi between June 1 and September 15. Three of the error-of-commission vehicles were tested outside of this period. ASTM guidelines allow RVP up to 13.5 psi in April and September, and up to 15 psi in December. Since these are only guidelines, they can be exceeded. Unseasonably warm test conditions can cause high RVP fuels to vaporize at an excessive rate, causing high canister loadings. If the RVP of the fuel in these error-of-commission vehicles was 13.5 psi or higher, it is plausible that these three vehicles had highly loaded canisters and/or high vapor generation rates in their fuel tanks.

Table 4-6

Variables Affecting CO Emissions

| Vehicle Number | Canister Purge Volume (liters) | Engine Displacement (liters) | I/M Lane Temperature (° F) | Lane Test Date |
|---|---|---|---|---|
| 685 | 35.7 | 2.3 | 100 | 9/6/90 |
| 1607 | 45.7 | 4.5 | 71 | 10/11/90 |
| 1624 | 79.7 | 5.7 | 57 | 12/10/90 |
| 1663 | 84.9 | 4.3 | 87 | 4/6/91 |

Canister loading and fuel tank vapor generation, in turn, generally increase with increasing ambient temperature. Vehicle 685 was the only error-of-commission vehicle that was tested during the RVP-control-season, and the ambient temperature recorded at the time of testing was 100°F, considerably above the typical FTP test temperature of 75°F. The lane temperatures were also unseasonably high for vehicles 1624 and 1663.

If the canister is highly loaded, CO is likely to increase as a function of increasing purge flow. The median purge volume for all vehicles tested at the lane was approximately 30 liters. Vehicle 1663 had an unusually high purge volume of 85 liters and was tested at an unusually high temperature (87°F) in April when RVP is not regulated. Similarly, vehicle 1624 had a purge volume of 80 liters and was tested at a lane temperature of 57°F in December. If the outdoor temperature was in the thirties and the fuel RVP was 15 psi, the warming of the fuel tank that would occur while in the I/M station is likely to have led to a high canister loading. High canister loading combined with the high purge rate probably caused the high emissions. Table 4-5 shows that the Bag-1 emissions were more than 5 times higher than the Bag-2 emissions, further indicating that a highly loaded canister was sufficiently purged during the first mode to achieve relatively clean Bag-2 results.

The evidence suggests that the fuel RVP and the conditions in the Hammond station caused high CO emissions. Indiana is unique in that existing buildings were adapted for I/M testing purposes and, as in the case of the Hammond station, tend to be closed-architecture structures like warehouses rather than open, airy test stations. The likelihood of the kind of false failures seen here should be much less in actual I/M programs for two reasons: fuel RVP will be regulated to 9.0 psi during the summer months, and the factors contributing to canister loading in the Hammond lane are better controlled in typical I/M programs. The Hammond IM240 lane residence time is 10-20 minutes for the research and

development type testing; also, there is considerably less ventilation (thus higher temperatures on sunny days) than in typical I/M facilities. In designing future facilities for enhanced I/M testing lanes it will be important to keep those considerations in mind, as is already the case in most centralized programs. Further, the number of vehicles receiving second-chance tests can be minimized by developing algorithms that consider canister purge rate, higher than normal ambient temperatures, and probable fuel RVP in determining whether to allow second-chance testing.

#### 4.2.3.3 Error-of-Commission Summary

EPA views false failures as a significant problem and is committed to investigating and utilizing strategies to prevent their occurrence. The IM240 can help, because it allows prevention strategies, such as two-ways-to-pass criteria, that are not relevant to steady-state I/M procedures. The following summarizes how errors of commission can be prevented in I/M programs by using the IM240.

- There is strong evidence indicating that no PFI Ecs would have occurred if the correct dynamometer inertia weight setting had been used. Vehicle 1674's dynamometer inertia weight setting was probably too high. EPA believes that automation and quality control procedures will prevent such mistakes.

- All of the false failures in EPA's sample could have been prevented by implementing pass/fail criteria that consider Bag-2 results in addition to composite results. Under this strategy, vehicles fail only if their composite emissions exceed 0.8/15 and their Bag-2 emissions exceed 0.5/12 gpm.

- Second-chance testing after preconditioning on marginally failing vehicles, especially those showing high purge rates and tested at higher than normal temperatures, could be used as a fail-safe mechanism to insure that no errors-of-commission occur.

In conclusion, the data indicate that these false failures were caused by unique circumstances rather than inherent test procedure flaws or standards that are too stringent. Experience with these vehicles suggests that the problem can be solved through automation, quality control, two-ways-to-pass criteria, and preconditioned second-chance tests on marginal failures.

### 4.3 Approval of Alternative Tests

Although the IM240, purge, and pressure tests represent EPA's current trio of recommended high-tech tests, we do not rule out the possibility of future, valid alternatives to these tests, including fast-pass and fast-fail transient testing strategies

(see section 4.4, "Transient Testing Fast-Pass/Fast-Fail Strategies"). States may seek approval of such strategies, contingent upon the state's demonstrating to EPA's satisfaction that such strategies are at least as effective as EPA's recommended tests at identifying excess emissions while maintaining a comparably low error-of-commission rate. As the sheer number of analyses contained in this report can attest, EPA does not promulgate new testing strategies capriciously. Before proposing the IM240, purge, and pressure tests, EPA amassed a compelling body of data on each through pilot programs conducted in Maryland and Indiana (see section 4.1, "Recent I/M Test Programs (Maryland and Indiana)" for further discussion of these pilot studies). Rigorous evaluations of each were conducted to determine their effectiveness at identifying excess emissions while maintaining low error-of-commission rates. Economic analyses were also conducted to assess the cost effectiveness of the tests, as no degree of technical excellence will justify a testing strategy that is exorbitant in its overall cost. For example, the FTP is the hallmark against which I/M testing strategies are measured, but cannot itself be used as an I/M test, given its cost.

Of the potential alternatives to EPA's recommended tests, the one which has garnered the most attention is the suggestion by some that steady-state loaded testing using a simple non-inertial dynamometer be used to perform the purge check. EPA pursued transient testing instead of steady-state because our best engineering and technical judgement suggested that steady-state testing as a mechanism for conducting the purge check would lead to decreased emission reduction benefits, higher errors-of-commission, and, ironically, higher overall costs per ton of emission reductions produced. The rationale behind the assumption that higher errors-of-commission rates would result is the fact that purge strategies vary from vehicle to vehicle, and the possibility of developing a steady-state test that successfully addresses this variety is small to none. The result of failing to address the full range of purge strategies is easy to predict: Cars that should pass will fail, leading to unnecessary expense and hardship for motorists, with no environmental benefit.

It has also been suggested by some that a loaded steady-state test is an adequate alternative to transient emission testing. One of the problems with this proposal arises from the requirement under section 182(c)(3) of the Act that programs in enhanced I/M areas achieve $NO_x$ benefits. EPA has found that $NO_x$ emission testing (as opposed to visual inspection of emission control devices) is essential for $NO_x$ emission reductions. Further, EPA believes that a reliable steady-state test for NOx does not exist and is not likely to be possible. Nevertheless, as indicated earlier, EPA is open to demonstrations by states or their representatives that proposed alternative testing strategies are equal or superior to EPA's proposed tests in terms of identifying excess emissions and keeping false failures to a minimum.

## 4.4 Transient Testing Fast-Pass/Fast-Fail Strategies

Among the alternative testing strategies that make environmental and economic sense, the potential for fast-pass and fast-fail transient testing ranks the highest. EPA is in the process of looking at potential fast-pass and fast-fail strategies, and preliminary results suggest that roughly 33% of the vehicles tested could be fast passed or failed based upon analysis of data gathered during the first 93 seconds of the IM240 (i.e., Bag 1) using separate fast-pass and fast-fail cutpoints.

In evaluating potential fast-fail criteria, EPA looked at a sample of 4,158 1983 and newer vehicles tested at the Hammond IM240 lane described in section 4.1, 1,033 (or 24.8%) of which failed the IM240. 298 (or 28.8%) of the 1,033 vehicles that failed would have failed within the first 93 seconds of the test if Bag 1 cutpoints of 2.5 gpm HC, 50 gpm CO, and 5.0 gpm $NO_x$ were used; there were no errors-of-commission. Although stricter Bag 1 cutpoints could be used to increase the percentage of fast-failed vehicles, the error-of-commission (Ec) rate would also rise. In turn, when fast-pass Bag 1 cutpoints of 0.41/3.4/1.0 were used, 1,074 (or 34.4%) of the 3,125 vehicles that passed overall passed within the first 93 seconds of the test. Seven additional false passes were also recorded, resulting in an error-of-omission rate of 0.7%. Tightening the fast-pass cutpoints to 0.25/1.5/1.0 eliminates the false passes but also reduces the fast-pass rate to 13.2%. Table 4-7 provides further details on the Bag 1 cutpoints looked at in this analysis. While more development of fast-pass and fast-fail criteria is needed, it is reasonable to conclude that criteria can be developed to accurately pass and fail about one third of all vehicles tested after only 93 seconds rather than the full 240 seconds. Further, EPA will soon begin collecting second-by-second IM240 data. This will allow the development of algorithms that will permit especially clean cars to pass well before 93 second, and others to pass after 93 seconds, but well before 240 seconds. Once the algorithms are developed, only vehicles that are close to the cutpoints are expected to continue for the full 240 seconds to ensure that they are not falsely failed.

Table 4-7

IM240 Bag-1 Fast-Pass/Fast-Fail Analysis

| Fast Fail | Fail IM240 Total | Fail Fast-Fail Total | Fail Both | Fail Fast-Fail Only | Fast-Fail ID rate | Ec Rate |
|---|---|---|---|---|---|---|
| 0.8/15/2.5 | 1033 | 1297 | 902 | 395 | 87.3% | 30.5% |
| 2.0/40/4.0 | 1033 | 450 | 445 | 5 | 43.1% | 1.1% |
| 2.5/50/5.0 | 1033 | 298 | 298 | 0 | 28.8% | 0.0% |

| Fast Pass | Pass IM240 Total | Pass Fast-Pass Total | Pass Both | Pass Fast-Pass Only | Fast-Pass ID Rate | False-Pass Rate |
|---|---|---|---|---|---|---|
| 0.8/15/2.5 | 3125 | 2861 | 2730 | 131 | 87.4% | 12.7% |
| 0.41/3.4/1.0 | 3152 | 1081 | 1074 | 7 | 34.4% | 0.7% |
| 0.25/1.5/1.0 | 3125 | 413 | 413 | 0 | 13.2% | 0.0% |

Another area that EPA is investigating is the possibility that the overall test time may be reduced. The IM240 is itself an FTP-like short test based upon a modified and condensed driving cycle that takes as its reference the LA-4 cycle used in the FTP. EPA is currently investigating the possibility of further abbreviating the test by comparing how well data from either of the two hills of the IM240 driving cycle (i.e., Bag 1 and Bag 2) taken separately correlate with the current two-mode IM240. Preliminary results based upon a sample of 188 1983 and newer fuel-injected vehicles which were recruited at the Indiana I/M lane and subsequently retested under lab conditions (which included each vehicle receiving an FTP) suggest that analysis of Bag 2 (i.e., emissions sampled during the second hill of the IM240 driving cycle) may be about as good as the full IM240 when it comes to identifying vehicles that would pass or fail on the basis of the full test. Using Bag-2 cutpoints of 0.60/12 for HC and CO respectively, and looking at Bag-2 results only, 90% of the excess HC emissions and 84% of the excess CO emissions were identified, with an Ec rate of 0.7%, as compared to the full IM240 using the 0.8/15 cutpoints only (i.e., no Bag-2 cutpoints), which identified 82% and 85% of the excess HC and CO emission, respectively, with an Ec rate of 0.8%. These findings come with the caveat that they are based upon a Bag 2 sample which followed the Bag 1 portion of the driving cycle, meaning that Bag 2's high degree of correlation with the IM240 may be the result of preconditioning occuring during the Bag 1 phase. Even if such is, in fact, the case, the prospect of a shorter overall test time still seems good since adequate preconditioning for Bag 2 could probably be obtained in less than 93 seconds by modifying Bag 1 to use a higher speed over less time.

To determine whether or not preconditioning is a factor, EPA plans to begin testing a sample of vehicles using what is, in effect, a three bag test, beginning with the second hill of the

IM240 driving cycle up front (hence no possibility for "Bag 1" preconditioning) followed by a regular IM240. This study should help EPA determine (1) whether or not preconditioning is a factor in Bag 2's high degree of correlation with the full test and (2) whether preconditioning would improve the correlation between Bag 1 and the full test. In addition, as mentioned above, EPA will soon begin collecting second-by-second data, which will allow us to determine whether or not there is some point in the testing cycle by which time if vehicle X is emitting at a rate Y, it will clearly pass or fail.

## 4.5 Estimating I/M Testing Credits for MOBILE4.1

As stated earlier, the data from the Indiana program were analyzed and re-assembled in a manner which allows a comparison of I/M program designs over a wide range of time frames and conditions, rather than just for the particular sample of vehicles tested in Indiana. This method for estimating the effect of I/M program options on exhaust emissions (i.e., the I/M credit) is fairly simple. Using the emission factor database, the fraction of total vehicle FTP emissions which is identified by a particular short test is determined for each of four strata of vehicles based on FTP emission level. Using a subsample of vehicles which have been repaired, the emission reductions attributable to these I/M-triggered repairs is estimated for each strata. The Tech4.1 model is used to calculate the emissions impact of a given short test by reducing the total FTP emissions identified at each age by the estimated emission reductions resulting from I/M repairs. When the fleet average emission rates are recalculated by considering the strata, the difference between the I/M and non-I/M case is stored as an I/M credit for use in MOBILE4.1.

### 4.5.1 Tech4.1 Background and Assumptions

The Tech4.1 model divides the 1981 and newer light-duty gasoline vehicle (LDGV) sample into several groups. The 1981 and 1982 model years are kept separate from the 1983+ model years. In each model year group, the vehicles are divided by technology type into closed-loop port fuel injection (PFI), closed-loop throttle-body fuel injection (TBI), closed-loop carbureted (Carb) and all (carbureted and fuel injected) open-loop (Oplp). Further, each of these groups are divided into emission levels for Normal, High, Very High and Super emitters. Table F-1 in Appendix F provides details on national fleet averages for passenger vehicle distributions by model year and technology type; Tables F-2 and F-3 provide data on emitter groups by model year group, technology type, emission levels and rates, and mileage accumulation.

The model allows a separate IDR and repair effectiveness estimate for each of these divisions of the data by I/M test type, as illustrated in Table 4-8. It should be noted that the IDRs listed in Table 4-8 for the traditional I/M tests (i.e., the idle

and 2500 rpm/Idle tests) are based upon historical emission factor data gathered at EPA's Motor Vehicle Emission Lab (MVEL) in Ann Arbor, Michigan, as well as elsewhere, and not at the Hammond, Indiana test lane. The IDRs mentioned elsewhere in this report (Appendices G and H, for example) were derived as part of the Hammond study, and are not divided by emitter group, as is the case in Table 4-8.

In practice, because of small sample sizes, several of the divisions represented in Table 4-8 share information. In particular, the small amount of steady-state Loaded/Idle testing required that all vehicles without Loaded/Idle testing be assumed to have the same short test result for Loaded/Idle testing as they had for the 2500 rpm/Idle test for the purpose of determining the IDR for the Loaded/Idle test.

For Super emitters (vehicles over 10 gpm HC or 150 gpm CO), the IDR is the same for all technologies, but is separate for 1981-82 and 1983+ vehicles. Most 1981-82 vehicles are carbureted. Most 1983+ vehicles are fuel injected. There are no Super open-loop vehicles in the sample.

The two fuel injection groups in the 1981-82 grouping use the same IDRs for Very High emitters (vehicles over 1.64 gpm HC or 13.6 gpm CO), High emitters (vehicles over 0.82 gpm HC or 10.2 gpm CO) and Normals. In some cases, such as the High emitters, the 1983+ open-loop and carbureted technologies were combined.

Repair effectiveness (Table 4-9) was determined by dividing the repaired sample by technology into PFI, TBI and Carb. Model year grouping was not used. To be eligible for the repair effectiveness analysis, a repaired vehicle must first fail the short test of interest before repairs, and then after repairs, must pass the same short test. Thus, different samples of repaired vehicles were used for each short test. The sample was then ranked by before repair emission level and divided into four equal-sized subgroups of increasingly more severe emissions failure. The before and after repair emission levels of each subgroup were then determined.

When plotted, before repair emission level versus after repair emission level, these four emission failure points represent a technology specific function used to determine repair effectiveness. Generally, the vehicles with higher before repair emission levels get larger absolute emission reductions from repairs, but do not reach as clean a level after repairs as vehicles which began with a milder degree of emission failure. Before repair emission levels of High, Very High and Super emitters in many cases will fall between the calculated points, and so had their after repair emission levels determined by interpolation. Before repair emission levels lower than the lowest point were interpolated between the low point and zero. Before repair emission levels above the highest point were assumed to be the same as the highest point.

Since few of the repaired vehicles had Loaded/Idle or IM240 testing data, it was assumed that vehicles repaired using a Loaded/Idle test and the IM240 test would use the same before and after repair curve as the 2500 rpm/Idle testing. EPA is being conservative in assuming that vehicles failing the Loaded/Idle test or the IM240 test, after repair, will have the same after repair emission level as we estimate for the 2500 rpm/Idle test vehicles. However, since the failure rates of vehicles in the high emitter groups are larger for the Loaded/Idle test and the IM240 transient test than for the 2500 rpm/Idle test, the total emission reduction due to repairs will be larger.

As an example, the zero mile HC emission level of Very High emitters for 1983+ PFI vehicles is 2.019 gpm and their slope is taken to be the same slope as the Normals (i.e., 0.0115 gpm/10,000 miles) (see Table F-2). At 5 years old, the average mileage of these vehicles will be 60,829 miles. The non-I/M emission level is therefore:

$$2.019 + .0115*6.0829 = 2.089 \text{ gpm}$$

Assuming a 2500 rpm/Idle test is done, the HC IDR (see Table 4-8) for this group is 0.6187, or nearly 62% of the total emissions from these vehicles is identified by failing vehicles using the 2500 rpm/Idle test. Table 4-9 shows the results of a data analysis indicating the predicted average after repair levels given the before repair emission level. The series of points in the table are used to predict the after repair emission levels for all emitter groupings, only dependent on the average before repair emission level for that group. The before repair emission level falls between the two emission levels 1.9846 and 3.9314. The after repair levels for these emissions are 0.59231 and 1.0271 respectively. Interpolating, the after repair level for the 2.089 gpm before repair emission level is:

$$0.59231+((2.089-1.9846)/(3.9314-1.9846))*(1.0271-0.59231)=0.6153$$

Therefore the after repair HC emission level for 5 year old, 1983+ PFI vehicles tested on the 2500 rpm/Idle test is:

$$0.6187*0.6153 + (1-0.6187)*2.089 = 1.1772 \text{ gpm}$$

Comparing the I/M and non-I/M cases indicates the "I/M benefit" among Very High emitters.

$$(2.089-1.1772)/2.089 = 43.6\%$$

Table 4-8

Short Test Identification Rates*

Super Emitters

| Test Type | Model Years | PFI HC | PFI CO | TBI HC | TBI CO | Carb HC | Carb CO | Oplp HC | Oplp CO |
|---|---|---|---|---|---|---|---|---|---|
| Idle Test | 81-82 | 0.6048 | 0.6968 | 0.6048 | 0.6968 | 0.6048 | 0.6968 | 0.0000 | 0.0000 |
| Idle Test | 83+ | 0.8978 | 0.9656 | 0.8978 | 0.9656 | 0.8978 | 0.9656 | 0.0000 | 0.0000 |
| 2500/Idle | 81-82 | 0.6523 | 0.8577 | 0.6523 | 0.8577 | 0.6523 | 0.8577 | 0.0000 | 0.0000 |
| 2500/Idle | 83+ | 0.8978 | 0.9656 | 0.8978 | 0.9656 | 0.8978 | 0.9656 | 0.0000 | 0.0000 |
| Load/Idle | 81-82 | 0.6523 | 0.8577 | 0.6523 | 0.8577 | 0.6523 | 0.8577 | 0.0000 | 0.0000 |
| Load/Idle | 83+ | 0.8978 | 0.9656 | 0.8978 | 0.9656 | 0.8978 | 0.9656 | 0.0000 | 0.0000 |
| IM240 | 81-82 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 0.0000 |
| IM240 | 83+ | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.0000 | 0.0000 |

Very High Emitters

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Idle Test | 81-82 | 0.2736 | 0.3231 | 0.2736 | 0.3231 | 0.3858 | 0.4108 | 0.4568 | 0.5194 |
| Idle Test | 83+ | 0.5676 | 0.6129 | 0.2651 | 0.2695 | 0.3640 | 0.3180 | 0.3640 | 0.3180 |
| 2500/Idle | 81-82 | 0.2736 | 0.3231 | 0.2736 | 0.3231 | 0.4789 | 0.5331 | 0.6197 | 0.6162 |
| 2500/Idle | 83+ | 0.6187 | 0.7465 | 0.3616 | 0.4206 | 0.5684 | 0.6832 | 0.5684 | 0.6832 |
| Load/Idle | 81-82 | 0.2736 | 0.3231 | 0.2736 | 0.3231 | 0.5476 | 0.6037 | 0.6197 | 0.6162 |
| Load/Idle | 83+ | 0.6187 | 0.7465 | 0.3904 | 0.4337 | 0.5684 | 0.6832 | 0.5684 | 0.6832 |
| IM240 | 81-82 | 0.8920 | 0.9460 | 0.8770 | 0.8750 | 0.8760 | 0.8680 | 0.8760 | 0.8680 |
| IM240 | 83+ | 0.8800 | 0.9400 | 0.8600 | 0.8600 | 0.9400 | 0.8300 | 0.9400 | 0.8300 |

High Emitters

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Idle Test | 81-82 | 0.0506 | 0.1135 | 0.0506 | 0.1135 | 0.0563 | 0.0492 | 0.2274 | 0.1522 |
| Idle Test | 83+ | 0.2507 | 0.2208 | 0.0336 | 0.0613 | 0.0694 | 0.0415 | 0.0694 | 0.0415 |
| 2500/Idle | 81-82 | 0.0506 | 0.1135 | 0.0506 | 0.1135 | 0.0898 | 0.0834 | 0.2274 | 0.1522 |
| 2500/Idle | 83+ | 0.3436 | 0.3501 | 0.1924 | 0.1532 | 0.0694 | 0.0415 | 0.0694 | 0.0415 |
| Load/Idle | 81-82 | 0.0506 | 0.1135 | 0.0506 | 0.1135 | 0.0910 | 0.0896 | 0.2274 | 0.1522 |
| Load/Idle | 83+ | 0.3866 | 0.3937 | 0.1924 | 0.1532 | 0.0694 | 0.0415 | 0.0694 | 0.0415 |
| IM240 | 81-82 | 0.0930 | 0.0600 | 0.5080 | 0.4190 | 0.1820 | 0.2060 | 0.1820 | 0.2060 |
| IM240 | 83+ | 0.1300 | 0.0800 | 0.5100 | 0.4200 | 0.1800 | 0.2200 | 0.1800 | 0.2200 |

Normal Emitters

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Idle Test | 81-82 | 0.0556 | 0.0774 | 0.0139 | 0.0139 | 0.0188 | 0.0204 | 0.0093 | 0.0131 |
| Idle Test | 83+ | 0.0360 | 0.0414 | 0.0425 | 0.0436 | 0.0023 | 0.0078 | 0.0023 | 0.0078 |
| 2500/Idle | 81-82 | 0.0556 | 0.0774 | 0.0139 | 0.0139 | 0.0371 | 0.0427 | 0.0201 | 0.0317 |
| 2500/Idle | 83+ | 0.0575 | 0.0694 | 0.0476 | 0.0514 | 0.0140 | 0.0156 | 0.0065 | 0.0208 |
| Load/Idle | 81-82 | 0.0556 | 0.0774 | 0.0139 | 0.0139 | 0.0371 | 0.0427 | 0.0201 | 0.0317 |
| Load/Idle | 83+ | 0.0907 | 0.1023 | 0.0712 | 0.0739 | 0.0140 | 0.0156 | 0.0231 | 0.0403 |
| IM240 | 81-82 | 0.0450 | 0.0560 | 0.0970 | 0.0750 | 0.1340 | 0.1200 | 0.1340 | 0.1200 |
| IM240 | 83+ | 0.0500 | 0.0600 | 0.1000 | 0.0800 | 0.2400 | 0.2100 | 0.2400 | 0.2100 |

* Identification Rate (IDR) is the fraction of the total sample emissions from vehicles failing the short test.

Table 4-9

Short Test Repair Effectiveness

| | | PFI/TBI | | Carb/Oplp | |
|---|---|---|---|---|---|
| | | Before Repair | After Repair | Before Repair | After Repair |
| Idle Test | HC | 0.7400 | 0.4108 | 0.9677 | 0.6224 |
| Idle Test | HC | 1.9223 | 0.6062 | 2.0226 | 1.1894 |
| Idle Test | HC | 3.9023 | 1.0769 | 3.1063 | 1.3254 |
| Idle Test | HC | 14.2820 | 1.3808 | 8.5543 | 1.5286 |
| Idle Test | CO | 9.2708 | 4.9900 | 10.4870 | 9.8624 |
| Idle Test | CO | 28.0310 | 9.4669 | 29.5500 | 12.9690 |
| Idle Test | CO | 90.0380 | 12.1480 | 53.5200 | 17.4340 |
| Idle Test | CO | 190.6600 | 20.6200 | 134.7500 | 18.2810 |
| 2500 rpm/Idle* | HC | 0.8267 | 0.4075 | 0.9303 | 0.5764 |
| 2500 rpm/Idle* | HC | 1.9846 | 0.5923 | 1.9431 | 1.0349 |
| 2500 rpm/Idle* | HC | 3.9314 | 1.0271 | 2.9862 | 1.1413 |
| 2500 rpm/Idle* | HC | 14.2820 | 1.3808 | 8.2523 | 1.4141 |
| 2500 rpm/Idle* | CO | 10.3340 | 4.8950 | 10.6220 | 9.2808 |
| 2500 rpm/Idle* | CO | 35.5180 | 9.8631 | 29.0530 | 12.4890 |
| 2500 rpm/Idle* | CO | 104.5000 | 11.9250 | 54.2820 | 13.1900 |
| 2500 rpm/Idle* | CO | 190.6600 | 20.6200 | 136.9700 | 13.5960 |

* Also used for Loaded/Idle and IM240 repair effects.

In the Tech4.1 model, the technologies and emission categories are combined before an average I/M benefit for the model year is calculated.

### 4.5.2 Evaporative and Running Loss Modeling, and the Effectiveness of Purge/Pressure Testing

A large part of the additional emission reduction available through the use of high-tech I/M tests is the result of the evaporative and running loss emission reductions achieved by the repair of vehicles which fail the new evaporative system pressure and purge tests. The effectiveness of evaporative system pressure and purge checks in reducing the rate of pressure and purge problems was calculated assuming that programs with these checks would detect 100% of all problems detected by the EPA checks run in the Hammond I/M program. This assumes that the program will use methods similar to the procedures used in Indiana. Although all of the pressure and purge problems are assumed to be detected, since some problems will re-occur with time, the average rate of problems over the inspection cycle will not be zero.

For purposes of determination of program effectiveness, the combined evaporative system pressure and purge failure rates from over 2,400 vehicles tested in Indiana were used. The resulting effectiveness estimates were then used for application of pressure checks, purge checks and combined pressure and purge checks in the MOBILE4.1 model.

The average reduction in the rate of failure is calculated by determining the rate of failure at the midpoint between two vehicle ages. The effect of inspection can be visualized by plotting the non-program rate over age with the calculated before and after repairs failure rate estimates assuming inspection (see figure in Appendix D). At each age, vehicles due for inspection are checked and necessary repairs made. Between inspections, the rate of failures increases until the vehicles are due for inspection again. The slope of this failure rate line between inspections is assumed to be equal to the slope of the non-program line for that vehicle age. This creates a rising and falling pattern of rates resembling a saw blade. The average reduction in rates is then the average value of the "saw teeth" compared with the non-program case.

With an inspection program, at age zero, when the calendar year equals the model year, no vehicles are yet one year old and due for inspection; therefore, no reductions are made. Assuming an annual inspection, at age one, 25% of the model year is one year old or older. Therefore, the rate at one year is reduced by 25% to reflect repairs on the vehicles due for inspection. By the second year, all vehicles are inspected each year and the after repair rate is always zero. The failure rate after a check is always zero, since the detection rate is 100%. Therefore, the midpoint failure rate is half the number of failures that occur in that year, once inspections begin. In the biennial case, vehicles are inspected every other year and the rate of failures accumulates in the years between inspections.

This method was used in a computer spreadsheet to calculate the reduction in failures from evaporative system pressure and purge checks used in the MOBILE4.1 model. The spreadsheet is shown in Appendix D with and without formulas. The spreadsheet originally contained errors which resulted in the benefits used in the MOBILE4.1 model to be <u>smaller</u> than the estimates reported in this document (which are based upon the corrected spreadsheet). The version of MOBILE4.1 released to the public does not yet reflect these changes, although they will be incorporated into the next MOBILE release.

### 4.5.3 <u>Benefits of IM240 NOx Inspections</u>

None of the existing I/M program models or the MOBILE4.1 model itself are designed to estimate the effect of $NO_x$ emission inspection as part of an I/M program. Therefore, to estimate the

effect of an IM240-based $NO_x$ inspection, a simple model was developed.

A sample of over 3,200 1983 and newer model year vehicles, tested in Hammond, Indiana using the IM240 test procedure, was analyzed. The sample was divided into three technology groups: multi-point fuel injection vehicles, throttle-body fuel injection vehicles and carbureted vehicles. Two $NO_x$ cutpoint cases were examined for each technology, one with a 10% failure rate and one with a 20% failure rate.

Using an emission correlation mapping between IM240 $NO_x$ measurements and $NO_x$ measured on the FTP, an FTP $NO_x$ emission level was estimated for each vehicle in the sample. A linear least-square regression was run for estimated FTP $NO_x$ emissions versus mileage for each technology for two model year groups: 1983 through 1985 model year vehicles and 1986 and newer model year vehicles. The regressions were then run again excluding vehicles which fail the IM240 $NO_x$ inspection first using the 10% failure rate cutpoints and then the 20% failure rate cutpoints. The exclusion of the higher $NO_x$ emitters was intended to represent their deletion from the fleet through repairs.

Using the technology mix used in MOBILE4.1, the regressions were weighted together to produce emission factor zero mile levels and deterioration rates for each model year from 1983 through 1992. The difference in the emission levels between the cases with and without $NO_x$ failures removed is assumed to be the benefit from the IM240 $NO_x$ emission test with only NOx related repairs performed. Results are shown in Table 4-10.

Since it is expected that most $NO_x$ emission testing will be done along with testing for HC and CO emissions, the side effect of HC and CO repairs on $NO_x$ emissions should also be accounted for. This effect is ignored in the standard MOBILE4.1 model. Typically $NO_x$ emissions will increase, on average, when HC an CO emission repairs are performed. The extent of this $NO_x$ emission disbenefit was determined by calculating average $NO_x$ emission levels corresponding to the Normal, High, Very High and Super HC/CO emitter categories used in the MOBILE4.1 Tech4 model.

Using the post-repair emission levels of the same vehicles used to calculate the after repair emission levels for HC and CO emissions, the $NO_x$ emission levels of these vehicles after repairs were determined. These $NO_x$ emission levels are not the result of $NO_x$ related repairs, but a by-product of HC and CO emission repairs. Using the standard HC/CO 2500 rpm/Idle test IDRs along with the repair effects on $NO_x$ and the $NO_x$ emission rates by emitter group in the Tech4 model, the effect of $NO_x$ disbenefits was determined for each age of each model year. See Table 4-11.

The $NO_X$ disbenefits, as a percent change, are applied to the emission levels estimated from the regression equations at each age. The resulting $NO_X$ emission levels by age are regressed versus mileage for each model year to give the final emission factor equation for $NO_X$. Comparing the emission factor results of the baseline case with the cases with 10% or 20% $NO_X$ emission testing failure rates was done to estimate the benefits, in tons, of the IM240 $NO_X$ emission test. Results are shown in Table 4-12. For example, at age 5 and mean mileage of 60,829 miles, the "20% fail" IM240 $NO_X$ cutpoints will reduce 1992 model year $NO_X$ from 0.887 to 0.710 gpm, a reduction of 20%.

The final emission factors were used as alternate input to the MOBILE4.1 model and, in combination with the CEM4.1 model, used to calculate the tons of $NO_X$ emission benefit from use of IM240 $NO_X$ cutpoints. These benefits were used in applying the cost credit. It should be noted that since both the cases with and without the IM240 $NO_X$ inspection cutpoints should include the disbenefits of HC/CO repairs, the disbenefits do not effect the calculation of incremental $NO_X$ reduction from IM240 cutpoints. For simplicity and consistency, therefore, the disbenefits were not applied to the I/M scenarios involving only HC/CO cutpoints.

Table 4-10

Lane IM240 Based Emission Factor Levels with IM240 $NO_x$ Cutpoints

| Age | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Miles | 0 | 1.3118 | 2.6058 | 3.8298 | 4.9876 | 6.0829 | 7.119 | 8.0991 | 9.0262 | 9.9031 | 10.7326 | 11.5172 | 12.2594 |
| Year | | | | | | | Base | | | | | | |
| 1983 | 1.146 | 1.197 | 1.248 | 1.296 | 1.341 | 1.384 | 1.425 | 1.463 | 1.499 | 1.533 | 1.566 | 1.597 | 1.626 |
| 1984 | 1.048 | 1.115 | 1.181 | 1.243 | 1.303 | 1.359 | 1.412 | 1.462 | 1.509 | 1.554 | 1.596 | 1.636 | 1.674 |
| 1985 | 0.983 | 1.049 | 1.114 | 1.175 | 1.233 | 1.288 | 1.340 | 1.389 | 1.436 | 1.480 | 1.521 | 1.561 | 1.598 |
| 1986 | 0.608 | 0.683 | 0.758 | 0.828 | 0.895 | 0.958 | 1.017 | 1.074 | 1.127 | 1.177 | 1.225 | 1.270 | 1.313 |
| 1987 | 0.593 | 0.669 | 0.744 | 0.815 | 0.882 | 0.946 | 1.006 | 1.063 | 1.117 | 1.168 | 1.216 | 1.262 | 1.305 |
| 1988 | 0.561 | 0.633 | 0.705 | 0.773 | 0.837 | 0.897 | 0.954 | 1.009 | 1.060 | 1.108 | 1.154 | 1.198 | 1.239 |
| 1989 | 0.570 | 0.639 | 0.707 | 0.772 | 0.833 | 0.890 | 0.945 | 0.997 | 1.046 | 1.092 | 1.136 | 1.177 | 1.216 |
| 1990 | 0.550 | 0.614 | 0.677 | 0.737 | 0.794 | 0.847 | 0.898 | 0.946 | 0.991 | 1.034 | 1.075 | 1.113 | 1.149 |
| 1991 | 0.547 | 0.610 | 0.672 | 0.731 | 0.787 | 0.840 | 0.889 | 0.936 | 0.981 | 1.023 | 1.063 | 1.101 | 1.136 |
| 1992 | 0.547 | 0.610 | 0.671 | 0.729 | 0.784 | 0.837 | 0.886 | 0.932 | 0.977 | 1.018 | 1.058 | 1.095 | 1.130 |
| | | | | | | | 10% Fail | | | | | | |
| 1983 | 1.078 | 1.092 | 1.106 | 1.120 | 1.132 | 1.144 | 1.155 | 1.166 | 1.176 | 1.185 | 1.194 | 1.203 | 1.211 |
| 1984 | 1.036 | 1.051 | 1.066 | 1.080 | 1.093 | 1.105 | 1.117 | 1.128 | 1.139 | 1.149 | 1.158 | 1.167 | 1.176 |
| 1985 | 0.970 | 0.984 | 0.998 | 1.011 | 1.023 | 1.034 | 1.045 | 1.056 | 1.065 | 1.074 | 1.083 | 1.091 | 1.099 |
| 1986 | 0.600 | 0.650 | 0.699 | 0.746 | 0.790 | 0.831 | 0.871 | 0.908 | 0.943 | 0.977 | 1.008 | 1.038 | 1.067 |
| 1987 | 0.591 | 0.640 | 0.688 | 0.734 | 0.777 | 0.817 | 0.856 | 0.893 | 0.927 | 0.960 | 0.991 | 1.020 | 1.047 |
| 1988 | 0.559 | 0.603 | 0.647 | 0.688 | 0.727 | 0.764 | 0.800 | 0.833 | 0.864 | 0.894 | 0.922 | 0.948 | 0.973 |
| 1989 | 0.556 | 0.600 | 0.643 | 0.684 | 0.723 | 0.759 | 0.794 | 0.827 | 0.858 | 0.887 | 0.914 | 0.941 | 0.965 |
| 1990 | 0.529 | 0.569 | 0.608 | 0.645 | 0.681 | 0.714 | 0.745 | 0.775 | 0.803 | 0.830 | 0.855 | 0.879 | 0.901 |
| 1991 | 0.525 | 0.564 | 0.602 | 0.639 | 0.673 | 0.706 | 0.737 | 0.766 | 0.793 | 0.820 | 0.844 | 0.868 | 0.890 |
| 1992 | 0.523 | 0.562 | 0.600 | 0.636 | 0.670 | 0.703 | 0.733 | 0.762 | 0.790 | 0.816 | 0.840 | 0.864 | 0.885 |
| | | | | | | | 20% Fail | | | | | | |
| 1983 | 0.985 | 0.992 | 0.999 | 1.006 | 1.012 | 1.018 | 1.023 | 1.028 | 1.033 | 1.038 | 1.042 | 1.046 | 1.050 |
| 1984 | 0.955 | 0.962 | 0.968 | 0.974 | 0.979 | 0.984 | 0.989 | 0.994 | 0.999 | 1.003 | 1.007 | 1.011 | 1.014 |
| 1985 | 0.911 | 0.917 | 0.922 | 0.927 | 0.932 | 0.937 | 0.941 | 0.945 | 0.949 | 0.953 | 0.956 | 0.959 | 0.962 |
| 1986 | 0.591 | 0.629 | 0.666 | 0.702 | 0.735 | 0.766 | 0.796 | 0.825 | 0.851 | 0.877 | 0.901 | 0.923 | 0.945 |
| 1987 | 0.582 | 0.619 | 0.656 | 0.691 | 0.724 | 0.755 | 0.785 | 0.813 | 0.839 | 0.864 | 0.888 | 0.910 | 0.932 |
| 1988 | 0.551 | 0.586 | 0.621 | 0.654 | 0.685 | 0.715 | 0.743 | 0.769 | 0.794 | 0.818 | 0.840 | 0.861 | 0.881 |
| 1989 | 0.550 | 0.585 | 0.619 | 0.652 | 0.683 | 0.712 | 0.739 | 0.765 | 0.790 | 0.813 | 0.835 | 0.856 | 0.875 |
| 1990 | 0.525 | 0.558 | 0.590 | 0.621 | 0.650 | 0.677 | 0.703 | 0.728 | 0.751 | 0.773 | 0.793 | 0.813 | 0.832 |
| 1991 | 0.521 | 0.553 | 0.585 | 0.616 | 0.644 | 0.671 | 0.697 | 0.721 | 0.744 | 0.766 | 0.786 | 0.805 | 0.824 |
| 1992 | 0.520 | 0.552 | 0.584 | 0.614 | 0.642 | 0.669 | 0.695 | 0.719 | 0.741 | 0.763 | 0.783 | 0.803 | 0.821 |

Table 4-10

- continued -

| 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | Age | Regression | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.9615 | 13.6257 | 14.254 | 14.8483 | 15.4104 | 15.9421 | 16.4451 | 16.9209 | 17.3712 | 17.7969 | 18.1997 | 18.5806 | 18.941 | Miles | ZML | DET |
| | | | | | | | | Base | | | | | | | |
| 1.653 | 1.679 | 1.704 | 1.727 | 1.749 | 1.770 | 1.790 | 1.808 | 1.826 | 1.842 | 1.858 | 1.873 | 1.887 | 1983 | 1.146 | 0.0391 |
| 1.710 | 1.744 | 1.776 | 1.807 | 1.835 | 1.863 | 1.888 | 1.913 | 1.936 | 1.957 | 1.978 | 1.998 | 2.016 | 1984 | 1.048 | 0.0511 |
| 1.633 | 1.666 | 1.698 | 1.728 | 1.756 | 1.782 | 1.808 | 1.831 | 1.854 | 1.875 | 1.896 | 1.915 | 1.933 | 1985 | 0.983 | 0.0501 |
| 1.353 | 1.392 | 1.428 | 1.462 | 1.494 | 1.525 | 1.554 | 1.581 | 1.607 | 1.632 | 1.655 | 1.677 | 1.698 | 1986 | 0.608 | 0.0575 |
| 1.345 | 1.384 | 1.420 | 1.455 | 1.488 | 1.519 | 1.548 | 1.575 | 1.602 | 1.626 | 1.650 | 1.672 | 1.693 | 1987 | 0.593 | 0.0581 |
| 1.278 | 1.314 | 1.349 | 1.382 | 1.413 | 1.442 | 1.470 | 1.497 | 1.521 | 1.545 | 1.567 | 1.588 | 1.608 | 1988 | 0.561 | 0.0553 |
| 1.253 | 1.288 | 1.321 | 1.353 | 1.382 | 1.410 | 1.437 | 1.462 | 1.486 | 1.508 | 1.530 | 1.550 | 1.569 | 1989 | 0.570 | 0.0527 |
| 1.183 | 1.216 | 1.247 | 1.276 | 1.303 | 1.329 | 1.354 | 1.377 | 1.399 | 1.420 | 1.439 | 1.458 | 1.476 | 1990 | 0.550 | 0.0489 |
| 1.170 | 1.202 | 1.232 | 1.261 | 1.288 | 1.313 | 1.338 | 1.360 | 1.382 | 1.402 | 1.422 | 1.440 | 1.457 | 1991 | 0.547 | 0.0481 |
| 1.164 | 1.195 | 1.225 | 1.254 | 1.280 | 1.306 | 1.329 | 1.352 | 1.374 | 1.394 | 1.413 | 1.431 | 1.448 | 1992 | 0.547 | 0.0476 |
| | | | | | | | | 10% Fail | | | | | | | |
| 1.218 | 1.226 | 1.232 | 1.239 | 1.245 | 1.251 | 1.256 | 1.261 | 1.266 | 1.271 | 1.275 | 1.279 | 1.283 | 1983 | 1.078 | 0.0108 |
| 1.184 | 1.191 | 1.198 | 1.205 | 1.211 | 1.218 | 1.223 | 1.229 | 1.234 | 1.239 | 1.243 | 1.248 | 1.252 | 1984 | 1.036 | 0.0114 |
| 1.107 | 1.114 | 1.120 | 1.126 | 1.132 | 1.138 | 1.143 | 1.148 | 1.153 | 1.157 | 1.162 | 1.166 | 1.169 | 1985 | 0.970 | 0.0105 |
| 1.093 | 1.119 | 1.143 | 1.165 | 1.187 | 1.207 | 1.226 | 1.244 | 1.261 | 1.277 | 1.293 | 1.307 | 1.321 | 1986 | 0.600 | 0.0381 |
| 1.074 | 1.098 | 1.122 | 1.144 | 1.165 | 1.185 | 1.203 | 1.221 | 1.238 | 1.254 | 1.269 | 1.283 | 1.296 | 1987 | 0.591 | 0.0372 |
| 0.997 | 1.020 | 1.041 | 1.061 | 1.080 | 1.098 | 1.115 | 1.131 | 1.146 | 1.161 | 1.174 | 1.187 | 1.199 | 1988 | 0.559 | 0.0338 |
| 0.989 | 1.011 | 1.032 | 1.052 | 1.071 | 1.088 | 1.105 | 1.121 | 1.136 | 1.150 | 1.164 | 1.176 | 1.188 | 1989 | 0.556 | 0.0334 |
| 0.923 | 0.943 | 0.962 | 0.980 | 0.997 | 1.013 | 1.028 | 1.043 | 1.056 | 1.069 | 1.081 | 1.093 | 1.104 | 1990 | 0.529 | 0.0303 |
| 0.911 | 0.931 | 0.949 | 0.967 | 0.984 | 1.000 | 1.015 | 1.029 | 1.042 | 1.055 | 1.067 | 1.078 | 1.089 | 1991 | 0.525 | 0.0298 |
| 0.906 | 0.926 | 0.944 | 0.962 | 0.979 | 0.994 | 1.009 | 1.023 | 1.037 | 1.049 | 1.061 | 1.072 | 1.083 | 1992 | 0.523 | 0.0296 |
| | | | | | | | | 20% Fail | | | | | | | |
| 1.054 | 1.058 | 1.061 | 1.064 | 1.067 | 1.070 | 1.073 | 1.075 | 1.077 | 1.080 | 1.082 | 1.084 | 1.086 | 1983 | 0.985 | 0.0053 |
| 1.018 | 1.021 | 1.024 | 1.027 | 1.029 | 1.032 | 1.034 | 1.037 | 1.039 | 1.041 | 1.043 | 1.045 | 1.046 | 1984 | 0.955 | 0.0048 |
| 0.965 | 0.968 | 0.971 | 0.973 | 0.976 | 0.978 | 0.980 | 0.982 | 0.984 | 0.986 | 0.987 | 0.989 | 0.990 | 1985 | 0.911 | 0.0042 |
| 0.965 | 0.984 | 1.002 | 1.019 | 1.035 | 1.051 | 1.065 | 1.079 | 1.092 | 1.104 | 1.116 | 1.127 | 1.137 | 1986 | 0.591 | 0.0288 |
| 0.952 | 0.971 | 0.988 | 1.005 | 1.021 | 1.037 | 1.051 | 1.065 | 1.077 | 1.090 | 1.101 | 1.112 | 1.122 | 1987 | 0.582 | 0.0285 |
| 0.900 | 0.918 | 0.935 | 0.951 | 0.966 | 0.980 | 0.994 | 1.006 | 1.019 | 1.030 | 1.041 | 1.051 | 1.061 | 1988 | 0.551 | 0.0269 |
| 0.894 | 0.912 | 0.928 | 0.944 | 0.959 | 0.973 | 0.987 | 0.999 | 1.011 | 1.022 | 1.033 | 1.043 | 1.053 | 1989 | 0.550 | 0.0265 |
| 0.849 | 0.866 | 0.882 | 0.896 | 0.910 | 0.924 | 0.936 | 0.948 | 0.959 | 0.970 | 0.980 | 0.990 | 0.999 | 1990 | 0.525 | 0.0250 |
| 0.841 | 0.858 | 0.873 | 0.888 | 0.902 | 0.915 | 0.927 | 0.939 | 0.950 | 0.961 | 0.971 | 0.980 | 0.989 | 1991 | 0.521 | 0.0247 |
| 0.838 | 0.854 | 0.870 | 0.885 | 0.898 | 0.911 | 0.924 | 0.935 | 0.947 | 0.957 | 0.967 | 0.976 | 0.985 | 1992 | 0.520 | 0.0246 |

Table 4-11

Side Effects of I/M on NOx Emissions

(Disbenefit of HC/CO repairs)

| Age | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Miles | 0 | 1.3118 | 2.6058 | 3.8298 | 4.9876 | 6.0829 | 7.119 | 8.0991 | 9.0262 | 9.9031 | 10.7326 | 11.5172 | 12.2594 |
| Year | | | | | | | Base | | | | | | |
| 1983 | 0.61 | 0.67 | 0.74 | 0.80 | 0.86 | 0.91 | 0.98 | 1.04 | 1.10 | 1.15 | 1.20 | 1.25 | 1.30 |
| 1984 | 0.63 | 0.69 | 0.75 | 0.81 | 0.87 | 0.92 | 0.99 | 1.05 | 1.11 | 1.17 | 1.22 | 1.27 | 1.32 |
| 1985 | 0.63 | 0.69 | 0.74 | 0.79 | 0.84 | 0.89 | 0.96 | 1.02 | 1.09 | 1.14 | 1.20 | 1.25 | 1.30 |
| 1986 | 0.51 | 0.56 | 0.62 | 0.67 | 0.72 | 0.76 | 0.81 | 0.85 | 0.89 | 0.92 | 0.96 | 0.99 | 1.02 |
| 1987 | 0.50 | 0.55 | 0.60 | 0.64 | 0.69 | 0.73 | 0.77 | 0.81 | 0.84 | 0.88 | 0.91 | 0.94 | 0.97 |
| 1988 | 0.47 | 0.52 | 0.56 | 0.60 | 0.64 | 0.68 | 0.72 | 0.75 | 0.78 | 0.81 | 0.84 | 0.87 | 0.89 |
| 1989 | 0.47 | 0.52 | 0.57 | 0.62 | 0.66 | 0.70 | 0.74 | 0.78 | 0.81 | 0.85 | 0.88 | 0.91 | 0.94 |
| 1990 | 0.46 | 0.50 | 0.55 | 0.59 | 0.64 | 0.68 | 0.71 | 0.75 | 0.78 | 0.82 | 0.85 | 0.88 | 0.90 |
| 1991 | 0.45 | 0.50 | 0.55 | 0.59 | 0.63 | 0.67 | 0.71 | 0.75 | 0.78 | 0.81 | 0.85 | 0.87 | 0.90 |
| 1992 | 0.45 | 0.50 | 0.55 | 0.59 | 0.63 | 0.67 | 0.71 | 0.75 | 0.78 | 0.82 | 0.85 | 0.88 | 0.90 |
| | | | | | | | Idle | | | | | | |
| 1983 | 0.61 | 0.69 | 0.76 | 0.82 | 0.88 | 0.93 | 0.99 | 1.05 | 1.10 | 1.15 | 1.20 | 1.25 | 1.29 |
| 1984 | 0.63 | 0.71 | 0.77 | 0.83 | 0.88 | 0.93 | 1.00 | 1.06 | 1.12 | 1.17 | 1.22 | 1.27 | 1.31 |
| 1985 | 0.63 | 0.70 | 0.76 | 0.81 | 0.86 | 0.90 | 0.97 | 1.04 | 1.09 | 1.15 | 1.20 | 1.25 | 1.30 |
| 1986 | 0.51 | 0.58 | 0.64 | 0.69 | 0.74 | 0.78 | 0.83 | 0.87 | 0.91 | 0.95 | 0.98 | 1.02 | 1.05 |
| 1987 | 0.50 | 0.56 | 0.61 | 0.66 | 0.71 | 0.75 | 0.80 | 0.84 | 0.87 | 0.91 | 0.94 | 0.97 | 1.00 |
| 1988 | 0.47 | 0.53 | 0.58 | 0.63 | 0.67 | 0.71 | 0.75 | 0.78 | 0.82 | 0.85 | 0.88 | 0.90 | 0.93 |
| 1989 | 0.47 | 0.54 | 0.59 | 0.64 | 0.69 | 0.73 | 0.77 | 0.81 | 0.85 | 0.88 | 0.91 | 0.94 | 0.97 |
| 1990 | 0.46 | 0.52 | 0.57 | 0.62 | 0.66 | 0.70 | 0.74 | 0.78 | 0.82 | 0.85 | 0.88 | 0.91 | 0.94 |
| 1991 | 0.45 | 0.52 | 0.57 | 0.62 | 0.66 | 0.70 | 0.74 | 0.78 | 0.82 | 0.85 | 0.88 | 0.91 | 0.94 |
| 1992 | 0.45 | 0.52 | 0.57 | 0.62 | 0.66 | 0.70 | 0.74 | 0.78 | 0.82 | 0.85 | 0.88 | 0.91 | 0.94 |
| | | | | | | | Two Speed | | | | | | |
| 1983 | 0.61 | 0.69 | 0.76 | 0.83 | 0.88 | 0.93 | 1.00 | 1.05 | 1.10 | 1.15 | 1.20 | 1.25 | 1.29 |
| 1984 | 0.63 | 0.71 | 0.78 | 0.83 | 0.88 | 0.93 | 1.00 | 1.06 | 1.12 | 1.17 | 1.22 | 1.27 | 1.31 |
| 1985 | 0.63 | 0.71 | 0.76 | 0.82 | 0.86 | 0.91 | 0.97 | 1.04 | 1.10 | 1.15 | 1.20 | 1.25 | 1.30 |
| 1986 | 0.51 | 0.58 | 0.64 | 0.70 | 0.75 | 0.79 | 0.84 | 0.88 | 0.92 | 0.96 | 1.00 | 1.03 | 1.06 |
| 1987 | 0.50 | 0.57 | 0.62 | 0.67 | 0.72 | 0.76 | 0.81 | 0.85 | 0.89 | 0.92 | 0.96 | 0.99 | 1.02 |
| 1988 | 0.47 | 0.54 | 0.59 | 0.63 | 0.68 | 0.72 | 0.76 | 0.80 | 0.83 | 0.87 | 0.90 | 0.93 | 0.95 |
| 1989 | 0.47 | 0.55 | 0.60 | 0.65 | 0.70 | 0.74 | 0.78 | 0.82 | 0.86 | 0.90 | 0.93 | 0.96 | 0.99 |
| 1990 | 0.46 | 0.53 | 0.58 | 0.63 | 0.67 | 0.72 | 0.76 | 0.80 | 0.84 | 0.87 | 0.90 | 0.93 | 0.96 |
| 1991 | 0.45 | 0.53 | 0.58 | 0.63 | 0.67 | 0.71 | 0.76 | 0.80 | 0.83 | 0.87 | 0.90 | 0.93 | 0.96 |
| 1992 | 0.45 | 0.53 | 0.58 | 0.63 | 0.67 | 0.72 | 0.76 | 0.80 | 0.84 | 0.87 | 0.90 | 0.93 | 0.96 |

Table 4-11

- continued -

| 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | Model | Regression | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.9615 | 13.6257 | 14.254 | 14.8483 | 15.4104 | 15.9421 | 16.4451 | 16.9209 | 17.3712 | 17.7969 | 18.1997 | 18.5806 | 18.941 | Year | ZML | DET |
| | | | | | | | Base | | | | | | | | |
| 1.34 | 1.38 | 1.41 | 1.44 | 1.47 | 1.49 | 1.51 | 1.53 | 1.55 | 1.56 | 1.58 | 1.60 | 1.61 | 1983 | 0.601 | 0.0550 |
| 1.36 | 1.40 | 1.44 | 1.46 | 1.49 | 1.51 | 1.53 | 1.54 | 1.56 | 1.58 | 1.59 | 1.60 | 1.62 | 1984 | 0.617 | 0.0549 |
| 1.35 | 1.39 | 1.41 | 1.44 | 1.45 | 1.47 | 1.48 | 1.50 | 1.51 | 1.53 | 1.54 | 1.55 | 1.56 | 1985 | 0.614 | 0.0527 |
| 1.05 | 1.08 | 1.10 | 1.13 | 1.15 | 1.17 | 1.19 | 1.21 | 1.23 | 1.25 | 1.26 | 1.28 | 1.29 | 1986 | 0.511 | 0.0415 |
| 1.00 | 1.02 | 1.04 | 1.07 | 1.09 | 1.11 | 1.13 | 1.15 | 1.16 | 1.18 | 1.19 | 1.21 | 1.22 | 1987 | 0.497 | 0.0383 |
| 0.92 | 0.94 | 0.96 | 0.98 | 1.00 | 1.02 | 1.04 | 1.05 | 1.07 | 1.08 | 1.10 | 1.11 | 1.12 | 1988 | 0.470 | 0.0345 |
| 0.96 | 0.99 | 1.01 | 1.03 | 1.05 | 1.07 | 1.09 | 1.11 | 1.13 | 1.14 | 1.16 | 1.17 | 1.18 | 1989 | 0.475 | 0.0375 |
| 0.93 | 0.95 | 0.98 | 1.00 | 1.02 | 1.04 | 1.05 | 1.07 | 1.09 | 1.10 | 1.12 | 1.13 | 1.14 | 1990 | 0.455 | 0.0364 |
| 0.93 | 0.95 | 0.97 | 1.00 | 1.02 | 1.03 | 1.05 | 1.07 | 1.09 | 1.10 | 1.12 | 1.13 | 1.14 | 1991 | 0.453 | 0.0365 |
| 0.93 | 0.95 | 0.98 | 1.00 | 1.02 | 1.04 | 1.06 | 1.07 | 1.09 | 1.11 | 1.12 | 1.13 | 1.15 | 1992 | 0.452 | 0.0367 |
| | | | | | | | Idle | | | | | | | | |
| 1.33 | 1.37 | 1.40 | 1.42 | 1.44 | 1.46 | 1.48 | 1.50 | 1.52 | 1.53 | 1.54 | 1.56 | 1.57 | 1983 | 0.628 | 0.0519 |
| 1.36 | 1.39 | 1.43 | 1.45 | 1.47 | 1.49 | 1.50 | 1.52 | 1.53 | 1.55 | 1.56 | 1.57 | 1.58 | 1984 | 0.640 | 0.0524 |
| 1.34 | 1.38 | 1.41 | 1.42 | 1.44 | 1.46 | 1.47 | 1.48 | 1.49 | 1.50 | 1.51 | 1.52 | 1.53 | 1985 | 0.637 | 0.0505 |
| 1.07 | 1.10 | 1.13 | 1.15 | 1.17 | 1.19 | 1.21 | 1.23 | 1.25 | 1.26 | 1.28 | 1.29 | 1.30 | 1986 | 0.530 | 0.0414 |
| 1.02 | 1.05 | 1.07 | 1.09 | 1.11 | 1.13 | 1.15 | 1.17 | 1.18 | 1.20 | 1.21 | 1.22 | 1.24 | 1987 | 0.516 | 0.0385 |
| 0.95 | 0.97 | 0.99 | 1.01 | 1.03 | 1.05 | 1.07 | 1.08 | 1.10 | 1.11 | 1.12 | 1.13 | 1.14 | 1988 | 0.491 | 0.0350 |
| 0.99 | 1.02 | 1.04 | 1.06 | 1.08 | 1.10 | 1.12 | 1.13 | 1.15 | 1.16 | 1.17 | 1.19 | 1.20 | 1989 | 0.497 | 0.0377 |
| 0.96 | 0.99 | 1.01 | 1.03 | 1.05 | 1.06 | 1.08 | 1.10 | 1.11 | 1.12 | 1.14 | 1.15 | 1.16 | 1990 | 0.479 | 0.0367 |
| 0.96 | 0.98 | 1.01 | 1.03 | 1.04 | 1.06 | 1.08 | 1.09 | 1.11 | 1.12 | 1.14 | 1.15 | 1.16 | 1991 | 0.477 | 0.0367 |
| 0.96 | 0.99 | 1.01 | 1.03 | 1.05 | 1.07 | 1.08 | 1.10 | 1.11 | 1.13 | 1.14 | 1.15 | 1.16 | 1992 | 0.476 | 0.0369 |
| | | | | | | | Two Speed | | | | | | | | |
| 1.33 | 1.36 | 1.39 | 1.42 | 1.44 | 1.46 | 1.47 | 1.49 | 1.51 | 1.52 | 1.53 | 1.55 | 1.56 | 1983 | 0.637 | 0.0509 |
| 1.35 | 1.39 | 1.42 | 1.45 | 1.46 | 1.48 | 1.50 | 1.51 | 1.53 | 1.54 | 1.55 | 1.56 | 1.57 | 1984 | 0.645 | 0.0516 |
| 1.34 | 1.38 | 1.40 | 1.42 | 1.44 | 1.45 | 1.46 | 1.48 | 1.49 | 1.50 | 1.51 | 1.52 | 1.53 | 1985 | 0.642 | 0.0499 |
| 1.09 | 1.12 | 1.14 | 1.17 | 1.19 | 1.21 | 1.23 | 1.24 | 1.26 | 1.28 | 1.29 | 1.30 | 1.32 | 1986 | 0.535 | 0.0421 |
| 1.04 | 1.07 | 1.09 | 1.11 | 1.13 | 1.15 | 1.17 | 1.19 | 1.20 | 1.22 | 1.23 | 1.24 | 1.25 | 1987 | 0.521 | 0.0395 |
| 0.98 | 1.00 | 1.02 | 1.04 | 1.06 | 1.08 | 1.09 | 1.11 | 1.12 | 1.13 | 1.14 | 1.16 | 1.17 | 1988 | 0.497 | 0.0362 |
| 1.01 | 1.04 | 1.06 | 1.08 | 1.10 | 1.12 | 1.14 | 1.15 | 1.17 | 1.18 | 1.19 | 1.21 | 1.22 | 1989 | 0.503 | 0.0385 |
| 0.98 | 1.01 | 1.03 | 1.05 | 1.07 | 1.09 | 1.10 | 1.12 | 1.13 | 1.14 | 1.16 | 1.17 | 1.18 | 1990 | 0.487 | 0.0374 |
| 0.98 | 1.00 | 1.03 | 1.05 | 1.07 | 1.08 | 1.10 | 1.11 | 1.13 | 1.14 | 1.15 | 1.17 | 1.18 | 1991 | 0.485 | 0.0374 |
| 0.98 | 1.01 | 1.03 | 1.05 | 1.07 | 1.09 | 1.10 | 1.12 | 1.13 | 1.15 | 1.16 | 1.17 | 1.18 | 1992 | 0.485 | 0.0376 |

Table 4-12

Lane IM240 Based Emission Factors with IM240 Cutpoints

with Disbenefits of HC/CO Repairs Included

| Age | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Miles | 0 | 1.3118 | 2.6058 | 3.8298 | 4.9876 | 6.0829 | 7.119 | 8.0991 | 9.0262 | 9.9031 | 10.7326 | 11.5172 | 12.2594 |
| Year | | | | | | | Base | | | | | | |
| 1983 | 1.146 | 1.235 | 1.288 | 1.336 | 1.374 | 1.413 | 1.448 | 1.480 | 1.509 | 1.536 | 1.565 | 1.590 | 1.614 |
| 1984 | 1.048 | 1.145 | 1.214 | 1.271 | 1.325 | 1.378 | 1.427 | 1.473 | 1.517 | 1.558 | 1.595 | 1.631 | 1.666 |
| 1985 | 0.983 | 1.081 | 1.147 | 1.208 | 1.260 | 1.313 | 1.361 | 1.406 | 1.448 | 1.486 | 1.526 | 1.561 | 1.594 |
| 1986 | 0.608 | 0.707 | 0.787 | 0.861 | 0.930 | 0.995 | 1.059 | 1.119 | 1.175 | 1.227 | 1.275 | 1.323 | 1.365 |
| 1987 | 0.593 | 0.695 | 0.775 | 0.851 | 0.922 | 0.989 | 1.053 | 1.114 | 1.172 | 1.226 | 1.278 | 1.325 | 1.368 |
| 1988 | 0.561 | 0.662 | 0.740 | 0.814 | 0.884 | 0.949 | 1.013 | 1.072 | 1.128 | 1.181 | 1.230 | 1.275 | 1.319 |
| 1989 | 0.570 | 0.667 | 0.742 | 0.812 | 0.877 | 0.939 | 0.999 | 1.054 | 1.106 | 1.155 | 1.200 | 1.243 | 1.283 |
| 1990 | 0.550 | 0.646 | 0.714 | 0.781 | 0.841 | 0.899 | 0.956 | 1.006 | 1.056 | 1.101 | 1.143 | 1.183 | 1.219 |
| 1991 | 0.547 | 0.642 | 0.710 | 0.775 | 0.835 | 0.891 | 0.947 | 0.998 | 1.045 | 1.091 | 1.131 | 1.170 | 1.206 |
| 1992 | 0.547 | 0.641 | 0.709 | 0.774 | 0.833 | 0.887 | 0.943 | 0.993 | 1.040 | 1.084 | 1.125 | 1.164 | 1.199 |
| | | | | | | | 10% Fail | | | | | | |
| 1983 | 1.078 | 1.126 | 1.142 | 1.154 | 1.160 | 1.168 | 1.174 | 1.179 | 1.183 | 1.187 | 1.193 | 1.198 | 1.202 |
| 1984 | 1.036 | 1.080 | 1.095 | 1.104 | 1.112 | 1.121 | 1.130 | 1.137 | 1.145 | 1.152 | 1.157 | 1.164 | 1.169 |
| 1985 | 0.970 | 1.014 | 1.027 | 1.039 | 1.045 | 1.054 | 1.062 | 1.068 | 1.074 | 1.079 | 1.087 | 1.091 | 1.097 |
| 1986 | 0.600 | 0.673 | 0.726 | 0.776 | 0.821 | 0.864 | 0.907 | 0.947 | 0.984 | 1.018 | 1.050 | 1.081 | 1.108 |
| 1987 | 0.591 | 0.664 | 0.717 | 0.766 | 0.812 | 0.854 | 0.896 | 0.936 | 0.973 | 1.008 | 1.041 | 1.071 | 1.098 |
| 1988 | 0.559 | 0.630 | 0.679 | 0.725 | 0.768 | 0.808 | 0.849 | 0.885 | 0.919 | 0.952 | 0.982 | 1.009 | 1.036 |
| 1989 | 0.556 | 0.627 | 0.675 | 0.720 | 0.761 | 0.801 | 0.839 | 0.874 | 0.907 | 0.938 | 0.967 | 0.993 | 1.018 |
| 1990 | 0.529 | 0.599 | 0.642 | 0.684 | 0.721 | 0.757 | 0.793 | 0.825 | 0.855 | 0.884 | 0.909 | 0.934 | 0.956 |
| 1991 | 0.525 | 0.593 | 0.636 | 0.676 | 0.715 | 0.749 | 0.784 | 0.816 | 0.845 | 0.874 | 0.898 | 0.922 | 0.944 |
| 1992 | 0.523 | 0.591 | 0.634 | 0.675 | 0.712 | 0.746 | 0.781 | 0.812 | 0.841 | 0.869 | 0.894 | 0.918 | 0.939 |
| | | | | | | | 20% Fail | | | | | | |
| 1983 | 0.985 | 1.023 | 1.032 | 1.037 | 1.037 | 1.039 | 1.040 | 1.040 | 1.040 | 1.040 | 1.041 | 1.042 | 1.043 |
| 1984 | 0.955 | 0.988 | 0.995 | 0.995 | 0.996 | 0.998 | 1.001 | 1.002 | 1.004 | 1.005 | 1.006 | 1.007 | 1.009 |
| 1985 | 0.911 | 0.945 | 0.950 | 0.953 | 0.952 | 0.955 | 0.956 | 0.956 | 0.957 | 0.957 | 0.959 | 0.959 | 0.960 |
| 1986 | 0.591 | 0.651 | 0.692 | 0.730 | 0.764 | 0.797 | 0.829 | 0.860 | 0.888 | 0.914 | 0.937 | 0.961 | 0.982 |
| 1987 | 0.582 | 0.643 | 0.684 | 0.721 | 0.757 | 0.790 | 0.822 | 0.852 | 0.881 | 0.908 | 0.933 | 0.956 | 0.977 |
| 1988 | 0.551 | 0.613 | 0.652 | 0.689 | 0.724 | 0.756 | 0.788 | 0.817 | 0.845 | 0.871 | 0.895 | 0.916 | 0.938 |
| 1989 | 0.550 | 0.611 | 0.650 | 0.686 | 0.719 | 0.750 | 0.781 | 0.809 | 0.835 | 0.860 | 0.883 | 0.904 | 0.923 |
| 1990 | 0.525 | 0.587 | 0.623 | 0.658 | 0.689 | 0.718 | 0.749 | 0.774 | 0.800 | 0.823 | 0.844 | 0.864 | 0.882 |
| 1991 | 0.521 | 0.582 | 0.618 | 0.652 | 0.684 | 0.712 | 0.742 | 0.768 | 0.792 | 0.816 | 0.836 | 0.856 | 0.874 |
| 1992 | 0.520 | 0.580 | 0.617 | 0.651 | 0.682 | 0.710 | 0.739 | 0.766 | 0.790 | 0.813 | 0.833 | 0.853 | 0.871 |

Table 4-12

- continued -

| 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | Model | Regression | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.9615 | 13.6257 | 14.254 | 14.8483 | 15.4104 | 15.9421 | 16.4451 | 16.9209 | 17.3712 | 17.7969 | 18.1997 | 18.5806 | 18.941 | Year | ZML | DET |
| | | | | | | | Base | | | | | | | | |
| 1.637 | 1.660 | 1.680 | 1.698 | 1.716 | 1.733 | 1.748 | 1.763 | 1.779 | 1.791 | 1.803 | 1.816 | 1.825 | 1983 | 1.196 | 0.0338 |
| 1.699 | 1.728 | 1.757 | 1.783 | 1.807 | 1.832 | 1.854 | 1.875 | 1.895 | 1.913 | 1.931 | 1.948 | 1.962 | 1984 | 1.087 | 0.0468 |
| 1.626 | 1.655 | 1.685 | 1.711 | 1.735 | 1.761 | 1.783 | 1.803 | 1.823 | 1.842 | 1.860 | 1.878 | 1.893 | 1985 | 1.022 | 0.0463 |
| 1.405 | 1.443 | 1.478 | 1.510 | 1.541 | 1.571 | 1.597 | 1.623 | 1.645 | 1.667 | 1.689 | 1.707 | 1.726 | 1986 | 0.638 | 0.0584 |
| 1.409 | 1.448 | 1.484 | 1.519 | 1.549 | 1.579 | 1.607 | 1.632 | 1.655 | 1.679 | 1.699 | 1.719 | 1.738 | 1987 | 0.623 | 0.0599 |
| 1.357 | 1.395 | 1.429 | 1.462 | 1.493 | 1.522 | 1.547 | 1.570 | 1.594 | 1.616 | 1.634 | 1.653 | 1.671 | 1988 | 0.594 | 0.0580 |
| 1.320 | 1.354 | 1.387 | 1.417 | 1.445 | 1.471 | 1.496 | 1.519 | 1.539 | 1.560 | 1.578 | 1.596 | 1.612 | 1989 | 0.605 | 0.0543 |
| 1.252 | 1.285 | 1.314 | 1.342 | 1.367 | 1.392 | 1.414 | 1.435 | 1.454 | 1.473 | 1.488 | 1.506 | 1.520 | 1990 | 0.589 | 0.0503 |
| 1.240 | 1.269 | 1.299 | 1.327 | 1.351 | 1.376 | 1.396 | 1.416 | 1.435 | 1.453 | 1.470 | 1.486 | 1.501 | 1991 | 0.587 | 0.0494 |
| 1.231 | 1.262 | 1.290 | 1.318 | 1.342 | 1.366 | 1.387 | 1.406 | 1.425 | 1.444 | 1.460 | 1.475 | 1.490 | 1992 | 0.587 | 0.0488 |
| | | | | | | | 10% Fail | | | | | | | | |
| 1.207 | 1.211 | 1.215 | 1.218 | 1.221 | 1.225 | 1.227 | 1.230 | 1.234 | 1.235 | 1.237 | 1.240 | 1.241 | 1983 | 1.118 | 0.0068 |
| 1.176 | 1.180 | 1.185 | 1.189 | 1.193 | 1.197 | 1.201 | 1.205 | 1.208 | 1.210 | 1.214 | 1.216 | 1.218 | 1984 | 1.067 | 0.0082 |
| 1.102 | 1.106 | 1.111 | 1.115 | 1.119 | 1.124 | 1.128 | 1.131 | 1.134 | 1.137 | 1.140 | 1.143 | 1.145 | 1985 | 1.001 | 0.0077 |
| 1.135 | 1.160 | 1.183 | 1.203 | 1.224 | 1.243 | 1.260 | 1.277 | 1.291 | 1.305 | 1.319 | 1.331 | 1.343 | 1986 | 0.628 | 0.0385 |
| 1.124 | 1.149 | 1.172 | 1.194 | 1.213 | 1.232 | 1.249 | 1.265 | 1.279 | 1.294 | 1.307 | 1.319 | 1.331 | 1987 | 0.619 | 0.0384 |
| 1.059 | 1.082 | 1.102 | 1.122 | 1.141 | 1.158 | 1.173 | 1.187 | 1.201 | 1.214 | 1.225 | 1.235 | 1.246 | 1988 | 0.590 | 0.0355 |
| 1.041 | 1.062 | 1.083 | 1.102 | 1.119 | 1.135 | 1.151 | 1.164 | 1.176 | 1.189 | 1.201 | 1.211 | 1.221 | 1989 | 0.588 | 0.0343 |
| 0.976 | 0.996 | 1.014 | 1.031 | 1.046 | 1.061 | 1.074 | 1.086 | 1.098 | 1.109 | 1.118 | 1.129 | 1.137 | 1990 | 0.564 | 0.0311 |
| 0.965 | 0.982 | 1.001 | 1.017 | 1.032 | 1.047 | 1.059 | 1.071 | 1.082 | 1.093 | 1.103 | 1.113 | 1.121 | 1991 | 0.560 | 0.0305 |
| 0.959 | 0.977 | 0.995 | 1.011 | 1.026 | 1.040 | 1.053 | 1.064 | 1.076 | 1.087 | 1.096 | 1.106 | 1.114 | 1992 | 0.558 | 0.0302 |
| | | | | | | | 20% Fail | | | | | | | | |
| 1.044 | 1.045 | 1.046 | 1.046 | 1.047 | 1.048 | 1.048 | 1.048 | 1.050 | 1.049 | 1.050 | 1.051 | 1.050 | 1983 | 1.021 | 0.0018 |
| 1.011 | 1.011 | 1.012 | 1.013 | 1.014 | 1.015 | 1.015 | 1.017 | 1.017 | 1.017 | 1.018 | 1.019 | 1.019 | 1984 | 0.982 | 0.0021 |
| 0.961 | 0.962 | 0.963 | 0.964 | 0.964 | 0.966 | 0.967 | 0.967 | 0.967 | 0.968 | 0.969 | 0.970 | 0.970 | 1985 | 0.939 | 0.0017 |
| 1.002 | 1.021 | 1.038 | 1.053 | 1.068 | 1.082 | 1.095 | 1.107 | 1.118 | 1.128 | 1.139 | 1.147 | 1.157 | 1986 | 0.617 | 0.0291 |
| 0.997 | 1.015 | 1.033 | 1.050 | 1.064 | 1.078 | 1.091 | 1.103 | 1.114 | 1.125 | 1.134 | 1.143 | 1.153 | 1987 | 0.608 | 0.0294 |
| 0.956 | 0.974 | 0.990 | 1.006 | 1.021 | 1.034 | 1.045 | 1.056 | 1.067 | 1.078 | 1.085 | 1.094 | 1.102 | 1988 | 0.581 | 0.0283 |
| 0.942 | 0.958 | 0.974 | 0.989 | 1.003 | 1.015 | 1.027 | 1.038 | 1.047 | 1.057 | 1.066 | 1.074 | 1.082 | 1989 | 0.581 | 0.0272 |
| 0.899 | 0.915 | 0.929 | 0.943 | 0.955 | 0.967 | 0.978 | 0.988 | 0.997 | 1.006 | 1.013 | 1.022 | 1.028 | 1990 | 0.559 | 0.0256 |
| 0.891 | 0.905 | 0.921 | 0.934 | 0.946 | 0.958 | 0.968 | 0.978 | 0.987 | 0.996 | 1.004 | 1.011 | 1.018 | 1991 | 0.555 | 0.0252 |
| 0.887 | 0.902 | 0.916 | 0.930 | 0.942 | 0.954 | 0.964 | 0.973 | 0.982 | 0.992 | 0.999 | 1.006 | 1.013 | 1992 | 0.554 | 0.0250 |

## 5.0 REGULATORY IMPACT ANALYSIS - ESTIMATING COST AND COST EFFECTIVENESS

### 5.1 Cost of Conventional I/M Testing

EPA has collected and analyzed cost data from all operating I/M programs that could provide the information. EPA has analyzed per vehicle costs in I/M programs based upon four basic pieces of information: The I/M program agency budget, number of initial tests, the fee for each test, and the portion returned to the state or local government. This discussion will deal with three aspects of I/M cost: Inspection costs, oversight costs, and repair costs. In addition, it should be noted that where programs are referred to as either "centralized" or "decentralized," this indicates only whether or not the functions of testing and repairing are separated and performed by different entities (i.e., in centralized networks - which can include multiple independent supplier test-only networks - the test and repair functions are separate, whereas in decentralized networks, these functions are typically performed at a single facility.

#### 5.1.1 Inspection and Administration Costs

Inspection fees are set in one of three ways: By a bid process for a contract to supply inspection services, by legislation or regulation establishing a maximum fee, or by market forces. Ideally the fee is scaled to cover the cost of providing the inspection, cover the fee to the state for oversight and management, and to provide a reasonable profit to the operator (except in government-run programs).

This ideal is not always met in actual I/M programs. In some programs the inspection fee does not include a share for the state's oversight costs, so these must be derived from the general fund, with the result that oversight efforts are often significantly underfunded. In many decentralized programs the maximum fee is set below the actual cost (with profit) for the test, so providers must make up for that cost by providing other goods and services.

The economies of scale and efficiency of operation in high volume test-only inspection networks enable motorists in these programs to enjoy lower average inspection fees than in low volume decentralized programs. Based upon 1989 I/M audits (which collected information from all I/M programs), and taking into account both inspection and oversight costs, decentralized programs using computerized analyzers have the highest costs, averaging about $17.70 per vehicle; centralized contractor-run programs average $8.42 per vehicle (recently gathered 1990 data show slightly different numbers, although these have not greatly

affected the overall averages). Table 5-1 shows the estimated cost of the I/M program on a per vehicle basis, including inspection and oversight costs.

Table 5-1

I/M Program Inspection Fees

| Decentralized Programs | | Centralized Programs | |
|---|---|---|---|
| Program | Cost Per Vehicle | Program | Cost Per Vehicle |
| Anchorage | $32.00 | Arizona | $6.00 |
| Fairbanks | $29.00 | Connecticut | $10.00 |
| California | $48.39 | Florida | $10.00 |
| Colorado | $11.20 | Illinois | $8.07 |
| Georgia | $10.68 | Louisville | $6.00 |
| Massachusetts | $17.18 | Maryland | $8.53 |
| Michigan | $10.87 | Minnesota | $8.00 |
| Missouri | $9.00 | Nashville | $6.00 |
| North Carolina | $15.40 | Washington | $9.00 |
| New Mexico | $16.00 | Wisconsin | $8.73 |
| Nevada | $21.26 | | |
| New York | $19.92 | | |
| Pennsylvania | $9.01 | | |
| Dallas | $17.25 | | |
| El Paso | $17.25 | | |
| Davis County | $9.00 | | |
| Utah County | $9.71 | | |
| Salt Lake City | $11.49 | | |
| Virginia | $13.50 | | |

In a centralized, contractor-run program, the contractor bears the cost of acquiring land, constructing and equipping inspection facilities, hiring and training staff, collecting and processing data, and doing the routine testing work. The state's role in this case is to make sure the contractor meets its obligations and to study the outcomes of the program to make sure it is meeting the goal.

In a decentralized program, individual firms and small businesses are licensed to perform the inspection. In this case, the state takes primary responsibility for many of the day to day functions, such as data collection and processing, public information, enforcement, inspector training, and so on. The fact that inspections are performed by many business entities instead of one, and that there are more inspection sites means that state oversight and program evaluation activities need to be more intensive in this type of program and, as a result, are significantly more costly.

Costs of quality assurance measures vary among programs depending upon the comprehensiveness of the quality assurance program and are not well documented in most state programs. EPA

has recommended that the portion of the inspection fee returned to the state be dedicated to program oversight, and that it be scaled to cover the cost of carrying out an effective quality assurance program. EPA audits have found that decentralized programs typically have inadequate quality assurance programs, often due to lack of funds, but also due to insufficient legal authority or willingness.

## 5.2 Estimated Cost of High-Tech I/M Testing

### 5.2.1 General Methodology

EPA's estimates of the costs of high-tech test procedures are driven by a number of assumptions. The first is that the new tests would be performed in currently existing inspection networks (i.e., centralized- and decentralized-based programs). Therefore, the starting point for the cost estimates are the current inspection costs in I/M programs as they are reported to EPA.

The second assumption is that adding the new tests will increase inspection costs in programs that are now efficiently designed and operated. In programs that are not now well designed, current costs are likely to be higher than necessary and the cost increase less if efficiency improvements are made simultaneously. In order to perform the high-tech tests new equipment will have to be acquired and additional inspector time will be required for some test procedures. The amount of the cost increase will be determined to a large degree by the costs of acquiring new equipment and the impact of the longer test on throughput in a high volume operation. Average test volume in decentralized programs is low enough to easily absorb the additional test time involved (although at a cost in labor time). Equipment costs are analyzed in terms of the additional cost to equip each inspection site (i.e., each inspection lane in centralized inspection networks, and each licensed inspection station in decentralized networks).

By focusing on the inspection lane or station as the basic unit of analysis, the resulting cost estimates are equally applicable in large programs, with many subject vehicles and inspection sites, or small programs, with few subject vehicles and inspection sites. Previous EPA analyses of costs in I/M programs have found that the major determinants of inspection costs are test volume and the level of sophistication of the inspection equipment. Costs of operating programs were not found to be measurably affected by the size of the program (for further information the reader may refer to EPA's report entitled, "I/M Network Type: Effects on Emission Reductions, Cost, and Convenience"). Figures on inspection volumes at inspection stations and lanes are available from I/M program operating data. This information enables the equipment cost per vehicle and the

additional staff cost per vehicle to be calculated for each test procedure.

The equipment cost figures presented in this paper are based on the costs of the equipment EPA believes is best suited for high-tech testing. They are current prices quoted by manufacturers, and do not reflect what the per unit prices might be if this equipment were purchased in volume. Staff costs are based on prevailing wage rates for inspectors in both types of programs as reported in conversations with state I/M program personnel. For centralized networks, site costs and management overhead are back calculated from current inspection costs. For decentralized networks, it is assumed that longer test times could be absorbed with no increase in sites. The current average volume in decentralized stations is 1,025 vehicles per year (between 3 and 4 vehicles per day, depending upon the number of days per year the station is open). Consequently, increasing the length of the test, to the degree that the new procedures would, is not expected to impact the number of inspections that can be performed.

### 5.2.2 Equipment Needs and Costs

A pressure metering system, composed of a cylinder of nitrogen gas with a regulator, and hoses connecting the tank to a pressure meter, and to the vehicle's evaporative system is needed to perform evaporative system pressure testing. Hardware to interface the metering system with a computerized analyzer is also needed and is included in the cost estimate. Purge testing can be performed by adding a flow sensor with a computer interface, a dynamometer, and a Video Driver's Aid. With the further addition of a Constant Volume Sampler (CVS) and a flame ionization detector (FID) for HC analysis, two non-dispersive infrared (NDIR) analyzers for CO and carbon monoxide ($CO_2$), and a chemiluminescent (CI) analyzer for $NO_x$, transient testing can be performed.

The analyzers used for the transient test are laboratory grade equipment. They are designed to higher accuracy and repeatability specifications than the NDIR analyzers used to perform the current I/M tests. Table 5-2 shows the estimated cost of equipment for conducting high-tech tests. This quality of technology is essential for accurate instantaneous measurements of low concentration mass emission levels.

Table 5-2

Equipment Costs for New Tests

| Test | Equipment | Price |
|---|---|---|
| Pressure | Metering System | $600 |
| Purge | Flow Sensor | $500 |
| | Dynamometer | $45,000 |
| | Video Drivers Aid | $3,000 |
| Transient | CVS & Analyzers | $95,000 |
| | TOTAL | $144,100 |

The figures in Table 5-2 do not include the costs of expendable materials. Nitrogen gas is used up in performing the pressure test. Additionally, the FID burns hydrogen fuel. Calibration gases are needed for each of the analyzers used in the transient test. Because the analyzers used in the transient test are designed to more stringent specifications than the analyzers currently used in the field, bi-blends, gaseous mixtures composed of one interest gas in a diluent (usually nitrogen) are used to calibrate them. Multi-blend gases, such as are typically used to calibrate current I/M equipment, are not suitable. Current estimates for expendables are shown in Table 5-3. The replacement intervals are estimated based on the usage rates observed in the EPA Indiana pilot program and typical inspection volumes as presented later in this section. Calculations of per vehicle equipment costs presented throughout this report include per vehicle costs of these expendables as well.

Table 5-3

Expendables for New Tests

| Test | Material | Cost | Replacement Interval Centralized | Decentralized |
|---|---|---|---|---|
| Pressure | N2 Gas | $30 | 250 tests | 250 tests |
| Transient | H2 Fuel | $60 | 2 months | 1 year |
| | HC Cal Gas | $60 | 2 months | 1 year |
| | CO Cal Gas | $60 | 2 months | 1 year |
| | $CO_2$ Cal Gas | $60 | 2 months | 1 year |

Staff costs have been found to vary between centralized and decentralized programs, as does the effect on the number of sites

in the network infrastructure. Therefore, the following sections are devoted to separate cost analyses for each network type.

### 5.2.3 Cost to Upgrade Centralized Networks

#### 5.2.3.1 Basic Assumptions

The starting point in this analysis is the current average per vehicle inspection cost in centralized programs. A figure of $8.50 was used based upon data from operating programs. This figure includes the cost of one or more retests and network oversight costs. The key variables to consider in estimating the costs in centralized networks are throughput, equipment, and staff costs. Data on these variables were obtained by contacting program managers in a number of these programs, and by surveying program contracts and Requests for Proposal.

Throughput refers to the number of vehicles per hour that can be tested in a lane. The higher the throughput rate, the greater the number of vehicles over which costs are spread, and the lower the per vehicle cost. EPA contacted program managers and consulted the contracts in a number of centralized programs to determine peak period throughput rates in the different systems. Rates were as reported in Table 5-4.

Table 5-4

Peak Period Throughput Rates in Independent I/M Programs

| Program | Vehicles Tested per Hour |
|---|---|
| Arizona | 20 |
| Connecticut | 25-30 |
| Illinois | 25 |
| Maryland | 25-35 |
| Wisconsin | 25-30 |

On the basis of this information, 25 vehicles per hour was assumed to represent the typical peak period throughput rate or design capacity in centralized I/M programs. During off-peak hours and days, throughput is lower since there is not a constant stream of arriving vehicles. Conversations with individuals in the centralized inspection service industry indicate that inspectors start at minimum wage or slightly higher, that by the end of the first year they earn $5.50 to $6 per hour, and that they generally stay with the job for one to three years. Thus, $6 per hour was used to estimate the average inspector's hourly wage.

Estimates of the costs of adding pressure testing, purge testing, and transient tailpipe testing were derived by taking the current costs for the new equipment to perform the new tests, dividing it by the number of inspections expected to be performed in the lane over a five year period and adding it to the current $8.50 per vehicle cost, with a further adjustment for the impact of test time on throughput, and thus on the number of sites and site costs. The same is done to estimate additional personnel costs associated with adding the new tests. When independent programs were surveyed to determine the length of a typical contract, it was discovered that Illinois, Florida, and Minnesota all have five year contracts, Arizona has a seven year contract, and the program in the State of Washington is operating under a three year contract, resulting in an average contract length of five years among the five programs surveyed. Five years was therefore chosen as the typical contract length.

The number of inspections expected to be performed over the five year contract period was derived by calculating the total number of hours of lane operation, estimating the average number of vehicles per lane and multiplying the two. A lane is assumed to operate for 60 hours a week (lane operation times were found to vary from 54 to 64 hours per week), 52 weeks a year for five years for a total of 15,600 hours. Lanes are assumed to have a peak throughput capacity of 25 vehicles per hour. Modern centralized inspection networks are designed so that they can accommodate peak demand periods with all lanes operating at this throughput rate. Networks are usually designed so that average throughput is 50-65% of peak capacity or 13-15 vehicles per hour. When operating for 15,600 hours over the life of a contract, a centralized inspection lane is estimated to perform a total of 195,000 inspections, or about 39,000 per year.

#### 5.2.3.2 The Effect of Changing Throughput

The addition of evaporative system pressure testing to a centralized program would result in a slight decrease in the throughput capacity. The addition of purge and transient testing, along with pressure testing, would result in a further decrease.

Assuming the same test frequency (i.e., annual or biennial) the reduced throughput rate means that the number of lanes needed to test a given number of vehicles would increase accordingly, as would the size of the network infrastructure needed to support the test program. The result is an increase in the cost per vehicle. Actual consumer cost depends on the test frequency; EPA would encourage states to adopt biennial programs to reduce the costs and imposition of the program. Less frequent testing only slightly reduces the emission reduction benefits while cutting test costs almost in half.

One way to estimate the cost would be to simulate an actual network of stations and lanes in a given city. One could attempt

to assess land costs, building costs, staff and equipment costs, costs for all necessary support systems, and other cost factors. However, this approach would be very time consuming and would rely on information which is proprietary to the private contractors that operate the programs and is, therefore, unavailable. Instead, the cost of the increased number of lanes and stations is derived by analyzing current costs and subtracting out equipment, direct personnel, and state agency oversight costs. The remainder is adjusted by the change in throughput in the new system. Then, new estimates of equipment, personnel and oversight costs are added back in to obtain the estimated total cost.

As discussed previously, the typical high volume station can test 25 vehicles per hour, performing (in most cases) a test consisting of 30 seconds of high speed preconditioning or testing, followed by 30 seconds of idle testing. In addition, a short time is spent getting the vehicle into position and preparing it for testing. This leads to a two to three minute test time on average, depending upon what short test is performed. EPA recently issued alternative test procedures for steady-state tests that reduce various problems associated with those tests, especially false failures, but at a cost of longer average per test time.

Current costs were estimated by contacting operating program personnel, equipment vendors and contractors. The most sophisticated equipment installation (i.e., the equipment for loaded steady-state testing) was used to estimate current equipment costs.

The cost to acquire and install a single curve dynamometer and an analyzer in existing networks is about $40,000 or 21¢ per vehicle using the basic test volume assumptions. As indicated previously, a staff person is assumed to earn $6.00 per hour. When this figure is multiplied by 15,600 total contract hours and divided by 195,000 vehicles, direct staff costs are estimated at 48¢ per vehicle. Existing centralized networks typically have two staff per lane. Thus, total staff costs work out to 96¢ per vehicle. In this analysis a figure of $1.25 is used to estimate the amount of the state retainer. This reflects EPA's best estimate of the per vehicle expense for a good state quality assurance program in a centralized network. Equipment, staff, and state costs add up to $2.42 per vehicle. Subtracting this amount from the current average of $8.50 leaves $6.08 in infrastructure costs and other overhead expenses including employee benefits and employer taxes as shown in Table 5-5. This amount is then factored by the change in the throughput rate and the equipment, oversight, and staff costs for the new tests are then added.

Table 5-5

Current Program Costs

| Increments | Per Vehicle Cost | Total Cost Less Increments |
|---|---|---|
| Current | | $8.50 |
| Equipment | $0.21 | $8.29 |
| Staff | $0.96 | $7.33 |
| State Retainer | $1.25 | $6.08 |

5.2.3.3 Evaporative System Pressure Testing

Most centralized programs use a two position test queue; emission test are done in one position while emission control devices are checked in the other, along with other functions such as fee collection. In this type of system the throughput rate is determined by the length of time required to perform the longest step in the sequence, not by length of the entire test sequence. With computer automation and refined pass/fail logic, the pressure test could be performed by an extra technician while the emission control device check and other functions are performed. In such a system the test would take between two and three minutes to perform. As a result, adding the pressure test is expected to reduce peak throughput to about 20 vehicles per hour. To accommodate peak demand periods and maintain short wait times, a design throughput rate of half of capacity is assumed, for a typical throughput rate of 10 vehicles per hour. Assuming the same number of hours of lane operation, the total number of tests per lane is estimated to be 156,000 over the five year contract period.

Calculations of the additional costs of adding pressure testing are detailed in Table 5-6. These are based upon the costs of equipment and expendables as shown in Tables 5-2 and 5-3 and staff costs and throughput assumptions detailed in the previous paragraphs. Staff costs are derived by assuming two staff per lane at a pay rate of $6.00 per hour for a total of 15,600 hours in the contract period, and dividing by 156,000 vehicles tested during that period. Equipment costs per lane are assumed to be $40,600, also divided by 156,000 vehicles. This works out to 25¢ per vehicle. Based on the cost and usage rates shown in Table 5-3, nitrogen gas for the pressure test costs an additional 13¢ per vehicle. Taken together, the pressure test would be expected to add about $2 to the cost of an efficient, high-volume test system.

Table 5-6

Costs to Add Pressure Testing to Centralized Programs

| Increments | Per Vehicle Cost | Running Total Cost per Vehicle |
|---|---|---|
| Adjust for Throughput | $6.08 * 12.5/10 | $7.61 |
| Staff | $1.20 | $8.81 |
| Oversight | $1.25 | $10.05 |
| Equipment and Nitrogen gas | $0.38 | $10.44 |

5.2.3.4 The Transient/Purge Short Test

The transient/purge test is a longer test procedure than the ones currently used in most I/M programs and is the longest single procedure in the whole inspection process. Thus, it is the determining factor in lane throughput and will therefore influence the number of test sites required.

The transient test takes a maximum of four minutes to perform. An additional minute is assumed to prepare the vehicle for testing, for a maximum total of five minutes. EPA is in the process of looking at potential fast-pass and fast-fail strategies, and preliminary results suggest that roughly 33% of the vehicles tested could be fast passed or failed based upon analysis of data gathered during the first 93 seconds of the IM240 (i.e., Bag 1) using separate fast-pass and fast-fail cutpoints. Hence, EPA estimates that the average total test time could be shortened to at least four minutes per vehicle. This translates into a throughput capacity of 15 vehicles per hour. To accommodate peak demand periods and maintain short wait times, a design throughput rate of half of capacity is assumed, for a typical throughput rate of 7.5 vehicles per hour. Assuming the same number of hours of lane operation as previously, the total number of tests per lane in a transient lane is estimated to be 117,000 over the five year contract period.

State quality assurance program costs would increase given the complexity and diversity of the test system; an estimate of an additional 50¢ is used here but the amount could vary depending upon the intensity of the oversight function the state chooses. Staff costs per vehicle are calculated using the same assumptions for wages and hours of operation as shown in Table 5-5; however, the cost is spread over 117,000 tests over the life of the contract rather than 195,000. The result is staff costs of 80¢ per staff per vehicle. Four staff per lane are assumed (it may be

that, in a well configured lane, three would suffice) to perform the tests. The additional tasks performed by inspectors in conducting the new tests - i.e., disconnecting vapor lines and connecting them to analytical equipment for the evaporative tests and driving the vehicle through the transient driving cycle - do not require that inspectors have higher levels of skill than they do presently. Rather, these tasks can be performed by comparably skilled individuals trained to these specific tasks. Total staff costs work out to $3.20 per vehicle. Equipment costs for each test procedure are derived by taking the equipment costs from Table 5-2 and calculating the costs of five years worth of expendables using the figures in Table 5-3 and dividing by 117,000. The resulting costs estimates are shown in Table 5-7. Table 5-7 shows the result of factoring the figure of $6.08, from Table 5-5, by the change in the throughput rate and adding in the equipment, staff, and state costs associated with the new test procedures. The figure of $6.08 is multiplied by 12.5/7.5, i.e., the ratio of the design throughput rate in the current program to the design throughput rate in a program conducting pressure purge and transient testing.

Table 5-7

Costs to Add Proposed Tests to Centralized Programs

| Increments | Per Vehicle Cost | Running Total Cost per Vehicle |
|---|---|---|
| Adjust for Throughput | $6.08 * 12.5/7.5 | $10.14 |
| Staff | $3.20 | $13.34 |
| Oversight | $1.75 | $15.09 |
| Pressure Test | $0.13 | $15.22 |
| Purge Test | $0.41 | $15.64 |
| Transient Test | $0.87 | $16.50 |

Thus, the cost of adding the new tests to centralized networks is found to be about double the current average cost. The cost of centralized test systems has been dropping in the past few years as a result of competitive pressures and efficiency improvements. These factors may drive down the costs of the new tests as well, especially as they relate to equipment costs. Given that conservative assumptions were made regarding two additional personnel, equipment costs of $144,000 per lane, and low throughput rates, the cost estimate presented here can be fairly viewed as a worst case assumption. As discussed earlier, the important issue is the quality of the test, not the frequency,

so doing these tests on a biennial basis would offset the increased per test cost.

### 5.2.4 Cost to Upgrade Decentralized Programs

#### 5.2.4.1 Basic Assumptions

A methodology similar to that described above is used to estimate the costs of upgrading decentralized programs. Equipment and labor costs are key variables as they were in determining costs for centralized programs. However, total test volume rather than throughput and test time are the critical factors affecting cost. Licensed inspection stations at present only perform, on the average, about 1,025 inspections per year, as shown in Table 5-8 (note that this number is a station-weighted average). This analysis is conducted based on the assumption that the number of inspections per station per year on average will not change (i.e., time and data available did not permit construction of a supply curve for testing services).

Table 5-8

Inspection Volumes in Licensed Inspection Stations

| Program | Vehicles per Year | Vehicles per Station |
|---|---|---|
| California | 6,180,093 | 799 |
| Colorado | 1,655,897 | 1,104 |
| Dallas/Ft. Worth | 1,948,333 | 1,624 |
| El Paso | 278,540 | 1,161 |
| Georgia | 1,118,448 | 1,729 |
| Houston | 1,482,349 | 1,348 |
| Louisiana | 145,175 | 1,037 |
| Massachusetts | 3,700,000 | 1,321 |
| Nevada | 523,098 | 1,260 |
| New Hampshire | 137,137 | 564 |
| New York | 4,605,158 | 1,071 |
| Pennsylvania | 3,202,450 | 834 |
| Rhode Island | 650,000 | 684 |
| Virginia | 481,305 | 1,301 |
| Weighted Average | | 1,025 |

Two conclusions can be drawn from this. The first is that adoption of the new tests is not likely to affect the total number of inspections the average station can perform. The second is that costs will be spread over a smaller number of vehicles than in the case of high volume centralized stations. The incremental cost per vehicle for each new test will therefore be larger in this type of inspection network.

The current average cost of vehicle inspection in decentralized programs is about $17.70 (again, the derivation of this figure can be found in EPA's technical information document, "I/M Network Type: Effects on Emission Reductions, Cost, and Convenience"). Note that this figure may substantially underestimate actual costs since most states limit the inspection fee that a station can charge. In many cases, this fee is likely to be below cost; stations presumably obtain sufficient revenue to stay in business by providing other services, which may include engine repair. The costs for adding high-tech tests are derived by adding the incremental costs for each test type to this amount. Incremental costs are again estimated by dividing the cost of the equipment and the staff costs by the number of inspections expected to be performed in a year, or 1,025 tests.

Equipment costs are spread over the useful life of the equipment. While a piece of equipment's useful life can vary considerably in actual practice, a five year equipment life is assumed.

While large businesses, such as dealerships, are often able to afford to purchase current analyzer equipment outright, the smaller gas stations and garages often have to finance these purchases. The higher cost of the equipment needed to perform purge and transient testing ($144,000 for the dynamometer, CVS, analyzers, etc., as opposed to $12,000 to $15,000 for the most sophisticated of the current NDIR-based analyzers) makes it even more likely that these purchases will have to be financed for most inspection stations. The costs of the CVS and analyzers for transient testing and the dynamometer are amortized over five years at 12% interest in the analysis in this report. The costs of the other, less expensive pieces of equipment are not amortized, but are assumed to be purchased outright and the cost spread out over five years worth of inspections, or 5,125 tests.

Program personnel in decentralized programs were contacted to determine inspector wage rates. In many cases, inspectors are professional mechanics earning about $25 per hour. However, most states do not require inspectors to be mechanics, and inspections may be performed by less skilled individuals who typically earn $6 or $7 per hour. The prevalence of different wage rates among inspectors is unknown. Therefore, EPA assumed an average wage of $15 per hour for this analysis. An overhead rate of 40% is assumed, for a total labor cost of $21 an hour.

#### 5.2.4.2 The Pressure Test

The pressure test can be performed while the inspector is conducting the anti-tampering inspection. Thus, virtually no extra labor time is added. The incremental cost for this test is the cost of the equipment including the nitrogen gas, which, using the costs from Tables 5-2 and 5-3 and spreading them over 5,125 tests, yields a cost of 23¢ per vehicle. Adding this to the current average cost of $17.70 yields a total cost of $17.93.

#### 5.2.4.3 The Transient/Purge Short Test

The transient/purge test is assumed to require five minutes of the inspector's time. With labor costs at $21 per hour, as described above, this works out to $1.75 per vehicle. Equipment costs are taken from Table 5-2, except that the costs for the CVS, analyzers, and dynamometer are amortized over the five year period as described previously. This brings the total costs for these pieces of equipment over the five year period to $126,793 for the CVS and analyzer system, and $60,060 for the dynamometer. These costs are divided by 5,125 inspections. The costs of expendables from Table 5-3 are added in according to the usage rates assumed for decentralized programs.

The incremental costs for these test procedures, and the total cost with pressure testing included, are detailed in Table 5-9.

Table 5-9

Costs to Conduct Pressure, Purge, and Transient Testing in Decentralized Programs

| Test Procedure | Incremental Cost | Total |
|---|---|---|
| Pressure | $0.23 | $17.93 |
| Labor | $1.75 | $19.68 |
| Purge (Equipment only) | $12.40 | $32.08 |
| Transient (Equipment only) | $24.97 | $57.05 |

## 5.3 Repair Costs

### 5.3.1 HC and CO Exhaust Repair Costs and Methodology

The repair costs for HC and CO exhaust emission repairs are split into two elements. One addresses the repair costs due to failure of a tailpipe test, such as the 2500 rpm/Idle idle test or the loaded transient test. The other element addresses the repair costs of correcting tampering identified as a result of the visual inspection for the presence and connection of emission control components such as the catalyst (also known as "ATP failures")

#### 5.3.1.1 Tailpipe Emission Test Failures

Based on current information from I/M programs which collect repair cost information, the average cost to repair a 1981 or newer vehicle failing the 2500 rpm/Idle test is approximately $75, including parts and labor. For example, 1989 repair data from the Louisville, Kentucky I/M program shows the average cost to be $54 for all model year vehicles if only commercial repairs are included. The overall average cost drops to $42 per repaired vehicle if the cost of self repairs (repairs performed by the individual vehicle owner) are also included[5]. In addition, the $75 average repair cost figure is further supported by the findings from an I/M repair study conducted in California which showed the average repair cost to be $72 for 1980 and later model year vehicles[6]. In this study, 500 vehicles that failed the California I/M test were recruited, tested, and repaired at independent commercial garages to pass I/M. Finally, a study of repair costs conducted by the Oregon I/M program in 1985 and 1986 found the average repair cost to be about $50 per failure.[7]

The average cost to repair a vehicle which fails both the IM240 and the 2500 rpm/Idle test is also assumed to be $75. This figure is based on the fact that these cars are likely to receive on average the same types of repairs as are received by vehicles failing only the 2500 rpm/Idle test. For the vehicles which fail only the IM240 emission test, the average repair cost is assumed to be $150, or twice as much. This higher repair cost accounts for the additional and more thorough diagnosis needed to identify the causes of the IM240 failures. In addition, it allows for the possibility of more costly engine parts being required to repair the IM240 failures. Therefore, blending the $75 cost of repairing combined IM240 and 2500 rpm/Idle failures with the $150 cost of repairing IM240-only failures, and assuming (based on observations in Indiana) that there are slightly more 2500 rpm/Idle/IM240 failures than IM240-only failures, yields an average cost of $120.

#### 5.3.1.2 Emission Control Inspection Failures

The average cost (separated by model year group) to repair emission control components identified as needing repair or replacement by a visual inspection are shown in Table 5-10.

These costs were estimated several years ago, based on average retail parts and labor costs. For example, the average air pump repair cost reflects the cost of replacing a broken air

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5 "1989 Annual Report Vehicle Exhaust Testing Program Jefferson County, Kentucky", April, 1990

6 "I/M Evaluation Program Series II", Summary from the California Air Resources Board's I/M Evaluation Program, October 25, 1991.

7 Jasper, W. P. "A Discussion of Reported Maintenance and Repair Expenses in an I/M Program", SAE Paper 861547

pump belt or reconnecting an air or vacuum line. This cost was based on the assumption that most air pump tampering or malmaintenance will focus on disabling the unit by disconnecting the belt or line rather than removing the entire unit. If this is the case, then the repairs will be relatively simple. The average catalyst replacement cost was based on the retail cost of an aftermarket converter. The misfueled catalyst replacement reflected the cost of the converter plus an additional amount to replace the poisoned oxygen sensor. The evaporative system repair is the average cost of reconnecting a vapor or vacuum line after a visual inspection of the system. The PCV and gas cap repairs are the average cost of replacing these components.

Table 5-10

Average Cost of Repairing Emission Control Components

| Component | Pre-81 | 1981+ |
|---|---|---|
| Air Pump | $15 | $15 |
| Catalyst Replacement | $150 | $165 |
| Misfueled Catalyst Replace | $175 | $190 |
| Evaporative System Repair | $5 | $5 |
| PCV System Repair | $5 | $5 |
| Gas Cap Replacement | $5 | $5 |

Repair of intentional tampering failures will contribute relatively little to the overall cost of repairing I/M-failed vehicles in the 1990s, due to decreasing tampering rates. The estimated costs per vehicle, therefore, were not revisited.

### 5.3.2 $NO_x$ Repair Costs and Methodology

Repair costs for $NO_x$ reduction, and the supporting analysis are discussed separately from the HC and CO repair cost analysis because repairs targeted to reduce HC and CO emissions often have no effect on $NO_x$ emissions. Moreover, the Indiana data showed that the HC/CO failures and the $NO_x$ failures were essentially separate sets of vehicles[8]. For example, many vehicles requiring repairs to correct high HC or CO emissions frequently have fairly low $NO_x$ emissions, and consequently do not require $NO_x$ repairs. Furthermore, for those vehicles which are high $NO_x$ emitters, the

8 November 1991, EPA memorandum from E. Glover to C. Harvey, "Average Repair Costs and Benefits from Repairing High $NO_x$ Emitters."

most common repair is to the EGR system, and this often has little impact on HC or CO emissions. In other words, the vehicles with excessive HC and CO emissions usually need different types of repairs than those with excessive $NO_x$ emissions. Thus, their repair costs were analyzed separately.

The data used to calculate the average cost and benefit of performing vehicle $NO_x$ repairs was collected in the on-going EPA Emission Factor test program at the EPA's Motor Vehicle Emission Laboratory (MVEL) in Ann Arbor, Michigan, as well as at the ATL facility in South Bend, Indiana. In this program, large numbers of in-use vehicles were recruited for testing and repair to better characterize the emissions of the fleet. However, for the analysis of $NO_x$ costs, the overall database was restricted to 1983 and later model year vehicles which had received an FTP test both before and after repair, and had been tested in the last few years. As a result, data from 169 1983+ model year vehicles with repair data were obtained.

Most of the 169 vehicles were high emitters of HC or CO, and had repairs aimed at those pollutants, since EPA had given the testing contractor instructions to focus on HC and CO emissions. In order to more accurately characterize the cost of effective $NO_x$ repairs, criteria were used to further select vehicles which clearly had high $NO_x$ emissions before repair, but had achieved lower $NO_x$ emissions as the result of the repair. These criteria were: Before repair FTP emissions had to exceed 2.0 gpm $NO_x$, and after repair FTP emissions could not exceed 1.25 gpm. As a result of these criteria, 10 cars out of 169 were selected, and 9 were used in the final cost analysis. Examining the individual vehicle repairs of these 9 vehicles (see Table 5-11) shows that all of them needed EGR repairs to lower the $NO_x$ emissions to levels which could meet the criteria. On 6 of these vehicles, the EGR was replaced, while on the other 3 the EGR passage was cleaned, or the delay valve was replaced.

The tenth car (683), a Chevrolet Chevette, was removed from the cost analysis because the repair it received was not targeted toward $NO_x$ reduction. Instead, $NO_x$ emissions decreased primarily due to an ineffective HC/CO repair, which caused the engine to go to a rich air/fuel mixture as evidenced by a very large CO emission increase (10 to 30 gpm).

The repair costs of the 9 individual vehicles as well as the overall averages are shown in Table 5-11. For example, the price of the repair parts averaged $44, using Mitchell's Summer Collision Estimating Guide. The labor cost averaged $34, based on 0.68 hours at $50 per hour. These labor hours were determined using Mitchell's 1991 Mechanic's Labor Estimating Guide. In addition, each car was assumed to require 0.5 hours of diagnostic time at the labor rate of $50/hour for an average cost of $25. Summing these costs puts the total average cost of an effective $NO_x$

repair at $103. For input into subsequent cost effectiveness models this overall cost was rounded to $100.

Table 5-11

$NO_x$ Repair Costs

| Veh | MY | Make | Model | NOx Repair Description | Labor Hours | Labor Cost | Parts Cost Retail | Diag-nostic Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|
| 861 | 87 | MERC | COUGAR | Replaced EGR Valve | 0.80 | $40 | $42 | $25 | $107 |
| 94 | 86 | FORD | THUNDERBIRD | Install EGR Vacuum Line | 0.30 | $15 | $0 | $25 | $40 |
| 803 | 86 | CHRY | NEW YORKER | Replaced EGR Valve Clean EGR Passage | 0.80 | $40 | $41 | $25 | $106 |
| 1095 | 89 | PONT | GRAND PRIX | Replaced EGR Valve Assembly | 0.80 | $40 | $161 | $25 | $226 |
| 23 | 87 | FORD | TAURUS | Clean EGR Passage | 1.00 | $50 | $0 | $25 | $75 |
| 545 | 84 | CADI | SEVILLE | Clean EGR Passage | 0.70 | $35 | $0 | $25 | $60 |
| 1131 | 86 | DODG | W150 | Replaced EGR Delay Valve | 0.30 | $15 | $22 | $25 | $62 |
| 1657 | 83 | CHEV | CELEBRITY | Replaced EGR Valve Clean EGR Passage | 0.70 | $35 | $65 | $25 | $125 |
| 41 | 85 | CHEV | S-10 | Replaced EGR Valve | 0.70 | $35 | $67 | $25 | $127 |
| 683 | 85 | CHEV | CHEVETTE | O2 Sensor, Coolant Temperature Sensor, Rebuilt Carburetor | 4.60 | $230 | $39 | $25 | $294 |
| AVERAGE with #683 | | | | | 1.07 | $53 | $43 | $25 | $122 |
| AVERAGE without #683 | | | | | 0.68 | $34 | $44 | $25 | $103 |

### 5.3.3 Evaporative System Repair Costs and Methodology

The repair and cost data used to calculate the average evaporative system repair costs and subsequent fuel economy improvements were collected during an EPA running loss test program conducted at ATL during the Spring of 1991 in which failing vehicles were repaired and retested. All comparisons were done with data obtained from running loss tests at 95° F using a 9.0 RVP emission test fuel, and 3 consecutive LA-4 test cycles (the first LA-4 being a cold start).

The cost-benefit calculation was based upon a sample of 25 vehicles which failed either the I/M purge or pressure test in this test program, and for which evaporative system repair cost information was available.[9] Only 24 vehicles (vehicle 1667 was not available) were used to calculate the average fuel economy cost

9 July 26, 1991, EPA memorandum from E. Glover to C. Harvey, "Average Repair Costs and Benefits from Repairing Purge and Pressure Failures."

savings resulting from evaporative system repair. The results are shown in Table 5-12.

Table 5-12

Average Repair Costs and Fuel Economy Benefits

| Test | Total Fuel Economy Improvement | | Total Fuel Economy Savings gal/mi | Average Parts Cost | Average Labor Hour | Average Total Cost* |
|---|---|---|---|---|---|---|
| Pressure | 7.87 gpm | 6.1% | 0.0034 | $15.03 | 0.45 | $37.76 |
| Purge | 8.26 gpm | 5.7% | 0.0035 | $21.89 | 0.96 | $70.10 |

* Labor costs are computed from labor time using a labor rate (including California) of $50 per hour

The evaporative repair costs, excluding gas caps, are based on parts costs as invoiced by ATL. If the cost of a repair part for a particular vehicle was not available, then the average cost from the other vehicles which also received that repair was used. For example, in the analysis, the value of $29.46, obtained from vehicle (1563) was used as an estimate of purge solenoid replacement cost on two other vehicles (1525 and 1552) which received that repair, but did not have invoiced repair costs. The ATL invoiced gas cap replacement cost was available on only two vehicles (1532 and 1542). For the other vehicles which required this repair, the gas cap cost was based on auto dealer retail prices for an OEM part. Typically, the gas cap OEM retail price was around $7. In addition, repair parts such as evaporative hoses, or inexpensive in-line tees were assumed to cost nothing, except as overhead in the labor cost of fixing them.

The time of repair is generally based on individual diagnostic and repair durations provided by ATL. Typically, they include both the time to diagnose the problem and replace or reattach the parts. For example, vehicle 1548 required 6 hours of diagnosis to discover the cause of the purge problem and replace the defective part. Most of the time was spent in diagnosis, though this length was unusual since most diagnoses and repairs were completed in a half an hour or less.

In some cases, actual labor times were not available to diagnose or replace a particular part. In these cases estimates were made regarding the duration of a typical repair. For example, gas cap replacement (including diagnosis) duration was not usually itemized and, therefore, was estimated to be 15 minutes. In other cases, repair times from similar repairs on other cars were used. However, for the sake of clarity, both the

parts and labor cost basis of each vehicle's repair are noted in Table 2 of reference 8.

## 5.4 Fuel Economy Benefits

### 5.4.1 Fuel Economy Benefits of Evaporative System Repairs

The analysis of the data shows a substantial fuel economy benefit under the 95° F test conditions as the result of evaporative system repair. This fuel economy benefit is attributed to two factors. The first is increased performance and efficiency of the vehicle's engine following an evaporative repair such as reconnection of a vacuum line or a TVS repair. This increase in efficiency was directly measured by the CVS equipment, and it was found that the measured fuel economy increased by an average 3.2% for vehicles failing the pressure test, and an average 2.8% for vehicles failing the purge test. The fuel economy improvement is calculated by dividing the fuel consumption reduction by the total fuel consumption, as illustrated in the following calculations:

4.13 grams fuel/mile/128.3 grams fuel/mile = 3.2% Pressure failures

4.05 grams fuel/mile/143.75 grams fuel/mile = 2.8% Purge failures

The second factor involved in the fuel economy benefit calculation is the utilization of the captured HC vapor which would have otherwise been lost as running loss emissions. In a properly designed closed-loop vehicle the engine should effectively substitute these vapors for liquid tank fuel, and reduce the vehicle's real fuel consumption. These vapor fuel flows from the engine and the evaporative canister are not measured during the running loss test.

Since actual fuel flow data were not measured, it was assumed that 100% of the captured running loss emissions (i.e., the difference between before and after repair levels) can be effectively utilized as fuel. This assumption may be slightly high given the fact that on average exhaust CO emissions increased somewhat as the result of evaporative repairs, indicating that some of the extra fuel was not fully combusted. However, such an error (i.e., using an 'R' factor of 1.0) is probably small, and its effect should not be large considering that the running loss reductions are not large in comparison to total vehicle fuel consumption.

The running loss vapors from pressure failures were converted to liquid fuel, using an R Factor of 1.0, the standard density of Emission Test Fuel, and a carbon weight factor of 0.83 for the fuel.

3.74 gpm running loss $CH_{2.33}$ * R Factor = 3.74 gpm liquid fuel ($CH_{1.85}$)

3.74 g C/mi * (1cm$^3$/ 0.745 g Fuel) * (1 g Fuel / 0.83 g C) * (1.0 liter/ 1000 cm$^3$) * (1.0 gal/3.79 liter) = 0.0016 gal/mi

The analogous running loss vapors from purge failures were converted to liquid fuel, and the percentage fuel economy improvement was calculated in a similar manner.

4.21 gpm running loss CH2.33 * R Factor = 4.21 gpm liquid fuel (CH1.85)

4.21 g C/mi * (1 cm3/ 0.745 g Fuel) * (1 g Fuel / 0.83 g C) * (1.0 liter / 1000 cm3) * (1.0 gal/3.79 liter) = 0.0018 gal/mi

The measured fuel economy improvements from better engine operation were combined with the measured running loss reductions to produce evaporative repair fuel economy benefits of 6.1% for pressure failures and 5.7% for purge failures. Averaging these together produced an overall fuel economy benefit from evaporative repair of 5.9%.

### 5.4.2 Fuel Economy Benefits of IM240 Repairs

The fuel economy benefit for repairing a vehicle that has been identified as failing the 0.8 gpm HC cutpoint or the 15 gpm CO cutpoint on the IM240 test has been estimated as an increase of 12.6% in overall fuel economy, after repairs. This compares to an 8.0% fuel economy benefit realized by identifying and repairing vehicles using the 2500 rpm/Idle test as a yardstick. These percentages are derived from data gathered from the IM240 test site in Hammond, Indiana, and are based upon an average difference in fuel economy before and after repairs.

The 12.6% fuel economy benefit assessed for identifying and repairing vehicles on the basis of the IM240 test lane results is based upon two groups of 1983 and newer vehicles recruited at the Hammond test site. The first group included those vehicles that failed the emissions cutpoints of 0.8 gpm for HC and/or 15.0 gpm for CO, which were subsequently FTP-tested, repaired and retested at the ATL facility in Indiana (a total of 42 vehicles). The second group consisted of those vehicles that failed the emissions cutpoints, were FTP-tested, but were not repaired (a total of 10 vehicles). Unrepaired vehicles were assumed to represent a fuel economy benefit of zero, with the net effect that the overall fuel economy benefit calculation is conservative.

The 10 IM240-failed vehicles mentioned above were not repaired and retested because the original design of the testing program sought to conserve testing slots by applying a criteria that only vehicles with an FTP result twice the certification standards for the vehicle would receive repairs and be retested. These unrepaired vehicles were included in the analysis to represent that fraction of vehicles (i.e., 19%, or 10 out of 52) expected to fail the IM240 (in a future I/M program) but which have only a marginal emissions problem and presumably only a

marginal fuel economy loss (if any), thus requiring only minimal repairs which will not result in improved fuel economy. The averaged fuel economy benefit represents a harmonic average of the FTP fuel economy before and after repairs for the 52 vehicle sample group.

Table 5-13 shows that 17 vehicles which failed at the Hammond lane were not repaired, which raises the issue of why only 10 vehicles were used to represent the "no improvement" vehicles. The logic and assumptions were as follows. Of the 72 vehicles that were repaired, only 42 (58.3%) had all the necessary data to do the calculations. Assuming the same attrition rate (due to incomplete data) for the vehicles that did not receive repairs (i.e., 58.3% of the 17 unrepaired vehicles) yields a total of 10 vehicles. The net effect of assuming this fraction of "zero improvement vehicles" is a lower fuel economy benefit for the IM240 (12.6% instead of a potential 15.7%).

Table 5-13

Zero Improvement Vehicle Sample Size Adjustments

| Original # of Vehs | Description of Data Used and Removed | Remaining Vehicles |
|---|---|---|
| 98 | 1983+ Failed lane 0.8 & 15 & received FTPs | 98 |
| 17 | were less than twice standard & not repaired | 81 |
| 9 | were greater than twice the standard, but were not repaired due to test schedule or cost (engine rebuild or catalyst) | 72 |
| 4 | had no as-received IM240s at ATL (IM240-based fuel economy benefits were initially evaluated, so this test was required. In retrospect, they should have been added back into the database for the FTP-based FE improvement) | 68 |
| 1 | had no after-repair IM240 #1643 (to verify repair success) | 67 |
| 25 | Failed after-repair IM240 (incomplete ATL repairs) | 42 |
| | % of 72 repaired that can be included in analysis = | 58.3% |
| | 58% of 17 <2 x standard & not repaired included as zero improvement = | 10 |

### 5.4.3 Fuel Economy Benefit for the 2500 rpm/Idle Test

The 8.0% fuel economy benefit assessed for identifying and repairing vehicles on the basis of the 2500 rpm/Idle test is based upon two groups of 1983 and newer vehicles recruited at the

Hammond test site. The first group consisted of 6 vehicles that failed the 220 ppm HC and/or 1.2% CO cutpoints on their initial 2500 rpm/Idle I/M test, received an IM240 before and after commercial repairs, and received passing scores on the retest. The second group consisted of those vehicles that returned to the Hammond lane after commercial repairs, but again failed the 2500 rpm/Idle test. These latter 6 retest failures are considered to be the result of incomplete repairs, which would be corrected in an enhanced I/M program.

The before and after IM240 fuel economy data was "corrected" to reflect FTP fuel economy by employing a correction factor of 1.0925, reflecting the fact that, on average, FTP fuel economy varies from IM240 measured fuel economy by 9.25%. This variance reflects the fact that the IM240 and FTP are, after all, different tests, using different driving cycles, etc. Still, the two tests show a high degree of correlation, and, in the area of fuel economy, the variance between the two tests is a relatively constant difference of 9.25%. Therefore, multiplying IM240 fuel economy readings by 1.0925 yields a reliable estimate of FTP fuel economy.

After successful repairs (i.e., those resulting in a passing retest), some marginal vehicles will fail to realize a noticeable fuel economy improvement. Using a database of 48 cars, it was determined that 4 of the vehicles that failed the 2500 rpm/Idle I/M test were not repaired because their FTP emissions scores were less than twice their certification standards, leading to the conclusion that, had these vehicles been repaired, their fuel economy benefit would be zero. These 4 vehicles represent 8.3% of the 48 database vehicles for which all the necessary data was available. Assuming that 8.3% of the 6 vehicles that were still failing I/M would not get a fuel economy benefit after repairs yields a figure of 0.48 vehicles that will show no noticeable fuel economy benefit. Given that half of a vehicle cannot be added to the database, each of the other 6 vehicles that did pass after repairs were duplicated yielding twelve vehicles, and 1 vehicle was added to represent the "no fuel economy improvement" case. Adding the single "zero improvement vehicle" lowered the fuel economy benefit of the 2500 rpm/Idle test from 8.6% to 8.0%. Table 5-14 further details how these numbers were arrived at.

Table 5-14

Adjusted Zero FE Benefit Vehicle Sample Size

| Original # of Vehicles | Description of Data Used and Removed | Remaining Vehicles |
|---|---|---|
| 312 | 1983+ Failed IN I/M at lane | 312 |
| 256 | not recruited to lab | 56 |
| 8 | missing data | 48 |
| 44 | dirty enough to expect an FE benefit | 4 |
| | % that failed IN I/M but too clean for a FE benefit (4 of 48) | 8.3% |
| | 8% of 6 commercially repaired included as zero improvement | 0.48 |

While 6 vehicles may seem like a slim database, we did not want to assume too low a fuel economy benefit for the conventional 2500 rpm/Idle test and risk overestimating the incremental benefit of the IM240 test. A mid-1980s study with actual or simulated commercial repairs of older technology 1981-83 vehicles showed only a 3.5% improvement. This has not been shown to be applicable to newer technology vehicles. We also did not want to claim too much benefit. We did not rely on the ATL-performed repairs (as we did for the fuel economy benefit when using IM240 cutpoints) because the ATL mechanics were instructed to repair all known malfunctions that would likely affect FTP HC and CO. Therefore, the emissions and fuel economy benefits would likely exceed what would actually occur with real world repairs that stop as soon as the 2500 rpm/Idle test cutpoints are met. In contrast, we judged that because the IM240 is a mass emissions test that correlates well with the FTP, real world repairs aimed at making vehicles pass the fairly stringent IM240 cutpoints would not be so different from those made by the ATL mechanics. The fact that 25 of the 67 ATL-repaired vehicles still failed the IM240 suggests that ATL mechanics in general did not go too far.

## 5.5 Recurring Failure and Repair Rates and Fraction of Fleet Affected by Fuel Economy Benefits

The rates at which vehicles recurrently fail tailpipe tests and emission control inspections in an ongoing I/M program (i.e., the percentage of failing vehicles in a program that has been established for a few years) are used within the Cost Effectiveness Model (CEM) for determining repair costs. Fuel economy credits for repairs resulting from tailpipe tests are based on the hypothetical failure rates that would occur in the

first cycle of the I/M program if it were just starting. These hypothetical rates in effect represent vehicles that have been and remain affected by the I/M program that has in fact been operating.

The exhaust test failure rates for calculation of repair costs in CEM are in the form of a zero-mile failure rate and a deterioration rate, such that the fraction of failing vehicles for a given test type is calculated by multiplying the deterioration rate by the average mileage and adding that result to the zero-mile failure rate. Table 5-15 shows the zero-mile and deterioration rates found in the BLOCK DATA section of the CEM program listing in Appendix A.

Table 5-15

Exhaust Test Failure Rates
(fraction)

| Test | Zero-Mile | Deterioration (per 10K miles) | Type |
|---|---|---|---|
| Idle | 0.00 | 0.01 | (recurring) |
| 2-Speed | 0.00 | 0.01 | (recurring) |
| Loaded | 0.0252 | 0.01190 | (recurring) |
| IM240 | 0.00 | 0.0373 | (first-cycle) |
| NOx | 0.032936 | 0.0084805 | (recurring) |

These numbers are based on regressions of emission test data from the IM240 lane in Indiana. In 1990 and 1991, Indiana had just revitalized its moribund I/M program and hence can be considered to represent a hypothetical I/M program in its first cycle of inspections). For the IM240 the first-cycle HC/CO failure rate per 10,000 miles was 0.0373 at an average of 50,000 miles observed among 3,436 model year 1983 and newer cars in Indiana. The above recurring rates include adjustment of the first-cycle rates by a factor of 1/1.87 (e.g., 0.01 = 0.0187/1.87). This adjustment factor is the recurring initial failure ratio for idle testing, derived by comparing the Indiana failure rates with failure rates from other operating I/M programs with longer histories.

The recurring zero-mile rate used by the model for the IM240 is half of the first-cycle deterioration rate (0.0373/2 = 0.01995). The recurring deterioration rate used by the model for the IM240 is half of 1/1.87 times the first-cycle failure rate. This method represents a 50-50 compromise between the following two assumptions, either of which would be reasonably plausible:

(a) The IM240 test will require vehicle repairs sufficient to return the emission control systems to like-new condition thus yielding a constant failure rate equal to the rate found for the first 10,000 miles of operation (0.0373), and (b) IM240 repairs will deteriorate similarly to idle and 2-speed test repairs, which would yield a deterioration rate of 0.0373/1.87 = 0.01995).

These failure rates assume cutpoints of 1.2% CO and 220 ppm HC for the idle and 2-speed tests, and 0.8/15 gpm for the IM240 test. For NOx, separate cutpoints of 1.69 for PFI, 2.50 for TBI, and 3.99 gpm for carbureted vehicles are used resulting in an overall nominal failure rate of about 10% on the IM240.

In the case of ATP emission control component inspections CEM calculates recurring repair rates for the first year a vehicle is inspected from the difference in tampering rates given by MOBILE4.1 for the no-program case and the with-ATP case. There is also a small residual repair rate assumed for latter years, with a very minor cost impact.

In the case of purge and pressure test failures MOBILE4.1 uses a lookup table which has different malfunction rates for each vehicle age up to 13 years, and older vehicles are assigned the rates of the 13 year old vehicles. The malfunction rates range from roughly 4% to 33% for purge or pressure malfunctions, and 8% to 50% for the combination of purge and pressure malfunctions. This lookup table can be found as the EFFECT array at the beginning of the FAIL function in the CEM program listing in Appendix A. After appropriately weighting together these purge and pressure failure rates, MOBILE4.1 uses them in its calculation of evaporative and running loss emission factors in the absence of an evaporative I/M program. These malfunction rates would become the first-cycle failure rates for a new I/M program rather than recurring failure rates.

CEM assumes these same initial failure rates in determining fuel economy benefits of purge and pressure tests, since the fuel economy effect of an I/M program in a given year depends on the difference between the number of failures that would exist in a no-program case and the near-zero number present with the I/M program in operation. The fuel economy benefit calculation using these failure rates is described in section 5.4.

To determine purge and pressure repair costs, CEM requires recurring failure rates corresponding to an ongoing I/M program wherein the failure rate would be lower than the initial failure rate observed in Indiana's first cycle and used in MOBILE4.1 and in the fuel economy benefit calculation to represent the no-program case. The recurring purge and pressure failure rates used for this purpose are:

Recurring Purge test failure rate: 3.0%

Recurring Pressure test failure rate: 2.5%

Recurring total Purge/Pressure failure rate: 5.0%

The exact use of these rates can be seen in the FAIL function of the CEM program listing in Appendix A.

These recurring purge and pressure test failure rates were derived from the initial rates of MOBILE4.1. As an example, the 5% total failure rate is based on roughly a 50% failure rate for ten year old vehicles indicating that roughly 5% went bad each year on average. For an analysis that did not treat age explicitly this was an assumption that could be used for all ages, and would definitely not underestimate costs, since much of the rise to the 50% failure rate happens at higher mileages when there are fewer cars still in use.

## 5.6 Method for Estimating Cost Effectiveness of I/M Programs

The cost of an I/M program is determined by summing the estimated inspection fee costs, the estimated repair costs, and the negative cost of estimated fuel economy benefits (gallons of fuel saved * $/gallon). The emission benefits of an I/M program are determined by subtracting the estimated emissions with the program from the emissions with no I/M program. CEM does the emissions calculation by making multiple runs of MOBILE4.1 and manipulating the results of the various runs. Since MOBILE4.1 does not include the necessary cost components, CEM itself calculates costs by combining the previously discussed information on per vehicle costs and fuel economy benefits with the estimates of failure rates.

Since MOBILE4.1 calculates the emission levels, tampering rates, and misfueling rates for January 1st of each calendar year, CEM performs two two consecutive sets of MOBILE4.1 runs and interpolates between them to get an annual average emission rate which is then converted into a ton per year value using the fleet vehicle miles travelled (VMT) data contained in MOBILE4.1. In order to separate out costs and benefits associated with various portions of an I/M program, two intermediate MOBILE4.1 runs are done between the full program and no-program runs. Therefore, each CEM run performs a total of eight MOBILE4.1 runs as follows.

1) Full I/M & ATP program (as requested)
2) Run 1 minus any ATP and evap testing
3) Run 2 minus any tailpipe I/M, but with tampering deterrence effect of I/M
4) Baseline, no program benefits at all)
5) Run 1 for next calendar year
6) Run 2 for next calendar year
7) Run 3 for next calendar year
8) Run 4 for next calendar year

### 5.6.1 Inspection Costs

Inspection costs are determined by multiplying user-input inspection costs by the number of vehicles adjusted for compliance rate (percentage of vehicles that fail to get inspected). Separate costs are input for tailpipe emission tests, emission control checks, purge test, and pressure test. If a program calls for biennial rather than annual inspections, the inspection costs per year are divided in half. All default costs are found in the SETUP routine of the CEM program listing in Appendix A. Default inspection costs are shown in Table 5-16. Note that the cost of performing the purge test overlaps many of the costs associated with transient testing, including the cost of a dynamometer, video driver's aid (VDA), and the throughput adjustment associated with the longer test time. If purge testing is assumed, the incremental cost of including the transient test is relatively minor, including the cost of a constant volume sampler (CVS) and the analyzers necessary to perform mass emissions testing.

Table 5-16

Default Inspection Costs in CEM4.1

| Test | Cost | Comments |
|---|---|---|
| Steady-state Tailpipe Test | $10 | $12 if biennial |
| Emission Control Checks | 25¢-1.75 | Depends on checks done |
| Pressure Test | 69¢ | |
| Purge Test | $6.53 | Includes dyno, adjusted thruput |
| Transient Emission Test | 67¢ | Increment over purge cost |

### 5.6.2 Repair Costs

Calculating total repair costs is performed similarly to the inspection costs, except that the costs are only applied to the percentage of vehicles estimated to fail a given I/M test. It is

further adjusted for the percentage of vehicles that do not get repaired because they require repairs costing more than the applicable cost waiver limit. Default repair costs are as follows.

Table 5-17

Default Repair Cost in CEM4.1

| Failure Triggering Repair | Pre-81 | 81+ |
|---|---|---|
| Idle or 2500 rpm/Idle Test | $50 | $75 |
| Transient Test (IM240) | N/A | $150 |
| Air Pump | $15 | $15 |
| Catalyst | $150 | $165 |
| Misfueled Catalyst Cost | $175 | $190 |
| Evaporative System | $5 | $5 |
| PCV System | $5 | $5 |
| Gas Cap | $5 | $5 |
| Purge Test | $70 | $70 |
| Pressure Test | $38 | $38 |
| $NO_x$ | Not Estimated | $100 |

In the case of transient exhaust testing, the fraction of failing vehicles that would have failed a 2500 rpm/Idle test is assigned the repair cost for the 2500 rpm/Idle test, while the remainder is assigned the higher transient test repair cost.

### 5.6.3 Fuel Economy Cost Benefits

Fuel economy benefits are based on cumulative repairs made to vehicles that fail an I/M tailpipe test and/or an evaporative system pressure test. As described in section 5.5, the repair rate used is the first-cycle failure rate corresponding to inspection of vehicles that have not previously been subject to an I/M program. The percentage improvement in fuel economy depends on the type of test that was failed. The following benefits are from the BLOCK DATA section of the CEM program listing.

Table 5-18

Fuel Economy Benefits in CEM4.1

| Test | FE Benefit |
|---|---|
| 2500 rpm/Idle (pre-81) | 0.0% |
| 2500 rpm/Idle (81+) | 8.0% |
| IM240 (83+) | 12.6% |
| Purge/Pressure | 5.9% |

The model converts these percent MPG benefits into dollar benefits using the VMT information from MOBILE4.1, fleet average fuel economies for appropriate model years from CEM and a user-input gasoline cost from CEM, which defaults to $1.25 per gallon.

## 6.0 REGULATORY IMPACT ANALYSIS - COSTS AND BENEFITS OF ENHANCED I/M OPTIONS

### 6.1 Emission Reduction Benefits

Grams per mile emission factors were calculated using MOBILE4.1 for low, medium, and high option enhanced I/M performance standards. The test procedure variables and the constant inputs are detailed in Table 6-1. All options are based on centralized testing of 1968 and later light duty vehicles and light duty trucks with annual frequency, as required by section 182(c)(3)(B) of the Clean Air Act Amendments of 1990. The major differences in the benefits of the options are due to the type of testing utilized, specifically, the adoption of evaporative system pressure testing in the medium option and of transient and evaporative system purge testing in the high option. Other inputs reflect national default values assumed in MOBILE4.1.

Table 6-1

MOBILE4.1 Inputs for Enhanced I/M Performance Standard Options

| Inputs | Low | Medium | High |
|---|---|---|---|
| Pre-1981 Stringency | 20% | 20% | 20% |
| Idle | 1968+ | 1968+ | 1968-1980 |
| 2500 rpm/Idle | none | none | 1981-1985 |
| Pressure | none | 1971+ | 1983+ |
| Purge | none | none | 1986+ |
| Transient | none | none | 1986+ |
| †Waiver Rate | 1% | 1% | 1% |
| †Compliance Rate | 98% | 98% | 98% |
| *Network Type | central | central | central |
| *Test Frequency | annual | annual | annual |
| *Vehicle Coverage | LDV/LDT1/LDT2 | LDV/LDT1/LDT2 | LDV/ LDT1/LDT2 |
| ATP MY coverage | 1981+ | 1981+ | 1984+ |
| Catalyst | Yes | Yes | Yes |
| Fuel Inlet | Yes | Yes | Yes |
| Air Pump | No | No | No |
| Tailpipe Lead Test | No | No | No |
| Evap Disablement | No | No | No |
| PCV Disablement | No | No | No |
| Gas Cap | No | No | No |
| Altitude | 500 feet | 500 feet | 500 feet |
| Period 1 RVP | 11.5 | 11.5 | 11.5 |
| Period 2 RVP | 8.7 | 8.7 | 8.7 |
| Period 2 Start Year | 1992 | 1992 | 1992 |
| Minimum Temperature | 72°F | 72°F | 72°F |
| Maximum Temperature | 92°F | 92°F | 92°F |
| Ambient Temperature | 87.5°F | 87.5°F | 87.5°F |
| Operating Mode | 20.6/27.3/20.6 | 20.6/27.3/20.6 | 20.6/27.3/20.6 |
| Onboard Controls | no | no | no |
| Stage II Control | no | no | no |
| Vehicle Speeds | 19.6 mph | 19.6 mph | 19.6 mph |
| VMT Mix | MOB4.1 default | MOB4.1 default | MOB4.1 default |

† These percentages may not be realistic for some programs, in which case the program will have to be "over designed" to make up the performance loss.

* Clean Air Act Amendments require these inputs as elements of the performance standard.

The gram per mile emission factors for each option and the emission reduction benefit as a percentage of the no-I/M case in the calendar year 2000 are shown in Table 6-2. The no-I/M factors were calculated assuming the same RVP, ambient temperatures, maximum and minimum temperatures, operating modes, altitude, vehicle speeds, and VMT mix variables as assumed for the enhanced I/M options. Stage II and on-board vapor recovery system effects were not modeled in either the no-I/M or enhanced I/M options case.

Emission benefits from basic I/M (the current performance standard) and from the biennial high option program (which EPA recommends) are also shown. Note that the proposed enhanced I/M performance standard listed below in Table 6-2 is an annual program, as required by the Act. Note further that emission reductions are expressed as a percentage of total highway mobile source emissions. Many other mobile source programs are described based on light-duty vehicles; doing so here would show a much higher percent benefit.

Table 6-2

Benefits of I/M Programs Options*

| | VOC Emission Effects | | CO Emission Effects | |
|---|---|---|---|---|
| Scenario | Emission Factor (gpm) | Percent Reduction | Emission Factor (gpm) | Percent Reduction |
| Base - No I/M | 2.084 | - | 11.874 | - |
| Basic I/M | 1.971 | 5.4% | 10.021 | 15.6% |
| Low Option | 1.870 | 10.3% | 8.927 | 24.8% |
| Medium Option | 1.661 | 20.3% | 8.927 | 24.8% |
| Biennial High Option | 1.495 | 28.3% | 8.223 | 30.7% |
| Proposed Enhanced Performance Standard | 1.503 | 27.9% | 8.230 | 30.7% |

* Total Highway Mobile Source Emissions in 2000

The results shown in Table 6-2 are our best estimates at this time but our test programs and data analyses are continuing and we anticipate refining the numbers as time goes on.

## 6.2 Cost Effectiveness Estimates

### 6.2.1 Assumptions and Inputs for the Program Options

EPA's estimates of the cost-effectiveness of the three scenarios are based upon modeling with MOBILE4.1 and CEM4.1 with assessments done for calendar year 2000. These are compared with a modeling scenario in which no I/M program is assumed.

The low, medium, and high options are the same as those described in Table 6-1. The assumed cost for an I/M inspection, including a visual check of emission control devices, is $8.50. The incremental cost of adding the evaporative system pressure

test is $1.94. The incremental costs of adding the purge and transient tests are $5.19 and $0.87, respectively. As indicated in section 5.6.1, the cost of the purge test includes the cost of a dynamometer and VDA, and also reflects a throughput adjustment to accommodate the longer test; adding transient testing to the purge test requires the addition of a CVS and the necessary emissions analyzers. In addition, gasoline is assumed to cost $1.25 per gallon. The average repair costs shown in Table 5-17 were assumed. It should be further noted that the incremental costs of adding purge and transient testing to a decentralized network ($12.40 and $24.97, respectively) are larger than in a centralized network because of the assumption these additional costs will be spread out over a smaller test volume (i.e., it is assumed that the average number of vehicles tested per station in a decentralized network will not change).

### 6.2.3 Cost-Effectiveness Calculations

Total annual program costs per million vehicles, as calculated by CEM4.1, are presented in Table 6-3, including inspection costs, repair cost and fuel economy benefits, shown on an annual basis. Note that the total cost of I/M increases as the option becomes more stringent; also note that the total cost (on a per million vehicle basis) of a biennial high option is less than both the annual low option and the basic I/M program. These results make it clear that biennial testing should be a top priority.

Table 6-3

Total Annual Program Cost

| Scenario | Cost |
|---|---|
| Basic I/M | $6,412,000 |
| Low Option | $9,885,000 |
| Medium Option | $11,628,000 |
| High Option | $11,390,000 |
| Biennial High Option | $5,429,000 |

The next step is to calculate cost-effectiveness ratios, or the annual cost per ton of emission reductions. For areas that are required to do enhanced I/M due to ozone nonattainment (the majority of enhanced I/M areas), the ratios could be calculated by dividing the annual program costs, from Table 6-3, and dividing them by the annual tons of hydrocarbon reductions. The results are shown in Table 6-4. Unlike the total costs in Table 6-3, the cost per ton decreases with program stringency. This is because a

major part of the cost is the inspection and the small marginal cost of doing a more effective test is overwhelmed by the large marginal benefit. This is a critical factor to keep in mind when choosing among various different ozone control strategies.

Table 6-4

Cost per Ton Allocating All Costs to VOC

| Scenario | Costs per Ton |
|---|---|
| Basic I/M | $5,410 |
| Low Option | $4,404 |
| Medium Option | $2,621 |
| High Option (Annual) | $1,694 |
| Biennial High Option | $879 |

Since the I/M program yields CO benefits as well as VOC benefits and some areas need reductions in both, it makes sense to split the cost among pollutants. High-tech I/M can also obtain significant $NO_x$ benefits and many ozone areas may need $NO_x$ control as well to bring ozone levels into compliance with EPA standards. To estimate the cost of only the VOC portion of the I/M benefit, one can assess what the cost would have been to obtain the CO and $NO_x$ reductions by other strategies. If all the program costs were allocated to $NO_x$ reductions (which only occur in the high option program), then the cost per ton for the annual high-tech program would be $6,298 per ton and for the biennial high-tech program $3,267 per ton of $NO_x$ benefit. Alternative costs for $NO_x$ reductions are estimated using cost per ton figures to obtain stationary source $NO_x$ reductions through the use of more efficient burners, estimated at $300 per ton. Allocating all of the program costs to CO yields a cost per ton of about $143 for the biennial high option. Costs for other control programs range from roughly $100-225 (without fuel economy benefits) for cold temperature CO standards. Oxygenated fuels programs range from about $200-400 per ton. A conservative, alternative cost per ton figure of $125 was chosen for this analysis. These alternative cost per ton figures are then multiplied by the annual ton reductions attributable to the various program scenarios. Other assumptions about the cost of alternate CO or $NO_x$ programs would change the cost remaining to allocate to VOC. Higher costs would leave less to assign to VOC and vice-versa.

Since CO reductions are not needed in all areas, and only about 44% of the vehicles that will be subject to enhanced I/M are in CO areas, costs are not assigned in all areas. This is done by

reducing the tons of emission reduction to 44% of full benefit and using that result to calculate the alternative cost per ton.

The results are shown in Table 6-5. As expected the costs are lower in all cases, and the biennial high option program is about $461 per ton.

Table 6-5

VOC Cost per Ton Accounting for $NO_x$ and CO Benefit

| Scenario | Cost Per Ton |
|---|---|
| Basic I/M | $4,518 |
| Low Option | $3,655 |
| Medium Option | $2,242 |
| High Option (Annual) | $1,271 |
| Biennial High Option | $461 |

### 6.2.4 National Cost of Choosing Low Option I/M

The Clean Air Act requires nonattainment areas to meet specific milestones of 15% reduction in VOC emissions by 1996 and a 3% reduction per year thereafter. There are two ways for states to achieve these goals: impose additional controls on stationary sources (i.e., those beyond RACT requirements) or additional controls on mobile sources. The question is: What is the cost of doing a less stringent I/M program and getting additional reductions from stationary sources instead?

A low performance standard for I/M means fewer tons of VOC reductions than a high option program, as shown in Table 6-6. The low option system, even when implemented in a centralized network, costs more per ton than the high-tech approach. Thus, if states choose to implement a low option program there is a direct cost to the nation because of the higher expense. In addition to the direct cost, there is also an indirect cost. As more and more controls are imposed on stationary sources, the law of diminishing returns would predict that the cost per ton will rise. It is estimated that the cost of these marginal controls will likely exceed $5,000 per ton.

Table 6-6

Total Cost and Benefits of I/M Options

| Per Million Vehicles | Tons | Total Cost |
|---|---|---|
| High Option | 6,724 | $8,544,000 |
| Centralized Low Option | 2,245 | $8,204,000 |
| Decentralized Low Option | 2,245 | $17,062,000 |

To estimate the total cost of implementing a low option program it was assumed that of the 56 million vehicles subject to enhanced I/M 42 million vehicles would be in a decentralized system and 14 million would be centralized. This reflects the current mix of programs in the affected areas. It was also assumed that each ton not obtained from I/M would be gotten from stationary source controls at $5000 per ton. The results are shown in Table 6-7. The extra direct cost of the low option would be about $353 million while the indirect cost of the more expensive stationary source controls amounts to about $1,254 million, for a total of about $1.6 billion in excess cost.

Table 6-7

Excess Cost of Choosing Low Option I/M

| | Vehicles millions | Benefits tons | Cost millions |
|---|---|---|---|
| High Option | 56 | 376,529 | $479 |
| Low Option Centralized | 14 | 31,426 | $115 |
| Low Option Decentralized | 42 | 94,279 | $717 |
| Total Low Option | 56 | 125,705 | $832 |
| High - Low | | 250,824 | $353 |
| Stationary Cost @ $5000/ton | | | $1,254 |
| Total Excess Cost | | | $1,607 |

## 6.3 National Costs and Benefits

### 6.3.1 Emission Reductions

Estimates of the total costs and emission reduction benefits of current and future I/M programs were obtained using CEM4.1. Because average costs and effectiveness vary between centralized

and decentralized programs[10] the costs and reductions were modeled differently for each program type. The MOBILE4.1 output showing the scenarios used are in Appendix K. Vehicle population figures are needed in order to calculate total costs and emission reductions. Because figures obtained from the states vary in reliability, estimates were derived based upon Census data for each area.

As shown in Table 6-8 below, current I/M programs obtain estimated total annual emission reductions of 116,000 tons of VOC and 1,566,000 tons of CO. Implementation of the high option requirements of this proposed action on a biennial basis would yield estimated annual emission reductions of 384,000 tons of VOC and 2,345,000 tons of CO from enhanced I/M programs, and 36,000 tons of VOC and 500,000 tons of CO from basic programs. Enhanced I/M programs would also reduce $NO_X$ emissions. The transient test with $NO_X$ cutpoints designed to fail 10% to 20% of the vehicles would yield estimated $NO_X$ reductions of 9% relative to emission levels with no program in place.

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[10]Tierney, E.,J. "I/M Network Type: Effects on Emission Reductions, Cost, and Convenience," U.S. EPA Technical Information Document, number EPA-AA-TSS-I/M-89-2, January 1991

Table 6-8

National Benefits of I/M

(tons of emissions reduced annually)

| | VOC | CO |
|---|---|---|
| Reductions from Continuing I/M Unchanged | | |
| Centralized Areas | 55,540 | 775,228 |
| Decentralized Areas | 60,476 | 791,167 |
| Current Total | 116,016 | 1,566,395 |
| Expected Reductions from Proposal | | |
| Enhanced Areas | 384,130 | 2,345,278 |
| Basic Areas | | |
| Centralized | 23,289 | 326,290 |
| Decentralized | 12,996 | 174,186 |
| Basic Total | 36,285 | 500,476 |
| Total Future Benefits | 420.415 | 2,845,754 |

Thus, enhanced I/M and improvements to existing and new I/M programs will result in national emission reductions substantially greater than current I/M programs.

### 6.3.2 Economic Costs to Motorists

EPA has developed estimates of inspection and repair costs in a "high-tech" I/M program. The derivation of these estimates is detailed in section 5.0. A conventional steady-state I/M test including ATP currently costs about $8.50 per vehicle on average in a centralized program, and $17.70 per vehicle on average in a decentralized program. A complete high-tech test, including transient, purge, and pressure testing, is expected to cost approximately $17 per vehicle in an efficiently run high-volume centralized program. In a program where 1984 and later vehicles received the high-tech test, and older vehicles received a steady-state test and ATP, and the inspection were performed biennially, the estimated annual per vehicle cost would be about $9. The cost is sensitive to whether test equipment and personnel face a steady stream of vehicles or have idle periods. Therefore the cost would be somewhat higher in a test-only multi-participant system if the

inspection network had more excess capacity than a typical centralized program. Test-only stations may also not be as proficient in testing each vehicle quickly, adding somewhat to costs.

The overall average repair cost for transient failures is estimated to be $120. Average repair costs for pressure and purge test failures are estimated to be $38 and $70, respectively. Repairs for $NO_x$ failures are estimated to cost approximately $100 per vehicle. Data from the Hammond test program indicate that it would be very rare for one vehicle to need all three of these repair costs.

These repairs have been found to produce fuel economy benefits that will at least partially offset the cost of repairs. Fuel economy improvements of 6.1% for pressure test failures and 5.7% for purge test failures were observed. Vehicles that failed the transient short test at the proposed cutpoints were found to enjoy a fuel economy improvement of 12.6% as a result of repairs. Fuel economy improvements persist beyond the year of the test.

Currently, there are an estimated 63,550,000 vehicles subject to I/M nationwide. Of these, 23,574,000 are in centralized programs and 39,976,000 are in decentralized programs (see Appendix K). Inspection fees currently total an estimated $747 million annually, $182 million in centralized programs, and $565 million in decentralized programs. Repair costs are estimated at $392 million, $140 million in centralized programs, and $252 million in decentralized programs. Current fuel economy benefits are estimated at $245 million, $92 million in centralized programs, and $153 million in decentralized programs.

As shown in Table 6-9 below, estimates using EPA's cost effectiveness model show that total inspection costs in the year 2000 in enhanced I/M programs accounting for growth in the size of the vehicle fleet are expected to be $451 million, with repairs totaling $710 million assuming that programs are biennial. Fuel economy benefits are expected to total $825 million, with $617 million attributable to the tailpipe emissions test and $208 million due to the functional evaporative tests.

In basic I/M programs, total annual inspection costs in the year 2000 are estimated at $162 million, and repair costs are expected to be approximately $113 million.

Thus, despite significant increases in repair expenditures as a result of the program, the switch to biennial testing and the improved fuel economy benefits from programs will result in a lower national annual cost of the inspection program.

Table 6-9

Program Costs and Economic Benefits

(millions of dollars)

| | Test Cost | Emission Test Repair Cost | Evap Repair Cost | Emission Test Fuel Economy Savings | Evap Fuel Economy Savings | Net Cost* |
|---|---|---|---|---|---|---|
| Costs and Economic Benefits of Continuing I/M Unchanged | | | | | | |
| Central | $182 | $140 | na | ($92) | na | $230 |
| Decentral | $565 | $252 | na | ($153) | na | $664 |
| Total | $747 | $392 | | ($245) | | $894 |
| Expected Costs and Economic Benefits From Proposal | | | | | | |
| Enhanced | $451 | $489 | $221 | ($617) | ($208) | $336 |
| Basic | | | | | | |
| Central | $67 | $60 | na | ($39) | na | $88 |
| Decentral | $95 | $53 | na | ($31) | na | $117 |
| Total | $162 | $113 | | ($70) | | $205 |
| Grand Total | $613 | $602 | $221 | ($687) | ($208) | $541 |

* Net cost is derived by adding inspection and repair costs and subtracting fuel economy benefits.

## 6.4 Motorist Inconvenience Costs

There is an additional cost factor associated with I/M, the cost of the time spent by vehicle owners in complying with the inspection requirement. This cost was estimated by assuming that motorists' leisure time is worth about $20 per hour. The amount of time spent getting an inspection can vary considerably as well and very little data on this subject is available. For the purpose of this analysis, it was assumed that motorists typically spend roughly 45 minutes travelling to the test site, getting tested, and returning in an efficiently designed high volume test program.

EPA calculated the cost effectiveness of the biennial high option with this additional cost included. Table 6-10 below shows

the estimated total program cost per million vehicles, the cost per ton with all costs allocated to VOC reduction, and the adjusted cost per ton of VOC with costs allocated among pollutants as discussed previously.

Table 6-10

Costs of the Biennial High Option including Inconvenience

| | |
|---|---|
| Total Cost | $12,254,000 |
| Cost per Ton | |
| All costs to VOC | $1,983 |
| Cost per Ton | |
| Adjusted VOC Cost | $1,566 |

Comparing these figures with those in Tables 6-4 and 6-5 show that the biennial high option, with motorist inconvenience costs included, is still more cost effective than the low and medium options without those costs considered.

## 7.0 REGULATORY FLEXIBILITY ANALYSIS

### 7.1 Regulatory Flexibility Act Requirements

The Regulatory Flexibility Act recognizes three kinds of small entities and defines them as follows:

- Small business - any business which is independently owned and operated and not dominant in its field as defined by Small Business Administration regulations under section 3 of the Small Business Act.
- Small organization - any not-for-profit enterprise that is independently owned and operated and not dominant in its field (e.g., private hospitals and educational institutions).
- Small governmental jurisdiction - any government of a district with a population of less than 50,000.

Small governmental jurisdictions, as defined above, are exempted from the requirements of this regulation. There are no private non-profit organizations involved in the operation of I/M programs. Consequently this analysis will be limited to the affects on certain small businesses, namely providers of inspection and repair services and of inspection equipment.

There is a significant impact on small entities whenever the following criteria are satisfied:

- Annual compliance costs (annualized capital, operating, reporting, etc.) increase total costs of production for small entities for the relevant process or product by more than 5%

- Compliance costs as a percent of sales for small entities are at least 10% higher than compliance costs as a percent of sales for large entities

- Capital costs of compliance represent a significant portion of capital available to small entities, considering internal cash flow plus external financing capabilities

- The requirements of the regulation are likely to result in closures of small entities

The enhanced I/M performance standard contained in the proposed action includes new "high-tech" test procedures for newer vehicles and enables states to obtain significantly higher emission reductions from their I/M programs than they have previously. This performance standard will affect different types of businesses differently. Test providers will need to invest in new equipment. Repair providers will be repairing more vehicles for more types of inspection failures. The enhanced performance standard will also affect different types of inspection networks differently.

### 7.1.1 The Universe of Affected Entities

The Regulatory Flexibility Act's definition of "small business" is based on the Small Business Administration's (SBA) definitions. These are listed in 13 CFR Part 121 by Standard Industrial Code (SIC) categories. The types of businesses that have either been licensed to perform inspections or have been involved in I/M in some other way, such as by selling inspection equipment, and their SIC categories are listed in Table 7-1, along with the size cutoffs used by SBA to define small business for each. Size cutoffs are defined either in terms of number of employees or gross annual revenue, expressed in millions of dollars.

Table 7-1

Affected Businesses

| SIC | Description | Cutoff |
|---|---|---|
| 5013 | Automotive Part and Supply Wholesalers (i.e., auto engine testing equipment, electrical) | 100 employees |
| 5511 | Motor Vehicle Dealers (New and Used) | $11.5 M |
| 5521 | Motor Vehicle Dealers (Used) | $11.5 M |
| 5531 | Auto and Home Supply Stores | $3.5 M |
| 5541 | Gasoline Service Stations | $4.5 M |
| 7531 | Top and Body Repair Shops | $3.5 M |
| 7534 | Tire Retreading and Repair Shops | $7.0 M |
| 7535 | Paint Shops | $3.5 M |
| 7538 | General Automotive Repair Shops | $3.5 M |
| 7539 | Auto Repair, Not Elsewhere Classified, (e.g., radiator shops muffler shops, transmission shops, etc.) | $3.5 M |
| 7549 | Automotive Services, Except Repair and Car Washes (e.g., diagnostic centers, inspection centers, towing etc.) | $3.5 M |

Note that although all analyzer manufacturers are "affected," the size cutoff of 100 employees prevents them from meeting the definition of "small business."

## 7.2 Types of Economic Impacts of Concern

This analysis looks at the types of impacts that inspection and repair providers in existing programs will experience as a result of the requirements of the proposed action. Since the requirements for basic I/M programs will remain essentially the same as the current I/M requirements, significant impacts are not expected in these programs. Hence, this analysis will focus on existing I/M programs that will have to become enhanced. This analysis assumes that the enhanced program implemented will reflect the high option on the basis that this would represent a "worst case" scenario (i.e., that with the greatest economic impact potential).

## 7.3 Changes in Repair Activity

The repair industry in enhanced areas that currently have I/M programs will enjoy a significant increase in repair revenues. The repair industry consists of motor vehicle dealers (SICs 5511 and 5521), general automotive repair shops (SIC 7538) and some gasoline service stations (SIC 5541).

### 7.3.1 Repair Activity in Current I/M Programs

Reliable data do not exist on the number of repair facilities in I/M program areas that do I/M repairs. However, repair revenues that accrue to the industry as a whole can be estimated using vehicle population data. EPA estimates that there are 64 million vehicles in current I/M program areas, 24 million of which are in areas with centralized programs. Of these, an estimated 15 million are in areas that will become enhanced. There are an estimated 40 million vehicles in decentralized programs. Of these, about 33 million are in areas that must implement enhanced I/M.

Repair cost information is generally not collected by the states except when a motorist applies for a waiver. However, as described in section 5.6, estimates of total repair costs can be made using CEM4.1. EPA estimates that $392 million worth of repair business would be generated by current I/M programs in the year 2000 if these programs continued unchanged, $302 million in areas that will go enhanced. Of this latter figure, an estimated $89 million would be performed in areas that currently operate centralized programs and $213 million in areas with decentralized programs.

### 7.3.2 Repair Activity in Future I/M Programs

The transient test, with its superior ability to identify excess emissions, is expected to generate more repairs than the steady-state tests, while the purge and pressure tests will enable I/M programs to identify excess evaporative emissions for the first time. Estimates using CEM4.1 indicate that an additional $100 million in annual repair business will be generated in areas that currently operate centralized programs, and an additional $212 million in areas that currently operate decentralized programs as a result of the requirements proposed in this action. The additional emission repairs identified by the transient test are expected to generate an additional $41 million in areas that currently have centralized programs and $79 million in areas that currently have decentralized programs. The addition of purge and pressure testing is expected to generate an additional $59 million in areas that currently have centralized programs, and $132 million in areas that currently have decentralized programs. Thus the repair industry in these areas is estimated to receive an additional $312 million, and a total of $613 million annually as a result of the proposed action, as summarized in Table 7-2.

Table 7-2

Repair Expenses in Enhanced I/M Programs

(millions of dollars)

| | Centralized | Decentralized | All Programs |
|---|---|---|---|
| Current | $89 | $213 | $302 |
| Additional | | | |
| Transient Repairs | $41 | $79 | $120 |
| Evaporative Repairs | $59 | $132 | $191 |
| Total New | $100 | $211 | $311 |
| Total | $189 | $424 | $613 |

The $311 million in extra repair expenditures is estimated to comprise about 40% parts cost and the remainder for labor, profit, and overhead. The automotive parts industry estimates that 20,000 jobs are created for every $1 billion spent on parts. Hence, the additional parts demand ($125 million) will create 750 jobs in parts manufacturing as well as additional business for retailers and distributors, and is likely to create more jobs for clerks and delivery employees. The remaining 60% is estimated to comprise about 50% profit and overhead at the repair shop and 50% labor. Hence, mechanics will earn an additional $93 million over all program areas. At an average pay rate of $25 per hour, this

translates into 1,800 full time equivalents (FTE) over all program areas.

Firms that pursue this repair business may need to upgrade repair technician skills and obtain additional diagnostic and other equipment to perform effective repairs on new technology vehicles. Inspection stations in decentralized programs, as well as many repair shops in centralized programs, possess emission analyzers. These will be useful in testing those vehicles still subject to steady-state tests and may be used to diagnose vehicles failing the transient test and to assess repair success. BAR90 analyzers, in particular, are designed to function as a platform for a variety of engine diagnostic functions and to download OBD fault codes.

## 7.4 Changes in Emission Testing Activity in I/M Areas

### 7.4.1 The Existing Market in Centralized and Decentralized Programs

A number of different types of entities are involved in providing inspections. The centralized programs in the States of New Jersey, Delaware, Oregon, and Indiana are operated by the state, those in the cities of Memphis, Tennessee, and Washington, D.C. are operated by the local government. These programs cover approximately 6 million vehicles. All of these programs except Oregon and Memphis will be subject to the enhanced I/M requirement. Therefore, 5 million vehicles in government operated programs will be covered by this requirement. The remaining 18 million vehicles are in programs operated by private contractors (SIC 7549), of which 10 million vehicles are in areas covered by the enhanced I/M requirement. Both the government agencies, and the private contractors exceed the cutoffs for small entities.

Inspection providers in decentralized programs fall into all SIC categories in Table 7-1 except 5013 - Automotive Part and Supply Wholesalers. However, the prevalence of the different categories among licensed inspection stations varies. The total number of inspection stations in decentralized areas covered by the enhanced I/M requirement are listed in Table 7-3.

Table 7-3

Number of Inspection Stations by State

| State | Stations |
|---|---|
| California | 8,752 |
| Colorado | 1,500 |
| Georgia | 647 |
| Houston | 1,100 |
| Louisiana | 140 |
| Massachusetts | 2,800 |
| Nevada | 415 |
| New Hampshire | 243 |
| New York | 4,300 |
| Pennsylvania | 3,838 |
| Rhode Island | 950 |
| Virginia | 370 |
| Total | 25,055 |

Data on the distribution of inspection stations among the different categories are not collected by most states, neither is data on the number of stations that fall below the cutoffs for small entities listed in Table 7-1. However, listings of inspection stations were obtained from California and Pennsylvania and stations were broken down into the following categories: Service Stations, gas stations that also perform repairs (5541); Dealerships (5511 and 5521); Independent Repair Shops (7538); Non-Engine Repair Shops, such as tire shops, body shops, or transmission shops (7531, 7534, 7535, and 7539); Retailers (5531); and Test Only Stations (7549). The California data is based on an analysis of the entire station population. The Pennsylvania data is based on an analysis of a 10% random sample of licensed stations.

Table 7-4

Inspection Stations by Category

California

| Station Type | Number | Percentage |
|---|---|---|
| Service Stations | 2,183 | 27 |
| Dealerships | 1,361 | 17 |
| Independent Repair Shops | 3,272 | 41 |
| Non-Engine Repair Shops | 734 | 9 |
| Retailers | 276 | 3 |
| Test Only Stations | 131 | 2 |
| Total | 7978 | |

Pennsylvania

| Station Type | Number | Percentage |
|---|---|---|
| Service Stations | 124 | 36 |
| Dealerships | 95 | 27 |
| Independent Repair Shops | 67 | 19 |
| Non-Engine Repair Shops | 46 | 13 |
| Retailers | 16 | 5 |
| Test Only Stations | 0 | 0 |
| Total | 348 | |

Information on number of subject vehicles in each I/M program, and the inspection fee and the portion of the fee returned to the state in each program is readily available. EPA also gathers data on the number of licensed stations in decentralized programs. With this information, inspection station revenue in decentralized programs can be estimated. These estimates for programs in enhanced I/M areas are presented in Table 7-5.

Table 7-5

Inspection Station Volumes and Incomes

| Program | Stations | Vehicles per Year | Vehicles /Station | Fee | State Share | Net Revenue |
|---|---|---|---|---|---|---|
| California [11] | 8,752 | 6,426,636 | 734 | $48.39[12] | $6.00 | $31,127 |
| Colorado | 1,500 | 1,655,897 | 1,104 | $9.00 | $1.50 | $8,279 |
| Georgia | 647 | 1,118,448 | 1,729 | $10.00 | $0.50 | $16,422 |
| Houston[13] | 1,100 | 1,482,349 | 1,348 | $11.25 | $3.50 | $10,444 |
| Louisiana[13] | 140 | 145,175 | 1,037 | $10.00 | $5.25 | $4,926 |
| Massachusetts | 2,800 | 3,700,000 | 1,321 | $15.00 | $2.50 | $16,518 |
| Nevada | 415 | 523,098 | 1,260 | $16.00 | $3.00 | $16,386 |
| New Hampshire | 243 | 137,137 | 564 | $14.00 | $1.25 | $7,195 |
| New York† | 4,300 | 4,605,158 | 1,071 | $17.00 | $1.25 | $16,868 |
| Pennsylvania | 3,838 | 3,202,450 | 834 | $8.48 | $0.48 | $6,675 |
| Rhode Island | 950 | 650,000 | 684 | $12.00 | -0- | $8,211 |
| Virginia | 370 | 481,305 | 1,301 | $12.50 | $1.10 | $14,829 |
| Total | 25055 | 24,127,653 | | | | |
| Averages weighted by # of stations | 2,088* | 2,010,638* | 963 | $15.39 | $3.35 | $18,914 |

* Simple averages (i.e., non-weighted)

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[11] BAR 90 analyzers are used in these programs. All others currently use BAR 84 except Houston, Louisiana, and Rhode Island.

[12] This figure was supplied to EPA by the State in October of 1991 and represents an estimate based upon data from calendar year 1990. In its Third Report to the Legislature (December 1991), the I/M Review Committee reported an average cost per inspection of $36.23. This number is based upon a survey conducted in September 1991, and includes only the cost of the inspection (not the $6 fee for the certificate). The resulting figure of $42.23 suggests that, at least during September 1991, the average fee charged to motorists may have dipped slightly.

[13] Current I/M inspection is anti-tampering only. Station, vehicle, and income data may change with the addition of tailpipe emissions testing.

The costs incurred by inspection stations are driven by a number of factors. Labor (i.e., the amount of time required to perform the inspection and the inspector's hourly wage) appears to be the largest component of cost. The cost of the analyzer is the second largest component. PC-based (BAR 90) analyzers are the latest generation of analyzers used in decentralized programs. Their cost can vary from $13,000 to $20,000. The most common price appears to be approximately $15,000 each. A number of service station based programs in areas required to implement enhanced I/M are currently using BAR 84 analyzers. These cost approximately $5,000 each. Many stations in the older BAR 84 programs have paid off the cost of their analyzers, which in turn decreases their annual inspection expenses. Analyzer service contracts and calibration gas add lesser increments to the total cost.

Estimates were made of the typical costs incurred by inspection stations, net profits were estimated and the results presented in Table 7-6. While large businesses may be able to afford to purchase current analyzer equipment outright, the smaller entities, with which this analysis is concerned, often have to finance these purchases. Analyzers are assumed to be purchased and paid off over a five year period at a 12% rate of interest. Conversations with program personnel in decentralized programs indicated that inspectors are paid about $15 per hour. Overhead (employers taxes, benefits, etc.) is assumed to be 40%, for a total labor cost of $21 per hour.

Some cost factors are subject to regional variability. Local data, as reported by state program officials and EPA Regional offices, is used for such parameters as number of vehicles per station per year, average length of test, and cost of service contracts. Labor and equipment costs are estimated as described previously. In programs where the equipment specification is more than five years old, the analyzers are assumed to be paid off. This, in turn, increases the stations' profits. The results are listed in Table 7-6.

Table 7-6

Average Inspection Station Revenues, Costs, and Profits

| State | Vehicles /Station | Fee | Net Revenue | Annual Cost | Net Profit |
|---|---|---|---|---|---|
| California[11] | 734 | $48.39 | $31,127 | $11,899 | $19,228 |
| Colorado | 1,104 | $9.00 | $8,279 | $5,202 | $3,078 |
| Georgia | 1,729 | $10.00 | $16,422 | $9,320 | $7,102 |
| Houston[13] | 1,348 | $11.25 | $10,444 | $7,075 | $3,369 |
| Louisiana[13] | 1,037 | $10.00 | $4,926 | $5,444 | ($518) |
| Massachusetts[14] | 1,321 | $15.00 | $16,518 | $13,498 | $3,020 |
| Nevada | 1,260 | $16.00 | $16,386 | $7,681 | $8,705 |
| New Hampshire | 564 | $14.00 | $7,195 | $4,257 | $2,938 |
| New York[11] | 1,071 | $17.00 | $16,868 | $20,268 | ($3,400) |
| Pennsylvania[14] | 834 | $8.50 | $6,675 | $2,811 | $3,864 |
| Rhode Island[14] | 684 | $12.00 | $8,211 | $2,653 | $5,557 |
| Virginia | 1,301 | $13.50 | $14,829 | $5,546 | $9,283 |
| Average | 963 | $15.39 | $18,914 | $10,818 | $8,096 |
| Average w/o CA | 1,086 | $12.39 | $12,357 | $10,238 | $2,120 |
| Average w/o CA & NY | 1,091 | $11.93 | $10,741 | $6,645 | $4,097 |

This analysis revealed anomalies in the California and New York programs relative to the others. California has a much higher average fee than the other programs, and estimated average profit is nearly twice that of the next highest program. The estimate for New York reflects an unusually long test duration (see Table 7-11) and shows the average station operating at a loss; this estimate is supported by reports that station operators have sued the state to be allowed to charge a higher fee. Therefore, average revenues and profits were also calculated with data from those states omitted.

These figures, based on the average inspection volumes for each state, show that inspection services, by themselves, do not

[14] Due to the age of the state analyzer specification, analyzer costs are assumed to be paid off in stations in these programs.

yield significant profit to the average inspection station. While the average profit is low, the amount of revenue and profit can vary a great deal among inspection stations since inspection volumes vary considerably as well. The best available data on station volumes was obtained from the California program. The data covers a three month time period and is shown in Table 7-7.

Table 7-7

Inspection Volumes in California

| Tests | Stations | % Total | % Active Stations |
|---|---|---|---|
| 0 | 1,958 | 22 | NA |
| 1-100 | 1,156 | 13 | 17 |
| 101-200 | 1,676 | 19 | 25 |
| 201-300 | 1,178 | 13 | 17 |
| 301-400 | 754 | 9 | 11 |
| 401-500 | 469 | 5 | 7 |
| 501+ | 1,571 | 18 | 23 |
| Total | 8,752 | | |
| Total Active | 6,794 | | |

EPA analyzed revenues and profits for inspection stations at different volumes; the results are presented in Table 7-8. Revenues, costs and profits are calculated as in Tables 7-5 and 7-6. California has a market based inspection fee, (i.e., stations charge what the market will bear, since the state does not regulate the fee). Conversations with California program officials indicate that higher volume stations charge lower fees than the average. The fees assumed for 1,200 and 2,000 inspection per year cases are based on figures suggested by the state.

Table 7-8

Station Revenues and Profits by Volume

| Veh/Qtr | Veh/Year | Fee | Net Revenue | Annual Cost | Net Profit |
|---|---|---|---|---|---|
| 0 | 0 | $48.39 | $0 | $5,474 | ($5,474) |
| 100 | 400 | $48.39 | $16,956 | $8,974 | $7,982 |
| 300 | 1200 | $42.00 | $43,200 | $15,974 | $27,226 |
| 500 | 2000 | $32.00 | $52,000 | $22,974 | $29,026 |

These figures indicate that inspections can be profitable if volume is high, however, relatively few stations have high inspection volumes. Based on the data in Table 7-7, 22% of the licensed stations perform no inspections and therefore are losing money invested in equipment, licensing, and training (only equipment costs are estimated here). An additional 32% perform 800 inspections per year or less, and therefore appear to be earning only a modest level of profit. 22% perform from 800 to 1,600 inspections per year, and an additional 23% perform more than 1,600 inspections per year. Profitability is higher in these latter two categories.

### 7.4.2 Future Market in Enhanced I/M Programs

Test providers will be required to invest in new equipment for that portion of the subject vehicle fleet that will undergo transient, purge, and pressure testing. The total cost to re-equip an existing inspection site to perform the new tests is estimated at about $144,000. EPA based this estimate on conversations with equipment manufacturers over the past year; more recent information indicates that a lower figure is likely.

### 7.4.3 Centralized Programs

As indicated in section 5.0, throughput rates would be lower in centralized lanes performing transient, purge, and pressure testing than in inspection lanes performing the current test procedures. Since programs will be able to switch from an annual inspection frequency to biennial at the same time they implement the high-tech tests, EPA does not anticipate that a significant number of new inspection lanes will need to be built in centralized programs in order to satisfy the proposed requirements and maintain waiting times at minimal levels.

### 7.4.4 Decentralized Programs

Enhanced areas that currently have decentralized programs will have two options in meeting the requirements of the proposed

action: they can institute either a multi-participant test-only network, or a single operator centralized system.

If a program were to switch to a multi-participant, test-only system, stations that currently participate in the test and repair network would have a choice between concentrating on inspections, and becoming test-only stations, or concentrating on repairs. That choice would likely be driven by the station's current inspection volume and the degree to which its prospective income is expected to be derived from inspection as opposed to repair and other services. This analysis utilizes the simplifying assumption that stations that perform a large volume of inspections, and that currently derive more income from inspection than from repair or other services, would be likely to become test-only stations. By the same reasoning, stations that are more oriented toward repair would focus on the additional repair business generated by the inspections conducted elsewhere.

Data correlating average inspection volume with station type are not available. However, survey data of motorists in I/M programs point to the fact that stations that currently focus on repair work and that do a steady volume of repairs are often unable to make facilities available to provide inspections promptly on request[15]. 27% of motorists in decentralized programs reported being asked to bring their vehicles back for testing another time. 20% reported having to take their vehicles to more than one station to obtain a test. Nearly one out of three had to leave their vehicles for inspection. On the average, the vehicles had to be left for five hours. These data suggest that a focus on repair leads to reduced opportunities to perform inspections and probably to lower inspection volumes as a result.

The converse appears also to be true. Stations that are readily able to provide inspections are often either unable, or simply have not chosen to perform repairs. 53% of motorists reported taking their vehicle to another station, other than the one where the inspection was performed, for repairs.

Based on the data from Pennsylvania and California, the following distribution of station types is assumed for this analysis:

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[15] "Attitudes and Opinions Regarding Vehicle Emission Testing," Riter Research. September, 1991

Table 7-9

Assumed Station Distributions

| Station Type | Percentage |
|---|---|
| Service Stations | 32 |
| Dealerships | 22 |
| Independent Repair Shops | 30 |
| Non-Engine Repair Shops | 11 |
| Retailers | 4 |
| Test Only Stations | 1 |

Some stations, such as dealerships and independent repair shops, would be likely to concentrate on I/M repairs since their business already has a decided orientation toward engine repairs. Together, these constitute 52% of the assumed station population. Because of their focus on repair, it is likely that these stations tend to have lower inspection volumes, as discussed above, and some of them are likely to be among the 22% of stations that report no testing activity. For the purposes of this analysis, it is assumed that half of the inactive inspection stations are in this repair-oriented group.

These repair oriented stations will likely get the majority, though not all, of the additional repair business estimated previously at $211 million among all decentralized programs. If these stations ultimately get 85% of this business (allowing for 15% of the repair stations to come from other categories, mainly service stations) it will amount to annual revenues of roughly $13,000 per year. This would offset inspection losses of $10,000 to $12,000 per year (Table 7-6).

The stations that have higher inspection volumes than average are likely to be deriving a substantial portion of their current profit from the inspection business and relatively little or none from repair. Based on the California data, it is assumed that the 23% of the stations that have inspection volumes of approximately 200% of the program average or more would be likely to opt to become test-only stations. Test-only stations, in those decentralized programs where they exist, would, of course, be in this group.

Some stations in this high volume group may be repair-oriented stations, such as dealerships, independent repair shops, and some service stations, and may prefer to opt out of the inspection business for more profitable repair business. This would create opportunities for other businesses to enter the test-

only market, including stations whose current inspection volume is somewhat lower.

Current repair revenues in decentralized enhanced programs are estimated at $213 million. If this 23% segment of the stations had been getting 23% of this business (based on the foregoing discussion, they have probably been getting less), then they are giving up current annual revenues of $8,500 each in order to pursue the inspection market.

The remaining 25% that do not have a clear orientation toward engine repair, and that do not perform a high volume of inspections, are a mix of service stations, whose business is a mix of gasoline sales and, in some cases, engine repairs including I/M repairs on some portion of the vehicles they test; non-engine repair shops, such as tire shops, muffler shops, transmission shops, etc.; and retailers. Members of this group are assumed to make up the other half of the 22% of stations that do no inspections. These stations would not be adversely affected by this rulemaking since they are currently deriving no income from the inspection business.

This leaves 14% of the population of licensed inspection stations that do not have a clear orientation toward engine repair and derive some income from inspections. Since they are not high volume stations, stations in this group do not derive high profits from inspections on the average. Table 7-10 shows the projected current revenues and profits for these stations assuming that they are evenly distributed among the four low to medium groups in Table 7-7 (those doing 1 to 400 inspections per quarter), assuming that all stations charge the average fee of $48.39. Note also that the numbers of inspections in each category represent the mid-points of the ranges presented in Table 7-7. The column entitled "% Avg Profit" shows the estimated profit for each category as a percentage of the program average profit for California in Table 7-6.

Given that the average profit in California is almost double that for the next most profitable program, the profits calculated based on California data were adjusted to reflect projected national profits for stations with inspection volumes ranging from about 25% to 200% of the average for the program. The national average profits are based on the figure of $4,097 obtained as the average net profit without data from California and New York.

Table 7-10

Revenues and Profits for Low and Medium Volume Stations

| Veh/Qtr | % Avg Vol. | % Total Stations | Net Revenue | Net Profit | % Avg.Profit | Profit Based on Nat'l Avg |
|---|---|---|---|---|---|---|
| 50 | 27 | 3.36 | $8,478 | $1,254 | 6.5 | $266 |
| 150 | 82 | 4.90 | $25,434 | $14,710 | 76.5 | $3,134 |
| 250 | 136 | 3.36 | $42,390 | $28,166 | 146.0 | $5,982 |
| 350 | 191 | 2.38 | $59,346 | $41,622 | 216.0 | $8,849 |

The first two categories, representing 8% of the total number of stations, appear to earn 77% of the program average profit or less. The two higher volume categories, representing roughly 6% of the total station population, derive substantial profits from the inspection business (these estimates are based on data from California which has the most profitable inspection program; profits in other states probably do not increase with increasing test volume as steeply as this analysis suggests, while revenues, on the other hand, do increase in direct proportion to volume). Data on the relative contribution of inspection revenue, compared to other types of business are not available. Some of these stations may be service stations that are currently doing a profitable business in engine repairs, and would continue to do so. Others, such as the 2.38% earning an estimated 216% of the average profit might still opt into the test-only business where a high volume station has opted out, as discussed previously. Others, such as the non-engine repair shops and the retailers have primary lines of business unrelated to I/M.

However, it may be that some of those stations earning 200% or more of the average revenue would be unable to recoup this loss any other way, and would be forced to close. The average revenue loss for these stations would be $37,828 nationally, and $21,482 outside California and New York. It may also be that some of the stations in the lower profit categories are so marginally profitable that loss of inspection business would result in closure as well. If 10% of this group of stations without clear I/M related alternatives (14% of the total) were to close it would amount to a total of roughly 350 stations nationwide.

If a single contractor centralized program were instituted in an area where a decentralized program is currently operating, the option to pursue the test-only business would not be available to the 23% of the station population that would be likely to pursue it. Based on the foregoing analysis, these stations have current inspection volumes of 200% or more of the program average, and may have average profits of roughly 220% or more of the program

average. Members of this group without profitable alternatives would also face the risk of closure.

The likelihood of closure would depend upon the fraction of income derived from inspections. Data on this is not available. Since many of these stations have other lines of business, such as gasoline sales, auto parts sales, or various types of vehicle repair and servicing, the loss of business will not necessarily mean closure. The fraction of these stations that would be unable to recoup this loss and face closure is difficult to estimate given the paucity of data. However, if, as before, 10% of these stations were to close as a result of a switch to a single-contractor centralized system, as well as 10% of the 14% of stations identified previously as being at risk, then 927 stations might close nationwide if all decentralized programs in enhanced I/M areas switched to centralized, single-contractor systems. If the areas containing half of the current inspection stations were to switch to single-contractor, centralized systems, then potential closures would number about 464.

The most severely impacted would be the test-only stations, which in California comprise 2% of the test stations. Given that they have no other lines of business to compensate for the loss of inspection revenue, these stations would almost certainly close if the area were to switch to a centralized, single-contractor system, unless these stations were able to win the contract (some of these businesses have indicated to EPA they they would try to do so).

### 7.4.5 Impact on Jobs in Decentralized Programs

Table 7-11 shows the number of inspectors in each program, and the average number of inspectors per station for all decentralized enhanced programs except Rhode Island, for which data on the number of inspectors is unavailable. The national weighted average number of inspectors per station excludes the highest and lowest averages in the set, those from New York (program officials in this state have indicated that the total number of licensed inspectors is likely to include individuals no longer working as inspectors) and Massachusetts.

Table 7-11

Numbers of Inspectors per Station by State

| State | Stations | Inspectors | Average | Time per Test |
|---|---|---|---|---|
| California | 8,752 | 18,000 | 2.06 | 25 |
| Colorado | 1,500 | 2,930 | 1.95 | 5 |
| Georgia | 647 | 2,845 | 4.40 | 10 |
| Houston | 1,100 | 2,645 | 2.40 | 15 |
| Louisiana | 140 | 513 | 3.66 | 15 |
| Massachusetts | 2,800 | 1,208 | 0.43 | 25 |
| Nevada | 415 | 1,249 | 3.01 | 10 |
| New Hampshire | 243 | 933 | 3.84 | 5 |
| New York | 4,300 | 21,640 | 5.03 | 40 |
| Pennsylvania | 3,838 | 19,221 | 5.01 | 3 |
| Virginia | 370 | 1,114 | 3.01 | 5 |
| National Weighted Average | | | 2.05 | 20 |

Average station volumes are low (Tables 7-5 and 7-6) - about four per day. Given that there are, on the average, two inspectors per station, and that the average inspection takes twenty minutes to perform, it follows that the average inspector spends 40 minutes per day performing inspections. This works out to 0.08 of an FTE (i.e., inspections take about three hours and twenty minutes out of a forty-hour work week). Hence, inspectors are generally individuals employed primarily for other jobs (in most cases as mechanics) who spend a small amount of their time on inspections. Communications with program officials in these states and EPA's experience in auditing these programs support this conclusion. Table 7-12 shows the estimated total number of FTE devoted to inspections in the different station categories developed in this analysis, using the volume assumptions developed previously.

Table 7-12

Estimated Inspection FTE

| Station Type | % | Number | Tests/Day | FTE |
|---|---|---|---|---|
| Repair Oriented | 52% | 13,029 | 3 | 1,612 |
| Inspection Oriented | 23% | 5,763 | 8 | 1,902 |
| No Inspections | 11% | 2,756 | 0 | 0 |
| Remainder | 14% | 3,508 | 4 | 579 |
| | | | Total | 4,093 |

In most cases, the time spent on inspections could be easily re-oriented toward other tasks if inspection business were to cease, however, some stations might experience some contractions as a result of losing inspection business, and some might close, as estimated previously. For the sake of analysis, all FTEs currently devoted to inspections in decentralized enhanced programs, as shown in Table 7-12, are counted as lost. Estimates are also made of additional FTEs lost as a result of potential station closures.

If a multiple independent supplier program were instituted, it was estimated that 10% of the 14% of stations that have some inspection business, and are not clearly positioned to pursue either the inspection or repair markets, might potentially close. Assuming that these stations have two FTEs in addition to inspector FTEs, total job losses would amount to an additional 700 FTEs.

In the event of a switch to a single-contractor centralized system, 10% of the 23% of stations that would otherwise have pursued the test-only option would also be at risk of closing. Potential closures are estimated to total 927. Average non-inspection FTE per station in this case is assumed to be 2.5 since some larger stations would be included in the risk group. In this case, losses could total an additional 2,318 FTEs.

New jobs would be created by the test-only program, and the increased repair business that would offset these potential losses to the small business community and to labor.

EPA estimates that in a high volume enhanced I/M lane, testing an average of 7.5 vehicles per hour, 3-4 inspectors would be needed per lane instead of the 1-2 typically employed in current high volume systems. Using an industry estimate of 267 FTE per million vehicles, and assuming a 20% retest rate, 5,340 FTEs are required to test the 33 million vehicles in currently decentralized programs on a biennial basis (this estimate is based

on the assumptions and methodology developed in section 5.2 of this report, "Estimated Cost of High-Tech I/M Testing").

In a multiple independent supplier system volume would likely be lower. This analysis estimates that 4,200 inspections per year, or about 16 per day would be likely. Therefore, two or three inspectors per lane would be adequate. If two inspectors per lane were employed, 11,525 FTEs would be created if all current decentralized areas adopted a multiple independent supplier system.

Additional jobs that would be created in the repair sector were estimated previously in this analysis. Approximately 1,217 mechanic FTEs, and 506 FTEs in auto parts manufacturing would be created, in addition to clerical, delivery and other support personnel. The results are summarized in Table 7-13.

Some new inspection facilities would be constructed whether programs adopted multiple independent supplier networks or single contractor networks, also creating jobs. FTE estimates are based on an industry estimate that construction of an inspection station requires 4.79 man years of construction and 5.1 man years of subcontracting. An average station is assumed to have 2.4 lanes. The number of lanes required to inspect the fleet is based on the assumptions of biennial inspections and a 20% retest rate. FTE calculations are based on the assumption that total effort, i.e., modification of existing structures in those areas adopting multiple independent supplier programs and construction of new facilities in those areas adopting single-contractor programs, is equal to that needed to construct lanes for half of the vehicles in decentralized enhanced areas. The results are summarized in Table 7-13.

Table 7-13

Summary of FTE Gains and Losses

(in currently decentralized areas required to do enhanced I/M)

| Losses | # | Gains | # |
|---|---|---|---|
| Current Inspection FTE | 4,093 | | |
| Station Closures | | New Inspector FTE | |
| Multiple Independent | 700 | Multiple Independent | 11,252 |
| Contractor | 2,318 | Contractor | 5,340 |
| | | New Repair FTE | |
| | | Mechanic | 1,217 |
| | | Parts Manufacture | 506 |
| | | Construction | 587 |
| Net Gain | | | |
| Multiple Independent | | | 8,769 |
| Contractor | | | 1,239 |

7.4.6 National Impact on Jobs

EPA has estimated the total FTE in current I/M programs and the projected changes in FTE nationwide as a result of the proposed changes. These are summarized in Table 7-14. Note that Table 7-14 includes areas which will be starting enhanced or basic programs from scratch, while earlier tallies included only areas already operating I/M programs.

Table 7-14

Impact on Jobs of I/M Proposal

Current Test and Repair Jobs

| Inspector Jobs | FTE |
|---|---|
| Decentralized Programs | 6,600 |
| Centralized Programs | 2,500 |
| **Repair Jobs** | |
| Decentralized Programs | 800 |
| Centralized Programs | 1,500 |
| Total Current Jobs | 11,400 |

Future Test and Repair Jobs

| | |
|---|---|
| **Enhanced I/M Programs** | |
| Inspector Jobs | |
| Multiple Independent Supplier | 10,500 |
| Single Contractor | 2,700 |
| Inspector Job Subtotal | 2,700 - 10,500 |
| Repair Jobs | 5,500 |
| **Basic I/M Programs** | |
| Inspector Jobs | 2,700 |
| Repair Jobs | 700 |
| Total Future Inspection and Repair Jobs | 11,600 - 19,400 |

Other Job Gains

| | |
|---|---|
| Parts Manufacturing | 1,034 |

| | |
|---|---|
| Construction | 1,800 |
| Small Business Services | 800 |
| Total Net Gain in Jobs | 3,800 - 11,600 |

Small Business Services are estimated by assuming 15 additional FTEs per urbanized area. The 800 FTEs presented in the table represent the jobs generated in the 52 urbanized areas that do not have I/M programs now, but will be implementing them as a result of the proposed action.

Whether programs adopt a multiple independent supplier network or a single-contractor centralized one there will be shifts in job opportunities with some net gain in either case. Hence, the shift to high-tech enhanced I/M may cause significant shifts in both business and job opportunities. Small businesses that currently do both inspections and repairs in decentralized I/M programs will have to choose between the two. Significant new opportunities will exist in these areas for small businesses to continue to participate. EPA believes there are ways states can help test stations make the transition to an enhanced I/M program.

## 7.5 Mitigating the Impact of Enhanced I/M on Existing Stations

Three potential approaches to helping test stations make the transition are presented here. The first approach would provide direct assistance to stations that might be adversely affected by the transition to a high-tech system. The second would be to design the enhanced program to include transitional mechanisms to soften the impacts of the new system. The third would be for states to establish programs to assist stations and inspectors through retraining and retooling programs. The previous section discussed various strategies to assist repair technicians in the retest process, including free retests and priority access to retest lanes, as well as diagnostic and repair assistance.

In some states that are currently decentralized and will have to implement enhanced I/M, analyzers have been in use for 10 years or more and are fully amortized. In states that upgraded to BAR90 equipment (California and New York), the equipment was purchased since 1990, and has years of useful life left. A number of other states upgraded their equipment to BAR84 in the period from 1987 to 1990. Stations in these areas are likely to still be paying for their equipment (see the footnote to Table 7-6). One means by which the state could provide direct assistance to current test stations would be to set up some type of state-supported analyzer buy-back program for stations that were no longer going to participate in either the test or repair business, possibly using funds obtained from inspection fees. BAR90 analyzers would be needed in the repair business both for diagnostic and repair work

as well as to check whether repairs on old technology vehicles were effective. BAR90 analyzers could also be used to test older technology vehicles in test-only stations. This concept would allow stations that were planning to leave the I/M business to recover all or part of their capital investment for equipment that could not be used for diagnostics and repair. Such a buy-back program might allow a fairer transition to test-only status.

A related strategy would be for EPA, the states, and industry to support the development of new and improved uses for BAR90 analyzers so that current as well as future analyzer owners can use this technology more effectively in the repair process. In particular, it was California's intent in developing the BAR90 specification for the computer in the analyzer, which is an IBM 386 DOS-based system, to become a platform for vehicle diagnosis and repair. EPA, the states, and industry could potentially provide technical and financial support to speed the development of such software. This would not only make better use of the equipment in the field but would serve as an excellent mechanism for providing critical technical assistance and training to the repair community.

A second strategy to mitigate the impacts is to design transitional features into the program. One approach would be to allow test and repair shops to continue to do testing on vehicles not subject to the transient/purge test for some transitional period (note that EPA's recommended enhanced program would require biennial, transient/purge tests on 1984 and later model year vehicles, and biennial steady-state tests on older vehicles). EPA is proposing to permit a phase-out of the decentralized test-and-repair portion of the program such that all vehicles would be inspected in test-only stations starting January 1, 1996. This would allow these decentralized stations to continue to obtain revenue to recover the investment made in testing equipment and would allow additional time to plan other strategies to replace the income to be lost from testing.

A related approach is to allow vehicles that have failed initial inspections in test-only stations to be retested in existing test and repair stations using conventional test techniques during the first inspection cycle. This would allow those stations to attract customers, conduct testing and perform repairs, with the added benefit of sparing the customer from returning to the test-only station for the retest.

A third strategy would be to provide targeted assistance to stations to assure they were able to provide high-tech repair services. This would require pre-program start-up training to bring repair technicians in these stations up to speed on the high-tech tests, vehicle diagnosis, and engine repair. It might mean tuition grants or other financial assistance. This dovetails with stronger repair technician training programs which EPA envisions as being part of future I/M requirements, but differs in

terms of funding, timing, and intensity. This approach might also include financial assistance to stations can for the purchase of equipment to perform sophisticated diagnosis and repair on new technology vehicles or to upgrade tools and equipment for more sophisticated diagnosis and repair.

EPA does not consider this to be an exhaustive list of possible strategies. The Agency expects to receive comments from the states and affected industries on additional ways to mitigate the impacts of upgrading to an enhanced program on current test and repair stations in decentralized programs.

## 8.0 ONBOARD DIAGNOSTICS AND ON-ROAD TESTING

### 8.1 Onboard Diagnostics, Interim Provisions

EPA is required to issue onboard diagnostic (OBD) regulations by May 15, 1992, while I/M programs will begin OBD checks two years after the regulation has been issued. OBD checks are not currently a part of EPA's performance standard and no credit has been assessed for such checks in the MOBILE4.1 model; such will be determined after formal issuance of OBD regulations. For the purpose of this cost-benefit analysis, the impact of OBD has not been addressed. The impact of OBD will be relatively minor up until the attainment deadline for serious areas, in November 1999. EPA will certainly revisit the issue once OBD regulations are final and as their implementation clarifies the potential of this strategy in an I/M setting.

### 8.2 On-road Testing, Interim Provisions

Section 182(c)(3)(B)(i) of the Act requires EPA to establish a performance standard for enhanced I/M "including on-road emission testing." The Act does not specify how programs or EPA are to address the "on-road testing" requirement, and neither is on-road testing defined within the Act itself. While potentially a fruitful supplemental testing strategy, it is clear from the legislative history of the 1990 Amendments that on-road testing was not viewed as a potential replacement for I/M programs, as has been suggested by some. Under the section addressing enhanced I/M programs, the legislative history notes:

> On-road emission testing is to be a part of the emission testing system, but is to be a complement to testing otherwise required since on-road testing is not intended to replace such testing. On-road emission testing may not be practical in every season or for every vehicle, and is not required. However, it should play some role in the state program. It is the Committee's intention that states should take into consideration that the results of on-road emission testing, when used, have not been shown to be consistent with Federal emission testing procedures. [Emphasis added]

In its current proposal for implementing this requirement, EPA has specified that on-road testing be defined as "the measurement of HC, CO, $NO_x$, and/or $CO_2$ emissions on any road or roadside in the nonattainment area or the I/M program," and that it be required in enhanced programs and an option for basic I/M areas. Minimally, the on-road testing effort must evaluate the emission performance of at least 0.5% of the subject fleet each year. EPA believes that the on-road testing requirement can be fulfilled by a range of approaches, including, but not limited to:

remote sensing devices (RSD), random road-side pull-overs using tailpipe tests and emission control device checks, or road-side pull-overs of vehicles with high RSD readings, as well as through the use of portable analyzers that can be placed on the vehicle prior to on-road driving.

Of the above approaches, RSD has gained the most public attention and has generated considerable interest. The objective of RSD is to remotely measure the concentration of emissions from vehicles as they are operated on public roads, and in this aim, RSD fully meets the definition of an on-road testing strategy. In its current version, RSD works by focusing a beam, or, in some cases, multiple beams, of infrared light across the roadway into an infrared detector. The concentration of certain pollutants in the exhaust stream are then determined by measuring the amount of infrared light absorbed at specific wavelengths as it passes through the exhaust in much the same way that astronomers study stellar atmospheres by analyzing specific portions of a star's spectrum. The analysis is tied to a vehicle through the use of a video camera which records the vehicle's license plate as it passes through the beam(s).

Given its non-intrusive nature and potentially high throughput capabilities, RSD warranted further investigation. EPA has conducted a preliminary analysis of RSD (see Appendix L, "Identifying Excess Emitters with a Remote Sensing Device: A Preliminary Analysis") that investigated the comparability of the results obtained to those in the 2500 rpm/Idle test. EPA found that, under controlled conditions and using stringent cutpoints, RSD's performance in measuring CO emissions was comparable to the 2500 rpm/Idle test. Since then, other researchers, such as the California Air Resources Board (CARB), have found that the accuracy of the device for measuring HC emissions, while less accurate than for CO, is within a practical range for roadside monitoring. For example, CARB researchers recently reported to the CARB I/M Review Committee[16] that the device, under highly controlled operating conditions, yielded results that compared to calibrated on-board measurements as follows: the remote sensors accurately measured CO within $\pm$ 5% and HC within $\pm$ 15% of the instrumented vehicle measurements, respectively. EPA, however, knows of no current RSD methodology for detecting and measuring $NO_X$ emissions, although developmental work is being done in this area. EPA encourages the states to be innovative in fulfilling the on-road testing requirement.

There have been and continue to be a number of efforts in the area of RSD evaluation, including those at the University of

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[16] D. Lawson, J. Gunderson, "In-Use Emission Study and High Emitter Phase," Presentation to I/M Review Committee, Sacramento, California, January 29, 1992.

Denver, where the first RSD testing strategies were developed. The bibliography[17] of research in this area continues to grow.

Currently, it is difficult for EPA to project a standard "emission credit" for on-road testing for the purpose of performance standard modeling. Hence, for the purpose of this cost-benefit analysis, the impact of on-road testing is not addressed. Nonetheless, emission reduction credits will be assessed for on-road testing efforts once additional experience is gained in the actual use of various on-road testing strategies, including RSD technology. Under EPA's current proposal, on-road testing programs required by the Act "shall provide information about the emission performance of in-use vehicles, by measuring on-road emissions through the use of remote sensing devices or roadside pullovers including tailpipe emission testing. The program shall collect, analyze and report on-road testing data" as part of the state's annual report to EPA. EPA shall use this data, in conjunction with data gathered as part of the Agency's on-going investigation of these testing strategies, to develop testing protocols and guidance.

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[17] In addition to the sources referenced in Appendix L, the following works have contribute to the body of information concerning RSD.

1. D.R. Lawson, P.J. Groblicki, et. al., "Emissions for In-use Motor Vehicles in Los Angeles: A Pilot Study of Remote Sensing and the Inspection and Maintenance Program," Journal of the Air Waste Management Association, 40(8): 1096 (1990)

2. R.D. Stevens and S.H. Cadle, "Remote Sensing of Carbon Monoxide Emissions," Journal of the Air Waste Management Association, 40(1):39 (1990)

3. G.A. Bishop, D.H. Stedman, et. al., "IR Long-Path Photometry, A Remote Sensing Tool for Automobile Emissions," Analytical Chemistry, 61, 671A-677A (1989)

4. D.H. Stedman and G.A. Bishop, "Evaluation of a Remote Sensor for Mobile Sources CO Emissions," Report to the Environmental Protection Agency, EPA-600-S4-90-032.

5. D.H. Stedman, G.A. Bishop, et. al., On-Road CO Remote Sensing in the Los Angeles Basin, Final Report on Contract No. A932-189, California Resources Board, Research Division, Sacramento, 1991.

6. D.H. Stedman and G.A. Bishop. An Analysis of On-Road Remote Sensing as a Tool for Automobile Emissions Control, ILENR/RE-AQ-90/05, Final Report to Illinois Department of Energy and Natural Resources, Springfield, IL, 1990.

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|---|---|
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# APPENDIX A

## COST EFFECTIVENESS MODEL VERSION 4.1 SOURCE CODE LISTING

```
C
C                #$$$$$$$$   CEM4.1   #$$$$$$$$
C
C           The Cost-Effectiveness Version of MOBILE4.1
C
C
C
C  Re-Revise repair cost adjustment for recurring IM240.   Dec 10, 1991
C  Fix problem in PCLEFT Tech 1 & 2 credits.
C
C  CEM version 4.1E                                        Dec 4, 1991
C  Trial change to CPFUEL, adding IMFLAG to coverage checks.
C  Trial init of CSIZE in RESET.
C  Changed Prg/Prs repair EF benefit from 7.4% to 5.9%
C  Install new PPEFF array in FAIL routine for revised
C    detection rates.
C  Change block FAIL to FAILRT to avoid confusion with
C    Function FAIL().
C  CEM version now based on November 1991 MOBILE4.1,
C
C  CEM version 4.1D                                    November 19, 1991
C  Revise repair cost adjustment for recurring IM240
C    from .0199/10K miles to .0373 constant.
C  Block Data from .0199 to .0373, and remove corresponding FE
C    1.87 adjustment.
C  Still needs revisions for November M4.1:
C    multiple runs and speed correction factors, etc.
C
C  CEM version 4.1C                                     November 6, 1991
C  Re-installed 1.87 FE benefit adjustment factor for non-IM240
C  (as it has been for IM240)
C
C  CEM version 4.1B                                     October 30, 1991
C  Revised FAIL to skip over program reductions when doing
C  recurring case for repair costs.
C  Still has excess code for multiple evaluation years
C  but can not be used.
C                                                       October 18, 1991
C
C  CEM Version 4.1A, 10/17/91, is the last version prior to
C  cutting out the excess evaluation year capability (JCYDX > 2).
C  It includes much unused code and variables, but is fully M4.1
C  compatible plus a couple little fixes (HDV handling in FAIL routine).
C  It includes input file list capability and 'interactive' I/O file
C  specification, but needs revision for November release of M4.1.
C
C
C
C                ****** Release MOBILE4.1 ******          November 4, 1991
C
C
C  Release MOBILE4.1 is derived from I02 (June 12, 1990) MOBILE4.
C
C  See Dnn.T-NOTES for a chronologically ordered summary of the coding changes
C  performed up through the current In-House Version.  See Dnn.T-UGBASE for the
C  In-House MOBILE4 User Guide Supplement for Version Dnn.  All In-House
C  Version files have the Dnn prefix.  The backup tape is *M4.1*, mounted by
C  Dnn.C-TAPE.  All files are on ST99.
C
C  Version 00 was opened 02/28/91 and closed 03/04/91.
C  Version 01 was opened 03/04/91 and closed 04/09/91.
C  Version 02 was opened 04/11/91 and closed 04/30/91.
C  Version 03 was opened 05/01/91 and closed 05/15/91.
C  Version 04 was opened 05/16/91 and closed 05/24/91.
C  Version 05 was opened 05/28/91 and closed 06/05/91.
C  Version 06 was opened 06/06/91 and closed 06/21/91.
C  Version 07 was opened 06/26/91 and closed 07/29/91.
C  Version 07 was rereleased as Corrected M41 on 08/28/91.
C  Version 07 was rereleased as FINAL M41 on 11/04/91.
C
C
C  MOBILE4 is the fourth version of the FORTRAN program implementation of the
C  Mobile Source Emission Model.  It updates and replaces MOBILE3. The model
C  estimates HC, CO and NOx exhaust and HC evaporative emission factors by
C  motor vehicles.  For information on using the program and on the
C  differences between MOBILE3 and MOBILE4, consult the User's Guide to
C  MOBILE3, EPA 460/3-84-002, and the User's Guide to MOBILE4,
C  EPA-AA-TEB-89-01.  Otherwise questions should be directed to:
C
```

```
C         Office of Mobile Sources
C         Emission Control Technology Division
C         Test and Evaluation Branch
C         2565 Plymouth Road
C         Ann Arbor, Mich. 48105
C         Telephone: 313-668-4462
C                    FTS 374-8462
C
C
C  Source Code Documentation
C  -------------------------
C
C  The source code itself is commented to assist the users who require a
C  more detailed understanding of the program than provided in the Guides.
C  This section provides the following information:
C
C  1) Execution summary
C  2) Source code structure
C  3) Source code comments structure
C     a) Subroutines and functions header format
C     b) BLOCK DATA subprograms header format
C     c) In-line comments
C  4) Subscript dictionary
C  5) Subroutine / function parameter dictionary
C
C
C  1) Execution summary
C
C  To run the program, attach the input file to logical I/O Unit 5 and the
C  output file to Logical I/O Unit 6.  If supplying optional alternate I/M
C  credits, attach the credits file to Logical I/O Unit 4.  Refer to the
C  User's Guide to MOBILE4 for more detail on setting up runs and check
C  your operating system documentation for the system commands for compiling
C  and executing the program.  There is discussion of running the program on
C  the IBM PC AT under DOS in the User's Guide.
C
C  For information on the source code itself, refer to the Programmer's Guide
C  to MOBILE4, EPA-AA-TEB-89-01.
C
C
C  2) Source code structure
C
C     This section describes the layout of the code plus the numbering and
C     naming conventions.
C
C     The source code for the subprograms is grouped as follows:
C
C        program header
C        MAIN
C        MOBILE subroutine
C        QUITER subroutine
C        input subroutines
C        computation subroutines & functions
C        pointer functions
C        output subroutines
C        BLOCK DATA subprograms
C
C     Within each grouping and nesting level, the routines usually appear in
C     calling order.
C
C     The User's Guide listing of the code has each subprogram starting at an
C     integral multiple of 1000, simplifying the construction of the Table
C     of Contents.  That listing also has the comments in mixed case, to
C     improve readability.  The MOBILE4 tape being mailed out to the user
C     community has this mixed case version in File 1.  An upper case only
C     version, with hyphens replacing underscores and blanks replacing plus
C     carriage controls, is in File 2, for use by installations not able to
C     process these features.  For example, EPCDIC PN character set is upper
C     case only.
C
C     Statement number ranges are defined for usage as follows:
C
C          1 -   9  -  not used
C         10 -  98  -  branching
C               99  -  branch to last RETURN / RETURN1 / STOP before END
C        100 - 199  -  READ formats
C        200 - 299  -  WRITE prompt and output formats
C        300 - 499  -  WRITE error and warning messages
C        500+       -  not used
C
```

```
C     Statement numbers are local.  For example, within each subprogram,
C     branch numbers start at 10, READ formats start at 100, etc.
C
C     Given FORTRAN's 6 character maximum on subprogram name lengths, useful
C     naming conventions are hard to come by.  There is also the limitation
C     posed by not wanting to change arbritrarily all the subprogram names of
C     the predecessor program, MOBILE3.  Hence, the only conventions are:
C
C     a) Input driver sections all have the suffix 'SEC'.
C     b) Pointer functions all begin with 'I' (to get default INTEGER typing).
C     c) Pointer functions all contain/end with 'PT' or 'PTR'.
C     d) Output subroutines all have the prefix 'OUT'.
C
C     Otherwise, new subprogram names were picked to indicate the purpose of
C     the code.
C
C  Note: some features during the course of the model development were
C  subsequently removed or "turned off".  The latter case would occur when
C  the prospect of restoring the feature for in-house MOBILE4 or for MOBILE5
C  seemed likely.  Commented out code to this end is done with a 'CC'.
C
C
C  3) Source code comments structure
C
C     Each subprogram contains a documentation header, set up in a standard
C     format as described below.  All variables and arrays used in the code
C     are defined in the comments.  The subroutine / function headers define
C     local parameters and local variables / arrays.  The BLOCK DATA headers
C     describe the COMMON storage areas.  Array subscripts and subprogram
C     parameters are specified in dictionaries following this section.  The
C     intent is to allow the user to scan the source code on-line for
C     definitions, rather than have to leaf through hard-copy documentation
C     such as the Prorammer's Guide to MOBILE4.
C
C     a) Subroutines and functions header format
C
C        <subprogram name>
C        C
C        C  <short description of purpose>
C        C
C        C  Called by <subprogram name(s)>
C        C
C        C  Calls <subprogram name(s)>
C        C
C        C  Input on call:
C        C
C        C    parameter list: <names>
C        C    common block(s):
C        C    /<cb name>/ <names>
C        C          .          .
C        C          .          .
C        C
C        C  Output on return:
C        C
C        C    parameter list: <names>
C        C    common block(s):
C        C    /<cb name>/ <names>
C        C          .          .
C        C          .          .
C        C
C        C  Local array subscripts:
C        C
C        C  <name>(<#>,...)  -  <name>(<name>,...)
C        C          .                    .
C        C          .                    .
C        C
C        C  Local variable / array dictionary:
C        C
C        C   Name   Type              Description
C        C  ------  ----  ------------------------------------------------
C        C  <name> <type>         <short description>
C        C    .      .                    .
C        C    .      .                    .
C        C
C        C  Notes:
C        C
C        C  <notes on subprogram, particularly changes from MOBILE3>
C        C
C        C
C        <code>
C
```

```
C       Notes on format:
C
C       A local variable is one not passed in via the parameter list
C       or a common block.  It can be used in the argument list of a
C       subprogram call made by the defining subprogram.
C
C       Also, if a section of the header is not needed, its format is
C       omitted.  For example, if no subprograms are called, then the
C       'C  Calls <names>' line is not included.  "Notes" are always included.
C
C       Finally, 'Output on return' includes any variable / array whose
C       contents can be modified by the subprogram.  This usually will not
C       include data that can be changed by subprograms called by the
C       subprogram, since the comment headers on those subprograms will
C       indicate what is being passed back up.
C
C    b) BLOCK DATA subprogram header format
C
C            BLOCK DATA
C       C
C       C  BLOCK DATA subprogram <#>
C       C
C       C  <short description of data initialized in this BLOCK DATA>
C       C
C       C  Common block array subscripts:
C       C
C       C  <name>(<#>,...)  -  <name>(<name>,...)
C       C         .                    .
C       C         .                    .
C       C
C       C  Common block dictionary:
C       C
C       C   Name   Type              Description
C       C   ------  ----  ------------------------------------------------
C       C  /<cb name>/:
C       C  <name> <type>         <short description>
C       C    .      .                    .
C       C    .      .                    .
C       C
C       C  Local array subscripts:
C       C
C       C  <name>(<#>,...)  -  <name>(<name>,...)
C       C         .                    .
C       C         .                    .
C       C
C       C  Local array dictionary:
C       C
C       C   Name   Type              Description
C       C   ------  ----  ------------------------------------------------
C       C  <name> <type>         <short description>
C       C    .      .                    .
C       C    .      .                    .
C       C
C            COMMON /<name 1>/ ...
C               .
C               .
C               .
C       C
C            DIMENSION (or type) <array 2>(subscript(s))
C               .
C               .
C       C
C            EQUIVALENCE (<array 1, subscripted>,<array 2, subscripted>)
C               .
C               .
C               .
C       C
C       C  /<name 1>/: <any comments on <name 1>'s labels, purpose or data
C       C               or on the structure of the initializing DATA
C       C               statement(s)>
C       C
C            DATA <var/arr name 1>/<data>...
C               .
C               .
C               .
C               .../
C       C
C       C  /<name 2>/: ...
C               .
C               .
```

```
C
C             END
C
C       Notes on format:
C
C       Local arrays are defined and then equivalenced to common block arrays
C       that are too large be intialized in 1 DATA statement.  Too large =
C       would require greater than 19 continuation lines, the FORTRAN limit.
C
C       The local arrays dictionary is often compressed by providing a
C       generic definition of the conventions used to construct and name the
C       set of local arrays to be equivalenced to a given common array.
C
C       "/<name #>/:" prefix is included only if a large number of common
C       blocks are being initialized in a single BLOCK DATA (see BD 23).
C
C
C    c) In-line statements
C
C       In-line comments are intended to describe the algorithm being used
C       by the code.  Where MOBILE4 is identical to MOBILE3 in operation,
C       the MOBILE3 comments have usually been left intact.  Where the
C       method has been updated or the whole section / subprogram is new,
C       the in-line comments describe the MOBILE4 methodology.
C
C       Particular attention is paid to the use of indices and pointers.
C       Some of the ambiguities of MOBILE3, such as the use of IDX vs JDX,
C       have been cleared up.  The usage of new keys and pointers is specified
C       in detail where they occur.
C       occur.
C
C
C 4) Subscript dictionary
C
C    Subscript variables used to index arrays in MOBILE4 are globally
C    defined, not in the sense that the values are available to all
C    subprograms, but rather that the same label is used for the same
C    subscript function throughout the code.  IP is the 3 pollutants index
C    for all of MOBILE4, although its instances are usually as a local
C    variable.  As array subscripts, all these variables must be of type
C    INTEGER. The default INTEGER typing syntax rule is employed by having
C    all subscripts begin with a letter from the range I through N.
C
C     Name    Range              Description
C     ------  -------  ----------------------------------------------------
C     IAD       1-5    index into ID dimension of ATR for ADJFAC equation
C
C     IADJ      1-2    index into CSIZE adjustment vector ADJFAC
C
C     IAY       1-2    anti-tampering program start year flag:
C                        1 = in year range up thru start year
C                        2 = in year range after start year
C
C     IB        1-3    bag number:
C                        1 = cold start
C                        2 = hot stabilized
C                        3 = hot start
C
C     IBER      1-3    terms of user supplied new emission rate equation:
C                        1 = zero mile level (intercept)
C                        2 = deterioration rate (slope)
C                        3 = deterioration rate (slope), LDGV 81+ HC/CO 50K+
C
C     IC        1-7    overlap effects categories computed direct from base
C                      tamper rates; each case is the set intersection of
C                      the indicated disablement types:
C                        1 = AorE * CATS
C                        2 = AorE        * NCKS
C                        3 = AorE                * TNKS
C                        4 = AIRS * CATS * NCKS
C                        5 = AIRS * CATS         * TNKS
C                        6 =        CATS * NCKS
C                        7 =        CATS         * TNKS
C                      AorE = AIRS if HC or CO
C                           = EGRS if NOx
C
```

```
C                8-12   no overlap effects categories computed from the 7
C                       overlap cases:
C                         8 = AIRS
C                         9 = CATS
C                        10 = NCKS
C                        11 = TNKS
C                        12 = <no tampering effect>
C
C       ICAT     1-3    catalyst technology configurations:
C                         1 = ox catalyst / no catalyst
C                         2 = 3 way catalyst
C                         3 = 3 way + ox catalyst
C
C       ICH      1-20   character string array position index:
C                         1 = 1st 4/8 characters (CHARACTER*4/8)
C                         2 = 2nd 4/8 characters
C                               .
C                               .
C                       also serves to subscript any other CHARACTER type array.
C
C       ICOEF2   1-6    coefficient number of 2nd degree polynomial
C                       (0th (intercept) to 2nd decree term coefficients)
C
C       ICOEF5   1-6    coefficient number of 5th degree polynomial
C                       (0th (intercept) to 5th decree term coefficients)
C
C       ICOL     1-3    index into EFF's column dimension (BD 24 defines abbrs):
C                       1 = PREV CAT ; 2 = PREV ; 3 = SUBS
C
C       ICOLD    1-2    index into cold CO standard case of MYCOL & CCSTD
C
C       ICR      1-2    Replace I/M credits inclusion vector NUDATA's array
C                       identifier subscript:
C                         1 = (CR12HC & CR12CO) - Technologies 1-2
C                         2 = CRED4V - Technologies 4+ LDGV
C
C       ICS      1-NT   secondary index: selects pointers to category
C                       sizes to be summed up to get SUB (in C8TO11) and
C                       DIV (in A8TO11)
C
C       IC11     1-11   positive tampering effects categories 1-11; 12 is the
C                       no effects case.
C
C       IC7      1-7    overlap tampering effects categories 1-7
C
C       ID       1-9    disablement types (1-5,9 for bag, 6-8 for evap):
C                         1 = AIRS = air pump disabled
C                         2 = CATS = catalyst removed
C                         3 = NCKS = misfueled - filler neck
C                         4 = TNKS = misfueled - tank (all but filler neck)
C                         5 = EGRS = EGR disabled
C                         6 = EVAP = evaporative system tampered - cannister only
C                         7 = PCVS = PCV disabled
C                         8 = CAPS = evaporative system tampered - cannister and
C                                    gas (fuel inlet) cap
C                         9 = MISF = misfueled - all sources = NCKS + TNKS
C
C       IDBAG    1-5    bag exhaust disablement types (see ID)
C
C       IDPB     1-3    misfueling related disablement types:
C                         1 = NCKS = misfueled - filler neck
C                         2 = TNKS = misfueled - tank (all but filler neck)
C                         3 = MISF = misfueled - all sources = NCKS + TNKS
C
C       IDU      1-5    index for Diurnal (DU) indicating full, 8AM-11AM,
C                       10AM-3PM, 8AM-2PM, and multiple
C
C       IDUSER   1-8    ID cases & order of cases presented to user in TAMFLG
C                       (TAMZML & TAMDR) & ATPFLG (DISTYP) options.  IDUSER
C                       differs as follows: 4 = MISF.  GETTAM derives TNKS =
C                       MISF - NCKS for TAMDR & TAMZML and stores the read and
C                       computed values in ID order. ATPAER does not need TNKS
C                       & uses DISTYP in the read in IDUSER order.
C
C       IDX      1-25   model year (my) window index:
C                         1 = 25+ my age group cell => tamper effect is
C                             always 0.0 => this case skipped in TAMPER (only)
C                         2 = 24th my cell
C                         3 = 23rd my cell
C                           .
C                           .
```

```
C
C                      24 = 2nd my cell
C                      25 = 1st my cell = calendar year (ICY)
C
C     IEG        1-7   tampering effects group:
C                        1 = air pump disabled, air pump only equipped
C                        2 = air pump disabled, air pump/catalyst equipped
C                        3 = catalyst removed
C                        4 = misfueled catalyst
C                        5 = EGR disabled
C                        6 = EGR disabled / catalyst removed
C                        7 = EGR disabled / misfueled
C
C     IEK        1-3   catalyst emission effects groups: IEK = IEG - 1
C
C     IELST      4-7   last non-zero tampering effects group size, given IPG
C
C     IEQU       1-20  pointer to idle equation to be zeroed out due to entry
C                      of new exhaust ef equation by user
C
C     IERNEW     1-20  pointer to location in default ef rates & model years
C                      arrays where new ef equation's parameters are to be
C                      stored (IERNEW = 0 => no space for new equation)
C
C     IEVEQ      1-9   HS and DU equation term coefficient - see definitions
C                      for HSEQ in BD 09 and DUEQ in BD 11
C
C     IEVP       1-4   index for gram evap rates EVP, GREVP and VGREVP:
C                        1=hot soak
C                        2=in-use diurnal
C                        3=multiple diurnal
C                        4=crankcase
C
C     IEVX       1-32  model year (my) window index for evaporative data input,
C                      i.e. to the IEVXth myg's rate(s) for a given N<> set
C
C     IE1ST      1-3   first non-zero tampering effects group size, given IPG
C
C     IFAC       1-100 index into new (user supplied) emission rates arrays;
C                      the user can enter up to 100 replacement cases.
C
C     IFDS       1-3   fuel delivery system type:
C                        1 = carbureted      2 = fuel injected    OR
C                        1 = CARbureted      2 = TBI      3 = PFI
C
C     IFG        1-13  flag names for prompts (listed by common block used):
C                         /FLAGS1/      /FLAGS2/       /FLAGS3/      /FLAGS4/
C                        1 = TAMFLG    4 = MYMRFG     8 = ATPFLG   12 = PRTFLG
C                        2 = SPDFLG    5 = NEWFLG     9 = TEMFLG   13 = IDLFLG
C                        3 = VMFLAG    6 = IMFLAG    10 = RLFLAG   14 = NMHFLG
C                                      7 = ALHFLG    11 = OUTFMT   15 = HCFLAG
C                      The 14th flag (or 0 = PROMPT) is read without a prompt.
C
C     IFL        1-2   myg bounds:    1 = First year    2 = Last year
C
C     IFUEL      1-3   fuel type: 1 = Gasoline, 2 = Ether Blend, 3 = Alcohol
C                      Blend
C
C     IG<i>      1-20  model year group (myg) pointer:
C                      <i> = null string,C,CAT,D,E,F,L,LM,S,T,U,W,1,2,3,4
C                      IG links a data array to its corresponding myg index
C                      array. These data arrays all have my as a subscript
C                      plus have cases of contiguous subsets of years with
C                      the same data point.  Core space is then saved by
C                      storing each point only once per my subset and then
C                      constructing an index array to enable the program to
C                      find the location IG<i> of the data point for a given
C                      my.
C
C     IGCSF      1-3   model year group index in the array CSF1ST:
C                        1 = pre-1981 model years
C                        2 = 1981-1983 model years
C                        3 = 1984+ model years
C
C     IGD        1-3   MYG index into 3rd dimension of TAMZML & TAMDR
C                        1 = pre-1981  2 = 1981-83  3 = 1984+ for LDGV/T
C                        1 = 1981+ for HDGV
C     IGER       1-20  myg pointer into basic emission rate arrays from IERPTR
C
C     IGIDL      1-15  myg pointer into idle emission rate arrays from IDLPTR
C
```

```
C     IG50       1-12   myg pointer into the 50K+ deterioration rate arrays
C                       ERB50K & ERU50K (the arrays differ in lookup algorithm)
C
C     IGTL       1-4    running loss HC: emission rate MYG pointer
C
C     IH         1-3    non-exhaust HC emission case:
C                         1 = hot soak evaporative
C                         2 = diurnal evaporative
C                         3 = crankcase
C
C     IHG        1-2    non-exhaust HC technology / tampering case:
C                         1 = evaporative
C                         2 = crankcase
C
C     IHDSAL     1-2    HDGV sales fraction case
C                         1 = HDGV weighing < 14000 lbs
C                         2 = HDGV weighing >= 14000 lbs
C
C     IHRD       1-6    evaporative temperature types:
C                         1 = hot soak
C                         2 = running loss
C                         3 = diurnal, 8 AM
C                         4 = diurnal, 10-11 AM
C                         5 = diurnal, 2 PM
C                         6 = resting loss
C
C     ILU        1-2    bounds of a value range (ex.: tags of nonzero
C                       category sizes):
C                         1 = lower bound
C                         2 = upper bound
C
C     IM         1-2    I/M program flag:
C                         1 = I/M program not in effect for MY x IV x ICY case
C                         1 = I/M program is in effect for MY x IV x ICY case
C
C     IMDL       1-2    coefficients for trips per day model equation:
C                         1 = intercept
C                         2 = slope
C
C     INO        1-2    index into NOYES character string vector:
C                         1 = No     2 = Yes
C
C     IP         1-3    pollutants:
C                         1 = HC  = hydrocarbon
C                         2 = CO  = carbon monoxide
C                         3 = NOx = oxides of nitrogen
C
C     IPAR       1-5    parameters identifying where and when to apply user
C                       supplied new emission rates:
C                         1 = region
C                         2 = vehicle type      4 = first my of range covered
C                         3 = pollutant         5 = last my of range covered
C
C     IPARTL     1-3    index for Partial Diurnal (PARD) indicating
C                       8AM-11AM, 10AM-3PM and 8AM-2PM
C
C     IPG        1-2    pollutants grouped for tampering effects & SK2 scfs:
C                         1 = HC and CO
C                         2 = NOX
C
C     IPIM       1-2    pollutants affected by I/M programs:
C                         1 = HC
C                         2 = CO
C
C     IP1        1-3    lower bound of output IP loop (first pollutant to
C                       have results printed)
C
C     IP2        1-3    upper bound of output IP loop (last pollutant to
C                       have results printed)
C
C     IP50       1-2    pollutant types affected by 1981+ LDGV 50K+ change in
C                       deterioration rate
C
C     IQG        1-6    emission control equipment group; 2 more groups
C                       computed from the stored 6 groups data:
C                         1 = air pump only
C                         2 = air pump / catalyst
C                         3 = catalyst only
C                         4 = EGR only
C                         5 = EGR / 3-way catalyst
C                         6 = no EGR / 3-way catalyst
```

```
C
C     IR          1-2     region code:
C                         IR has same value range as IREJN, but is not necessarily
C                         the scenario field's value
C                           1 = low altitude
C                           2 = high altitude
C
C     IREC        1-999    input record number, on a given READ
C
C     IROW        1-15    index into EFF's row dimension = the 8 ID cases split
C                         into 15 subcases (see BD 24 definition of EFF)
C
C     IRT           1-4     temperature cases in RVP cf calculations, the values
C                           referenced depending on the (sub)array.  See /RVPEX1/.
C
C     IRQ1          1-3     RVP cf equation parameters set 1 (RVP > 9.0 adj.):
C                           RADJCF=(b1+b2*RVP)/b3
C
C     IRQ2          1-2     RVP cf equation parameters set 2 (T interpolation)
C                             1 = initial temperature (T range lb)
C                             2 = temperature difference (interval length)
C
C     IRQ3          1-3     RVP & high T combined cf formula coefficients:
C                           TCF(IB)=EXP(a1*(RVP-9)+a2*(T-75)+a3*(RVP-9)*(T-75))
C
C     IRVP          1-2/4   types of non-certification RVP: 1 = Base, 2 = In-use
C                                                  3 = Uncontrolled refueling loss
C                                                  4 = Hot soak (weathered)
C
C     IS          1-4     overlap tampering effects category sizes 8-11
C                         ( IS = IC - 7 ); used in A8TO11.
C
C     ISC         1-5     underscore string repetition counter - for example,
C                         ISC = 3 => repeat the string 3 times
C
C     ISP         1-21    my group pointer into speed correction equation array;
C                         found by ISPPTR; indexes SK1 & SCUNA1.
C
C     IS2a        1-2/3   number of coefficients in a new scf equation:
C                             IS2C = 2 (A/X+B);  IS2N = 3 (A+B*X+C*X**2)
C
C     IT          1-9     pointer to temperature correction equation
C                         coefficients; found by ITCPTR; indexes TTA/4/7COF
C                         arrays.
C
C     ITECH<a>    1-15    emission control technology class wrt I/M impact;
C                         f(MY,IVLD) as determined by IMPTR; indexes I/M credits
C                         arrays CR12HC/CO & CRD4VA/B. ITECHA/B/C are in BD8&34.
C
C     ITEM        1-2     NAMTEM index: 1 = 'mini', 2 = 'maxi' prefixes
C
C     ITER        1-4     unspecified string iterations counter; same usage as
C                         ISC, only with any string
C
C     ITL         1-13    running loss HC: defined trip lengths for 3 cycle types:
C                             1-6 - NYCC      7-12 - LA-4      13 - HFET
C
C     ITLR        1-4     running loss HC: RVPs at which measured rl HC available
C
C     ITLT        1-4     running loss HC: temperatures at which measured rl HC
C                                          emission rates are available
C
C     ITY         1-3     type tampering rates wrt I/MxIGD table heading substring
C                         pointer
C
C     IUDI        1-5     index into Uncontrolled Diurnal rate UDI:
C                           1 = standard FTP conditions
C                           2 = in-use conditions
C                           3 = 8AM-11AM conditions
C                           4 = 10AM-3PM conditions
C                           5 = 8AM-2PM conditions
C
C     IV          1-8     vehicle types evaluated by MOBILE4:
C                           1 = LDGV  = light duty (ld) gasoline fueled vehicle
C                           2 = LDGT1 = ld gasoline fueled truck, <= 6000 lbs.
C                           3 = LDGT2 = ld gasoline fueled truck, 6001-8500 lbs.
C                           4 = HDGV  = heavy duty gasoline fueled vehicle
C                           5 = LDDV  = light duty diesel fueled vehicle
C                           6 = LDDT  = light duty diesel fueled truck
C                           7 = HDDV  = heavy duty diesel fueled vehicle
C                           8 = MC    = motorcycle
```

```
C
C     IV<i>      1-6    vehicle type subgroups; index correction factor arrays;
C                       <i> = LM, TEMP, A, B or LDG, defined as:
C                          IVLM          IVTEMP        IVA           IVB         IVLDG
C                        1 = LDGV      1 = LDGV      1 = LDGV      1 = HDGV    1 = LDGV
C                        2 = LDGT1     2 = LDGT1     2 = LDGT1     2 = LDDV    2 = LDGT1
C                        3 = LDGT2     3 = LDGT2     3 = LDGT2     3 = LDDT    3 = LDGT2
C                        4 = LDDV      4 = HDGV      4 = MC        4 = HDDV
C                        5 = LDDT      5 = MC
C                        6 = MC
C                       indexes:
C                        MYGSP1        MYGTCF        SCADJ1        GPBSCO      TTFC
C                        BFRCOF                      ISPGRP
C                                                    ALHRET
C                       See subroutines BIGCFX & BIGALH and function ISPPTR.
C
C     IVEFF      1-2    vehicle class groupings for Stage II vrs percent
C                       efficency in reducing HC refueling losses:
C                         1 = LDGV, LDGT1 & LDGT2     2 = HDGV
C
C     IVF1       1-6    vehicle class types for MOBILE1 numeric output
C                       format (OUTFMT = 1):
C                         1 = LDV       3 = LDT2      5 = HDD
C                         2 = LDT1      4 = HDG       6 = MC
C
C     IVF2       1-9    vehicle class types for MOBILE2 numeric output
C                       format (OUTFMT = 2):
C                         1 = LDGV      4 = LDGT      7 = LDDT
C                         2 = LDGT1     5 = HDGV      8 = HDDV
C                         3 = LDGT2     6 = LDDV      9 = MC
C
C     IVF3       1-10   vehicle class types for MOBILE4 descriptive output
C                       format (OUTFMT = 3): same as IVF2 plus 10 = All Vehicles
C
C     IVIM       1-4    vehicle class types that can be included in MOBILE4
C                       inspection / maintenance (I/M) programs:
C                         1 = LDGV     2 = LDGT1     3 = LDGT2     4 = HDGV
C
C     IVHD       1-2    vehicle class types for heavy duty only (used for
C                       units conversion of user entered hd zml & dr):
C                         1 = HDGV      2 = HDDV
C
C     IVP        1-3    vehicle types whose ef's can be modified by correction
C                       factors for extra load, trailer towing &/or CO offset:
C                         1 = LDGV      2 = LDGT1     3 = LDGT2
C
C     IVREV      1-4    vehicle types covered by the revised idle EF algorithm:
C                         1 = LDGV      2 = LDGT1     3 = LDGT2     4 = HDGV (HC&CO)
C                       IVI = IVREV, except 3 & 4 -> 3 (HDGV uses LDGT2 data)
C
C     IVTAM      1-4    vehicle types impacted by tampering:
C                         1 = LDGV      2 = LDGT1     3 = LDGT2     4 = HDGV
C
C     IV9        1-9    vehicle type categories for output arrays EFEVAP,
C                       EFIDLE, & EFFTP.  First 8 are identical to IV's.
C                         9 = LDGT
C                           = LDGT1 + LDGT2, each weighted by its vmt share
C
C     I2ND       1-4    secondary index (pointer into a pointer vector)
C
C     JCS        1-7    pointer to category size to be summed into DIV
C                       (in A8TO11) or (* TGSUSE) into EGS (in SETEGS)
C
C     JDX        25-1   model year window index = age of vehicle relative to
C                       ICY + 1. In detail:
C                        25 = 25+ my age group cell => tamper effect is
C                             always 0.0 => this case skipped in TAMPER (only)
C                        24 = 24th my cell
C                        23 = 23rd my cell
C                           .
C                           .
C                           .
C                         2 = 2nd my cell
C                         1 = 1st my cell = calendar year (ICY)
C
C     JG         1-20   model year group pointer = IG or 21 - IG, depending on
C                       whether looking for match or unused cell, respectively,
C                       in MYGERB.  Also used (as is KG) to distinguish (from IG)
C                       myg dimension size differences in BD comments.
C
```

```
C     JOU        1-3     output unit key:
C                          cell 1 is assigned IOUREP's value
C                          cell 2 is assigned IOUERR's value
C                          cell 3 is assigned IOUASK's value
C
C     JPGD       1,5     pointer to base tamper rate to be used in
C                        computing CSIZE(1-3,IAY).  Depends on IPG.
C
C     JSTD       1-6     emissions standard model year group for gas fueled IV.
C                        The group key is the same as ISTD, but JSTD is set
C                        internally, instead of being passed in via EVMAIN.
C                        (The ISTD definition is in the Parameter Dictionary.)
C
C     JU         1-9     input / output (i/o) device unit numbers
C
C     JV         1-2     vapor pressure calculation loop & vectors index (CALUDI)
C
C     KSTD       1-2     mapping of JSTD used to index R2ALT:
C                            KSTD = 1, unless JSTD = 4 -> KSTD = 2
C
C     KDX        1-21    model year window index = ICY - 1979, unless result is
C                        < 1 (=> = 1) or > 21 ( => = 21); used by HDDMYM
C
C     LAY        1-2     same as IAY, but set for DISCAL call only.
C
C     LIM        1-2     = IM, except = 1 when there is an I/M kink, but it is
C                          after LDXSY & the PREV segment is being evaluated:
C
C                        IM   IMKINK   LKINK   LIM   Comments
C                        --   ------   -----   ---   --------------------------
C                         1      1       1      1    P & S: no I/M
C                         2      1       1      2    P & S: all I/M
C                         2      2       1      1    P: no I/M; S: kinked I/M
C                         2      2       2      2    P: kinked I/M; S: all I/M
C
C     LIMIT      1-2     index for range check on a variable's value assignment:
C                        1 = lower bound    2 = upper bound
C
C     LINES      1-9     number of lines in user entered data set title
C
C     LJDX       25-1    model year relative to LAPSY = JDX - LDXSY + 1;
C                        used with CUMMIL to get mileage of "previous" segment
C
C     LKINK      1-2     same as IMKINK, except IMDXSY must be within (JDX,LDXSY)
C
C     NCKIAY     1-3     index into ECK = ICOL index
C
C
C
C  5) Subroutine / function parameter dictionary
C
C     Variables /arrays occurring in 1 or more of the subprogram parameter
C     lists are defined in this section, unless the variable is a subscript,
C     in which case look it up in 4)'s subscript dictionary.  The motivation
C     for defining all the parameter lists in one place is to have only one
C     instance of a definition in the code plus to encourage only one use
C     for a mnemonic in the code plus the combined lists contain only 18
C     names after subscripts have been removed.  Whether scanning on-line or
C     off a listing, the lookup will be quick.
C
C     Parameter array subscripts
C     --------------------------
C     CSFUSE(7)          -  CSFUSE ( IC7 )
C     CSF1ST(7,2,3)      -  CSF1ST ( IC7, IPG, IGCSF )
C     S2LEFT(4)          -  S2LEFT ( IVTAM )
C
C      Name   Type              Description
C     ------  ----  ------------------------------------------------------
C     CSFUSE   R    category size factors used * ATR to calculate CSIZE
C     CSF1ST   R    category size factor for 1st calculation of CSIZE
C     FLGERR   I    number of flag values found to be out of range
C     IBEFSW    0-2    switch identifying routine calling BEF & result returned
C                        0 = BEFIDL = always return uncorrected basic non-idle ef
C                        1 = BEFIDL = return uncorrected basic ef
C                        2 = EFCALX or HCCALX = return basic ef corrected for
C                            operating mode, temperature, RVP (if high temp),
C                            I/M, oxy fuel and tampering
C     ICASE    I    flags the my groups array to be searched.
C     ICY      I    calendar year for which emission factors are calculated
C     INERR    I    cumulative count of data entry errors
C     IOUOUT   I    unit number on which title is printed
```

```
C     IOUSUM   I    sum of acceptable changed i/o unit numbers
C     IVALUE   I    entered integer value causing error / warning message
C     IY       I    year to test and adjust to 4-digit year
C     IY1      I    lower 4-digit bound for IY
C     IY2      I    upper 4-digit bound for IY
C     MESSAG   I    message code sent by calling subprogram
C     MY       I    model year
C     NERR     I    number of error if IY is out of bounds
C     NREC     I    number of records to be skipped on next READ
C     RVALUE   R    entered real value causing error / warning message
C     S2LEFT   R    See local dictionary definition in REFUEL header.
C     VMLDGT   R    sum of vmt for LDGT1 and LDGT2 (= X23 in MOBILE2)
C     VMTAGE   R    vehicle cumulative mileage
C
C  Evap Study II Parameter List Dictionary for CCEVRT block of routines:
C
C      Name    Range              Description
C     ------  -------  ------------------------------------------------
C     EVRATE     R     dependent variable value from evaporative component
C                      equation(s) calculation:
C
C                        KEYEVP      EVRATE
C                          1     => hot soak rate
C                          2     => diurnal rate
C
C     ISTD      1-7    emissions standard model year group for gas fueled IV:
C                        IVGAS     value     myg
C                        -----     -----     --------------------------------
C                          1         1       pre-1971
C                                    2       1971
C                                    3       1972-1977
C                                    4       1978-1980
C                                    5       1981+ carbureted (KEYEQ=1 or 2)
C                                    6       1981+ TBI KEYEQ=1 or 2
C                                    7       1981+ PFI KEYEQ=1 or 2
C                          2         1       pre-1971
C                                    2       1971
C                                    3       1972-1977
C                                    4       1978-1980
C                                    5       1981+ carbureted (KEYEQ=1 or 2)
C                                    6       1981+ TBI KEYEQ=1 or 2
C                                    7       1981+ PFI KEYEQ=1 or 2
C                          3         1       pre-1979
C                                    2       1979-1980
C                                    3       1981+ carbureted (KEYEQ=1 or 2)
C                                    4       1981+ TBI KEYEQ=1 or 2
C                                    5       1981+ PFI KEYEQ=1 or 2
C                          4         1       pre-1985
C                                    2       1985+ (KEYEQ=1 or 2)
C                          5         1       pre-1978
C                                    2       1978-1979
C                                    3       1980-81
C                                    4       1982-84
C                                    5       1985+
C
C     ITRSTL    1-2    technology type for resting losses calculation
C                        1=fuel injected with open bottom canister
C                        2=fuel injected with closed canister
C                       (currently carbureted=fuel injected, open)
C
C     IVGAS     1-5    gasoline fueled vehicle types (= IVTEMP):
C                        1 = LDGV  2 = LDGT1  3 = LDGT2  4 = HDGV  5 = MC
C                      IVGAS = IV, except MC (5 vs 8); IVEVAP is an alt name.
C
C     IVTL      1-4    running loss HC: vehicle classes with rl HC emissions
C
C     KEYEQ     1-3    HS/DU equation group selection key:
C                        1 = passing
C                        2 = failed purge
C                        3 = failed pressure
C
C     KEYEVP    1-2    Evaporative component calculation selection key
C                        1 = hot soak  2 = diurnal
C
C     RIVAL      R     independent variable value in evaporative component
C                      equation(s) calculation:
C                        KEYEVP                    RIVAL
C                          1     => hot soak => fuel RVP
C                          2     => diurnal  => diurnal Index
C
C  ************************************************************************
```

```
C
C     IC, IDX, IFDS, IG, IM, IP, IP1, IP2, IR, IV and JSTD are parameters
C     defined in the subscript dictionary.
C
C  Notes:
C
C  **** NOT IN USE **** = the subroutine/function is not called by the current
C  version of MOBILE4.  Release MOBILE4 (final version), for example, does not
C  use WTLRUL or OUTTAM.
C
C
```

```
C
C  MAIN
C
C  Dummy main program for MOBILE4.1.
C    Required to allow proper RUN entry to MOBILE subroutine.
C
C  Called by:  none
C
C  Calls MOBILE
C
C  The following variables are passed in argument lists or common blocks
C
C    argument lists: none
C    common blocks:
C    /SAVE01/ JCALL
C
C  Output on return:
C
C    parameter list: none
C
C  Local variable dictionary:  none
C
C  Reset JCALL (initialized to 1 by BD12) to indicate stand-alone
C
C     COMMON /SAVE01/ JCALL,VA001(15,3,8,2),VA002(15,3,8,2)
C     JCALL=0
C     CALL MOBILE(INERR, *99)
C     STOP
C  99 STOP 1
C     END
C
C*****************************************************************
C
```

```
      SUBROUTINE MOBILE(INERR, *)
C
C  Called by user's program (example: Air Quality Analysis System).
C
C  Calls BDSAVE, CONSEC, EFCALX, ONESEC, OUTDT5, OUTNEW, OUTPUT,
C        PARSEC, QUITER, REINIT, RESTOR and REGMOD.
C
C  The following variables are passed in argument lists or common blocks and
C  in MOBILE:
C
C    argument lists: ICY,INERR
C    common blocks:
C    /FLAGS3/ OUTFMT
C    /IOUCOM/ IOUERR
C    /REGION/ IREJN
C    /SAVE01/ JCALL
C
C  Output on return:
C
C    parameter list: INERR
C
C  Local variable dictionary:
C
C   Name    Type              Description
C  ------   ----  ------------------------------------------------------
C  ICYOLD    I    calendar year from previous pass of scenario loop
C  IROLD     I    region from previous pass of scenario loop
C  ISAV93    I    flag for 1993 disclaimer message (QUITER #130)
C                       0 = message has not yet been given
C                       1 = message has been given: not again!
C  LEAST1    I    flag: 0 = OUTPUT has not yet been called.
C                       1 = OUTPUT has been called at least 1 time.
C
C  Notes:
C
C  MAIN was converted to subroutine MOBILE in Version 01 of development MOBILE4.1
C  The /BYMYCd/ CBs were added for Version 02.
C
C
      CHARACTER*26 BYVTN
      CHARACTER*17 YFM
      CHARACTER*8 NAMFLG,NAMMMR
      CHARACTER*8 USNAME
      CHARACTER*7 PN,U7
      CHARACTER*8 NAMRVP
      CHARACTER*4 NAMTEM
      CHARACTER*4 NOYES,COMMA,PERIOD
      CHARACTER*4 IMNAME,PROJID,SCNAME
      CHARACTER*3 PSEC
      CHARACTER*1 COLON,VB
      INTEGER PROMPT,TAMFLG,SPDFLG,VMFLAG,OXYFLG,DSFLAG
      INTEGER ALHFLG
      INTEGER ATPFLG,TPDFLG,RLFLAG,TEMFLG,OUTFMT,OUTPRF
      INTEGER PRTFLG,HCFLAG,COLDFG
      INTEGER ATPPGM,ATPFQT,DISTYP
      INTEGER ADDCSW
      REAL JULMYR,JANMYR
      REAL LHDVM,MHDVM,HHDVM,LHDRG,MHDRG,HHDRG
C
      COMMON /ALUHAC/ ACEQIP(8,3,2),ACCF(2,3,2,3,2)
      COMMON /ALUHIN/ AC,XLOAD(3),TRAILR(3),ABSHUM,DB,WB
      COMMON /ALUHLT/ XLCF(3,6,3,2),TWCF(3,6,3,2)
      COMMON /ALUOUT/ ALHRET(25,4,3)
      COMMON /ALUPAC/ MYGACE(8,3,2),MYGACC(2,3,2)
      COMMON /ALUPLT/ MYGXLC(6,3,2),MYGTWC(6,3,2)
      COMMON /ATPAR1/ LAPSY,LAP1ST,LAPLST,LVTFLG(4)
      COMMON /ATPAR2/ ATPPGM,ATPFQT,CRATP,DISTYP(8)
      COMMON /ATPAR3/ AIR(2),CAT(2),ECK(3),TNK(2),EGR(2)
      COMMON /ATPAR4/ CAN(2),PCV(2),CAP(2),EFF(2,3,15)
      COMMON /BASEQ1/ ERBZML(23,3,8,2),ERBDR(23,3,8,2),ERB50K(12,2,3,2)
      COMMON /BASEQ2/ MYGERB(23,3,8,2),MAXERB
      COMMON /BASEQ3/ NEWVEH,NEWMYF,NEWMYL,ZMLNEW,DRNEW,KINKS
      COMMON /BASEQ4/NEWPAR(5,100),BERNEW(3,100),NEWFIT(100),NEWCT,MAXCT
      COMMON /BASEQ5/ ERUZML(12,3,8,2),ERUDR(12,3,8,2),ERU50K(12,2,3,2)
      COMMON /BASEQ6/ MYGERU(12,2,3,8,2),MAXERU,NUMERU(3,8,2),KEYER,IGER
      COMMON /BASEQ7/ IPMOD(3)
      COMMON /BASEQ8/ IHDVMY(23,2),HDVZML(23,2),HDVBDR(23,2)
      COMMON /BYMYC1/ IVPICK(8),IMPICK,IDPICK,BYCUM(25,8)
      COMMON /BYMYC2/ BYBEF4(3,25,8),BYTAM(3,25,4),BYFER(3,25,8)
      COMMON /BYMYC3/BYEVAP(25,8),BYRUNL(25,4),BYREFL(25,4),BYRSTL(25,8)
      COMMON /BYMYC4/ BYVTN(8),YFM,PN(10),U7,PSEC(3),VB
```

```
COMMON /BYMYC5/ BYIMCR(2,25,4),BYIMRE(2,25,4),REDSUM(2,4)
COMMON /CEVCOM/ USRTPD(8),USRMPD(8)
COMMON /CEVBMY/ BMYMPD(25,8),BMYTPD(25,8),BMTPDF(25,8)
COMMON /CITCIN/ UDI(5),IUDI,PFRATE(3)
COMMON /CITPAR/ SCNAME(4)
COMMON /CITRV1/ RVPBAS,RVPIUS,RVPICY,IUSESY,RVPUWX
COMMON /CITRV2/ RVPHS,RVPX,RVP090,RVP115
COMMON /CRACOM/ MAXCRA,CRAVAL(3,8,2),MYGCRA(3,8,2)
COMMON /CUMCOM/ CUMMIL(25,8)
COMMON /EGSCAL/ AER(11,11,2,2),TGS(11,6,4),EGS(7,2)
COMMON /EMECAL/ EM3W(3,3,3),EMOX(3,3,3),EMEGR(4,3,3),EMI(7,3,3)
COMMON /EVADU1/ DUEQ(3,2,3),EFDU(3,2,5,5)
COMMON /EVADU2/ HIDU(3,2),R2DU(2,2)
COMMON /EVAHIA/ HIHS(3,2),HIADJ
COMMON /EVAHS1/ HSEQ(3,2,9),EFHS(3,2,5,5)
COMMON /EVAPAR/ IFDS,ISTDC,ISTDT,ISTDP,FINJ(2)
COMMON /EVAPGR/ EVP(4),GREVP(4,9),VGREVP(4),PARD(3),GRPD(3,9)
COMMON /EVAPHD/ HDSAL,HDWGT(2),IVVMAP(5)
COMMON /EVASTD/ MYGSTD(5,5),MAXSTD,KSTD81(4,3)
COMMON /EVPDAT/ EVPAER(3,2),EVPTGS(3,2,4),CCEMI(7,4)
COMMON /FID/ MAXFID,MYFID(16,5),TOGCF(16,5,3),VOCCF(16,5,3)
COMMON /FLAGS1/ PROMPT,TAMFLG,SPDFLG,VMFLAG,OXYFLG,DSFLAG
COMMON /FLAGS2/ MYMRFG,NEWFLG,IMFLAG,ALHFLG
COMMON /FLAGS3/ ATPFLG,TPDFLG,RLFLAG,LOCFLG,TEMFLG,OUTFMT
COMMON /FLAGS4/ PRTFLG,IDLFLG,NMHFLG,HCFLAG,COLDFG
COMMON /GSFCOM/ MAXGSF,GSFRAC(22,8,2),MYGSF(22,8,2)
COMMON /HDCCOM/ HDCFAC(37,2),LOWYR,MAXCIG
COMMON /HDDMAR/ C2BDVM(25),LHDVM(25),MHDVM(25),HHDVM(25)
COMMON /HDDREG/ C2BDRG(21),LHDRG(21),MHDRG(21),HHDRG(21)
COMMON /IDLEQ1/ ZMLIDL(15,3,8,2),DRIDL(15,3,8,2)
COMMON /IDLEQ2/ MYGIDL(15,3,8,2),MAXIDL
COMMON /IDLEQ3/ UTIDOF(14,3,2)
COMMON /ICR4VA/ CRD4VA(24,2,12,3)
COMMON /ICR4VB/ CRD4VB(24,2,12,3)
COMMON /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER(2),CRIM
COMMON /IMPAR2/ ILDT(4),ITEST,NUDATA(2),NLIM,IMNAME(20,9)
COMMON /IMPAR3/ IMDX1,IMDX2,IMCASE,IMVEH,IM
COMMON /IMPAR5/ MYGIM2(3,3),LBIM4P,CRHDGV(2,2),DISCNT(3)
COMMON /IMPAR6/ IFREQ,INTYP
COMMON /IM12HC/ CR12HC(19,20,5,2)
COMMON /IM12CO/ CR12CO(19,20,5,2)
COMMON /IM240P/ DSIZE(25,4),IM24YR,IPRGYR,IPRSYR
COMMON /INJECT/ TBI(13,4),PFI(13,4),MAXFIY,MINFIY
COMMON /IOUCOM/ IOUIMD,IOUGEN,IOUREP,IOUERR,IOUASK
COMMON /IVPCOM/ IVPTRL(8),IVPTRT(8),IVPTRA(8),IVPTRB(8)
COMMON /LOOKUP/ IVTAM,IQG,IPG,JPGD,IHG,IGCSF
COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
COMMON /MPDCOM/ MAXMPD,VALMPD(2,8),MYGMPD(2,8)
COMMON /MYCODE/ MY,IDX,JDX,LDXSY,LMYRVT,IAY,IMDXSY,IMKINK
COMMON /MYRCAL/ XMYM(25,8),JANMYR(25,8),TF(25,8),TFMYM(25,8)
COMMON /MYRSAV/ AMAR(25,8),JULMYR(25,8),NEWCUM
COMMON /MYUB1/  MYTGS(11,6,4),MYEGR(4,4),MYVTS(3,2,4)
COMMON /MYUB2/  MYCCEI(7,4)
COMMON /NAMES1/ NAMFLG(19),NAMMMR(2,3,8),NAMRVP(4),NAMTEM(2)
COMMON /NMETH1/ ZDMTH1(2,3,2,7,3,2),ZDMTH2(2,7,2,2),ZDMTH3(7,3,2)
COMMON /NMETH2/ MYGMTH(7,8,2),MTHMYG
COMMON /OFFSET/ OFFCO(25,3),OFFMTH(25,8)
COMMON /OMTCOM/ OMTCF(25,3,8),OMTTAM(25,3,4),OMTCFF(25,3,8)
COMMON /OPMOD1/ BFRCOF(8,8,3,6),BFSTEP(8,12,3,3),BFR50K(4,12,3)
COMMON /OPMOD2/ MYSTEP,MAXBFR,MYGBFR(8,3,6)
COMMON /OPMOD3/ BFMILE,KINKBF,BFGT50
COMMON /OXY1/ SHRMKT(3),OXYCNT(2),IGASHW
COMMON /OXY2/ NFUEL,MXOXMY,MAXOXY,OXYVAL(25,12),OXYBF(25,12),OXYCF
COMMON /PROJEC/ PROJID(20)
COMMON /QUITXQ/ N1QUIT
COMMON /REGION/ FEET(2),IREJN,ALT,INITPR
COMMON /REGISF/ GSFVCT(8),USRGSF(25,2)
COMMON /RESUL1/ EFFTP(3,9),EFEXH(9),EFEVAP(9),EFREFL(9),EFRUNL(9)
COMMON /RESUL2/ RLGGAL(9),RSTGPH(9),EFRSTL(9),EFIDLE(3,9)
COMMON /RESUL3/ VFTP(3),VEXH,VEVAP,VLOSS,VRUNLS,VRSTLS,VIDLE(3)
COMMON /RLCOM1/ ROADFE(32,4),DISPL,SPILL,OBED,OBES,OBDF(4)
COMMON /RLCOM2/ IOBMY,IVOB(4),IS2SY,NPHASE,S2EFF(4)
COMMON /RLCOM3/ RLRATE(25,4)
COMMON /RUNLS1/ TLEMI(6,3,4,4,4,4),TLVMT(6),TLVMTU(6),MAXTL
COMMON /RUNLS2/ TLFAIL(6,4,4)
COMMON /RUNLS3/ MYGRUL(4,4),RULRVP(4),RULTEM(4),RULSPD(3),MAXRUL
COMMON /RESTLS/ PTGRST(13,5,2),RESTA(2),RESTB
COMMON /RVPEX1/ R9G1(3,2),RG23(3,3,3,2),TLL(2)
COMMON /RVPEX2/ MYGRVP(4,4),RVPCF(25,3,4)
COMMON /RVPNAT/ RVPLIM(2),RVPDIU(2),PFUL
COMMON /SCENE1/ SPD(8),PCCN,PCHC,PCCC
```

```
      COMMON /SCENE2/ FCC,FCN,FHC,FHN
      COMMON /SPEED1/ SK1(6,18,3),SK2C(2,14,3,3),SK4C(2,14,3,3)
      COMMON /SPEED2/ MYGSP1(18,2,3),MYGSMC(18,2,3),MYGSP2(3,3)
      COMMON /SPEED3/ SADJ,SCUNA1(18,3,8),SCADJ1(3,4),ISPGRP(3,4)
      COMMON /SPEED4/ MAXSP1,LB1STS(3),LBLAST,IVB,IVA,SCUNA0(18,3,8,2)
      COMMON /SPEED5/ MYHSPC(2,3),MAXHSP(3)
      COMMON /SPEED6/ SALHCF(25,3,8),SCFIDL(25,4),SCIADJ(25,3,8)
      COMMON /SPEED7/ GPBSCO(3,3,4)
      COMMON /SIZCAL/ ATR(5,2),TGSUSE,CSIZE(12,2),CSAE(12)
      COMMON /SIZPAR/ NTERMS(4),INDXCS(5,4)
      COMMON /STRING/ NOYES(2),COMMA,PERIOD,COLON
      COMMON /TAMEQ1/ TAMZML(9,4,3,2),TAMDR(9,4,3,2),TAMA50(9,4,3,2)
      COMMON /TAMEQ2/ MYGTAM(3,4),F50K
      COMMON /TAMEQ3/ CUMCAP,CUMALL,CUMNIM,CUMIM,GT50KA,GT50KN,GT50KI
      COMMON /TAMEQ4/ BTR(9,2)
      COMMON /TAMID1/ EMI3W(3,3,3),EMIOX(3,3,3),EMIDL(3,4,3)
      COMMON /TAMID2/ MYIDLE(3,3),IEK
      COMMON /TAMID3/ OFFIDL(3,25,4)
      COMMON /TAMOUT/ TAMBAG(3,3,25,4),THS(2,25,4),TDU(25,4),TCC(25,4)
      COMMON /TAMOU2/ TOB(25,4),GCONLY(25,4)
      COMMON /TAMPB1/ LPOD,PBBTR(3,2,25,4)
      COMMON /TEMPC1/TTFC(2,3,9,3),TTFD(3,3,3),TT4(2,6,3),TT8(2,3,4,3)
      COMMON /TEMPC2/ MAXTCF,MYGTCF(9,3,5),MYGTFD(3),ISHIFT
      COMMON /TEMPC3/ MDLOHI(3),TDIFF(3),CHFRAC(3),TCF(3)
      COMMON /TEMPC4/ MYGCOO(3),LOWCO,COOTFC(3),COOTFD(3)
      COMMON /TEMPC5/ NCC,MYCOL(2),CCSTD(3,2)
      COMMON /TEMPC6/ CSUB(3,2),CMUL(3,2),PIVPCT(3,3,2)
      COMMON /TEMPC7/ ICOLD,ADDCSW,MULCSW
      COMMON /TEMPS/ AMBT,TEMMIN,TEMMAX,TEMEXH(3),TEMEVP(6)
      COMMON /TPDCOM/ TPDCO(2,8)
      COMMON /USDATA/ USNAME(4,4),NUSD,IUSD(4)
      COMMON /VMXCOM/ REGMIX(8),TFNORM(8),VMTMIX(8),VCOUNT(39,8)
      COMMON /YEARS4/ IY1941,IY1960,IY2020
C
      COMMON /SAVE01/ JCALL,VA001(15,3,8,2),VA002(15,3,8,2)
      COMMON /SAVE02/ VA003(24,2,12,3),VA004(24,2,12,3)
      COMMON /SAVE03/ VA005(19,20,5,2),VA006(19,20,5,2)
      COMMON /SAVE04/ VA007(25,8),VA008(25,8)
      COMMON /SAVE05/ VA009(9,4,3,2),VA010(9,4,3,2)
      COMMON /SAVE06/ VA011(8)
C
C
C  The CEM Post-Processor COMMON BLOCKS
C
      COMMON /COST02/ IFEVYR,ILEVYR
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
      COMMON /COST27/ IGRFLG,IATPLP,IDIFF,OUTPRF
C  Add JPRGYR & JPRSYR, 5/29/91
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
C
      COMMON /COSTXX/ JMYR1,JMYR2
C
      COMMON /IONAME/ M4IN,M4OUT,M4IMC,C4IN
C
C      CHARACTER*20 M4IN,M4OUT
C
C      CALL GETCL(M4IN)
C
      ISAV93=0
      IF(JCALL.EQ.0) GOTO 10
C
C  Subroutine call, setup run.
C
      CALL REINIT
C
      IF(JCALL.EQ.1) CALL BDSAVE
C
      IF(JCALL.EQ.2) CALL RESTOR
      JCALL=2
C
C... Set for pc file i/o
C
C      OPEN(UNIT=5,FILE='M4INPUT',STATUS='OLD')
CC     OPEN(UNIT=5,FILE=M4IN,STATUS='OLD')
C      OPEN(UNIT=6,FILE='M4OUTPUT',STATUS='NEW',
C     *  CARRIAGE CONTROL="FORTRAN")
C
C  Initialize non-COMMON variables (INERR & local variables).
C
   10 INERR=0
      ICYOLD=-1
```

```
      IROLD=-1
      PRECY=0
      LEAST1=0
C
C  Control and One-Time Data Sections:
C
C  Get the execution control flags and parameters, and then use them to read
C  in data, if any, that is read in once and applied to all scenarios.  Note:
C  alternate RETURN1 is the fatal read error exit: execution stops.
C
      CALL CONSEC(*99,*999)
C
C  Set up for an ATP only run.
C
      IATPLP = 1
      IF(IMFLAG.EQ.1 .AND. ATPFLG.EQ.2) IATPLP = 2
C
      CALL ONESEC(INERR,*99)
C
C  Store original input settings
C  (ISTRT=IMSTRT set in ONESEC)
C
      ISTRT= IMSTRT
      JIM  = IMFLAG
      JATP = ATPFLG
      JPRGYR = IPRGYR
      JPRSYR = IPRSYR
      JMYR1 = MODYR1
      JMYR2 = MODYR2
C
      GOTO 15
C
C  Enter scenario loop.
C
      ENTRY MOBNXT(INERR, *)
C
   15 CALL PPINIT
C
C
C  Note that if INERR > 0 coming out of CONSEC/ONESEC, then the scenarios will
C  be read and processed, but EFCALX/OUTPUT will not be called.  The user will
C  only get error diagnostics out of the run.
C
C  20 CALL PARSEC(ICY,INERR,*98)
   20 CALL PARSEC(ICY,INERR,*999)
C
C  Display status on screen...
C
      WRITE(0,100) ICY,PROJID
  100 FORMAT(' Start CEM4.1 Run for Evaluation Year: ',I4,/,
     *  1X,20A4 )
C
      IF(ICY.LT.ICYIM .AND. ICY.LT.LAPSY) GOTO 20
C
C  Removed old CALL CHKSEN...
C
      IFEVYR = ICY
C
C  later add direct input of # of consec yrs (IDIFF) to ilevyr
C
      ILEVYR = IFEVYR + IDIFF - 1
C     IDIFF = ILEVYR - IFEVYR + 1
C
C... later can change 1 to some cem input number of consecutive yrs if want.
C
   22 JCYDX = ICY - IFEVYR + 1
C     WRITE(8,102) JCYDX,ICY,IFEVYR,ILEVYR
  102 FORMAT(1X,'jcydx,icy,ifevyr,ilevyr:',4I6)
C
C  Enter program scenario loop.
C
      DO 25 JSCEN=1,4
C
         ISCEN = 4 - JSCEN + 1
C
C  If ATP-Only case, skip I/M MOBILE4 runs
C
         IF(IATPLP.EQ.2 .AND. JSCEN.GE.3) GOTO 26
C
         CALL RESET
C
```

```
C  50+ errors is (arbritrary) run limit => stop execution.  Otherwise,
C  one or more input processing errors => abort current scenario & then do
C  input processing for error diagnostics on the remaining scenarios.  INERR
C  is never reset to 0, but instead accumulates until the run ends or the
C  cutoff value (50) is reached.
C
      IF(INERR.GT.50) GOTO 30
C     IF(INERR.GT.0) GOTO 20
      IF(INERR.GT.0) GOTO 30
C
      IF(ICYOLD.NE.ICY.OR.IROLD.NE.IREJN) CALL REGMOD(ICY,INERR)
      IF(INERR.GT.50) GOTO 30
C     IF(INERR.GT.0) GOTO 20
      IF(INERR.GT.0) GOTO 30
      ICYOLD=ICY
      IROLD=IREJN
C
C   Warning 130 - for ICY's 1993+ MOBILE4.1's disclaimer
C
      IF(ISAV93.EQ.0.AND.ICY.GE.1993) CALL QUITER(0.,0,120,INERR)
      IF(ICY.GE.1993) ISAV93=1
C
      CALL EFCALX(ICY,INERR)
C...
C     IF(INERR.GT.50) GOTO 30
C     IF(INERR.GT.0) GOTO 20
      IF(INERR.GT.0) GOTO 30
C...
      CALL EFSAVE(ISCEN,JCYDX)
      CALL SAVER(ICY)
      IF(OUTPRF.EQ.1) GOTO 25
      IF(OUTPRF.EQ.2 .AND. JCYDX.LE.IDIFF .AND.
     *  JSCEN.EQ.1) CALL OUTPUT(ICY)
      IF(OUTPRF.EQ.3 .AND. JCYDX.LE.IDIFF .AND.
     *  (JSCEN.EQ.1.OR.JSCEN.EQ.4)) CALL OUTPUT(ICY)
      IF(OUTPRF.EQ.4 .AND. JCYDX.LE.IDIFF) CALL OUTPUT(ICY)
      IF(OUTPRF.EQ.5) CALL OUTPUT(ICY)
C
   25 CONTINUE
C
      LEAST1=1
C     GOTO 20
      GOTO 28
   26 CALL ATPSAV(ICY)
C
   28 IF(JCYDX.LE.IDIFF) THEN
        ICY = ICY+1
        GOTO 22
      ENDIF
      GOTO 99
C
C     GOTO 20
C
   30 CALL QUITER(0.0,0,28,INERR)
C
C  If user is supplying replacement basic FTP ef parameter records, always
C  print the records contents and disposition table, even when input errors
C  have prevented the normal output routines from being called.  The only
C  exception is when a READ error / end-of-file occurs in CONSEC or ONESEC.
C
C  This section can be expanded to print other optional input.
C
   98 IF(LEAST1.EQ.0.AND.NEWFLG.EQ.2) CALL OUTNEW
C
   99 RETURN
C
C  End-of-file on 1st read of call => input for call missing entirely.
C  Calling program can branch to attach a new input file or terminate
C  calls to MOBILE.
C
  999 RETURN 1
C  End MOBILE
      END
```

```
      SUBROUTINE TAMPER(ICY)
C
C  TAMPER computes tampering effects in grams/mile on bag 1, 2 & 3 HC, CO,
C  & NOX and on hotsoak, diurnal & crankcase HC.
C
C  Called by EFCALX.
C
C  Calls BAGEME, DISATP, EFFGRP, EMIRAT, EVPEME, FINDPB, and IMCHEK.
C
C  Input on call:
C
C    parameter list: ICY
C    common blocks:
C    /ATPAR1/ LAPSY,LAP1ST,LAPLST,LVTFLG
C    /FLAGS4/ PRTFLG
C    /IMPAR1/ ICYIM
C    /IMPAR3/ IM
C    /MAXIMA/ MAXYRS
C    /TAMPB1/ LPOD
C
C  Output on return:
C
C    common blocks:
C    /LOOKUP/ IVTAM
C    /MYCODE/ MY,IDX,JDX,LDXSY,LMYRVT,IMDXSY,IMKINK
C
C  Local variable / array dictionary:
C
C   Name    Type              Description
C  ------   ----  ------------------------------------------------------
C  LDX1ST    I    JDX order pointer to first model year covered by ATP
C  LDXLST    I    JDX order pointer to last model year covered by ATP
C  LMYR      I    flag relating model year to ATP parameters
C                   1 = model year not covered by an ATP
C                   2 = JDX is covered by an ATP (but IVTAM may not be,
C                       hence, check for inclusion to set LMYRVT)
C
C  Notes:
C
C  TAMPER was changed for MOBILE4.1v6 to call FINDPB.
C
C...  ATPFLG.EQ.1 check added, and ATPFLG declared as INT.
C...
      INTEGER PRTFLG,HCFLAG,COLDFG,ATPFLG
C
      COMMON /ATPAR1/ LAPSY,LAP1ST,LAPLST,LVTFLG(4)
C...
      COMMON /FLAGS3/ ATPFLG,TPDFLG,RLFLAG,LOCFLG,TEMFLG,OUTFMT
C
      COMMON /FLAGS4/ PRTFLG,IDLFLG,NMHFLG,HCFLAG,COLDFG
      COMMON /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER(2),CRIM
      COMMON /IMPAR3/ IMDX1,IMDX2,IMCASE,IMVEH,IM
      COMMON /LOOKUP/ IVTAM,IQG,IPG,JPGD,IHG,IGCSF
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
      COMMON /MYCODE/ MY,IDX,JDX,LDXSY,LMYRVT,IAY,IMDXSY,IMKINK
      COMMON /TAMPB1/ LPOD,PBBTR(3,2,25,4)
C...
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
C
C  Relate start year of anti-tampering program (ATP) and 1st and last model
C  years covered to calendar year.  Put them in JDX order.  For example:
C
C       ICY = LAPSY => LDXSY = 1
C       ICY = LAPSY + 1 => LDXSY = 2
C           .
C           .
C       ICY = LAPSY + 24 => LDXSY = 25
C
C  JDX order is used because these values are used to access the JDX ordered
C  CUMMIL.  Note that LDXSY <= 0 => ICY < LAPSY => no ATP was in effect during
C  any part of the calendar year's 25 model year window.
C
C  The ATP has to be in effect at least 1 year prior to ICY for it to affect
C  ICY's emissions.  The mileage accumulated through LAPSY all goes to the no
C  program case.
C
C  Only calculate these values once per scenario => compute them here before
C  the tamper loops begin.
C
      LDXSY=ICY-LAPSY+1
      LDX1ST=ICY-LAP1ST+1
```

```
      LDXLST=ICY-LAPLST+1
C
C  Decide whether to use "Non-I/M" (IM=1) or "I/M" (IM=2) TAMZML and TAMDR:
C
      CALL IMCHEK(1,ICY,IVTAM,IDX)
C
C  Relate I/M start year to calendar year, using JDX ordering.  This pointer
C  will be used within IDX loop to set kinked tampering rate curves flag.
C
      IMDXSY=ICY-ICYIM+1
C
C  For each tampering vehicle type and each model year in the 24 year window
C  from ICY-23 thru ICY (25+ year case is always zeroed), compute the bag and
C  evaporative tampering offsets.
C
      DO 40 IVTAM=1,4
C
      CALL IMCHEK(2,ICY,IVTAM,IDX)
C
      DO 30 IDX=2,MAXYRS
C
C  MY pointer info using IDX & ICY may be done here, before sub calls.
C
C  Identify this loop's model year for use in ITAMPT lookups.
C
      MY=ICY-(MAXYRS-IDX)
C
C  Assign the reverse order (ICY -> 1, increases with age) my index for use in
C  apportioning mileage weights.
C
      JDX=MAXYRS-IDX+1
C
C  Reset (turn off) the ATP my range switch.  Turn on if there is an ATP
C  program, it starts before the calendar year, the model year JDX is in the
C  affected range and the vehicle type has been selected by the user for
C  coverage.
C
C      LMYRVT = 1 => switch is off.  ATP not a factor in my JDX's tampering
C      LMYRVT = 2 => switch is ON.  ATP is a factor in my JDX's tampering
C
C  Note: ATPFLG = 1 => LAPSY = 2020 => LDXSY < 1 => 1st 2 criteria can be
C        checked using LDXSY.    (...Except for CEM, which changes ATPFLG
C        without changing LAPSY or LDXSY accordingly.  So we need to include
C        the ATPFLG check for use with CEM.)
C
      LMYR=1
      LMYRVT=1
C
      IF(LDXSY.GT.1.AND.LDX1ST.GE.JDX.AND.JDX.GE.LDXLST)  LMYR=2
C
C     IF(LDXSY.GT.1.AND.ATPFLG.GT.1.AND.LDX1ST.GE.JDX.AND.JDX.GE.LDXLST)
C    *  LMYR=2
C
C  either add next line or use revised long IF line above for CEM...
C...
      IF(ATPFLG.EQ.1) LMYR=1
C
      IF(LMYR.EQ.2.AND.LVTFLG(IVTAM).EQ.2) LMYRVT=2
C
      CALL IMCHEK(3,ICY,IVTAM,IDX)
C
C  Set kinked disablement rate curves flag.
C
      IMKINK=1
      IF(IM.EQ.2.AND.JDX.GT.IMDXSY) IMKINK=2
C
C  Figure the base tampering rates for both exhaust and non-exhaust emissions.
C
      CALL DISATP
C
C  If ICY is beyond LPOD, use the tampering rates as of LPOD for the misfueling
C  categories (ID=3,4,9) for vehicles in ICY's fleet produced thru LPOD.
C
      IF(ICY.GT.LPOD) CALL FINDPB(ICY)
C
C  The next 3 subroutines compute the tampering bag emission additives.
C
      CALL EFFGRP
      CALL EMIRAT
      CALL BAGEME
C
```

```
C  The non-exhaust HC emission additives calculation procedure is much
C  simpler because there are no overlaps.  EVPEME does all the work.
C
      IF(PRTFLG.EQ.1.OR.PRTFLG.EQ.4) CALL EVPEME
C
   30 CONTINUE
   40 CONTINUE
C
      RETURN
C End TAMPER
      END
```

```
      SUBROUTINE EFFGRP
C
C  EFFGRP builds the tampering effects group sizes array.  The tampering
C  rates from DISATP are modified  to account for technology vs tampering
C  types, overlap factors, anti-tampering program effectiveness factors and
C  technology group sizes.  The output rates are divided into effects groups
C  corresponding to the significant emission impact tampering groups.
C
C  Called by TAMPER.
C
C  Calls ADJ12, ATPEFF, A8TO11, C1TO7, C8TO12, ITAMPT, SETEGS and TECH0.
C
C  Input on call:
C
C    common blocks:
C    /EGSCAL/ TGS
C    /LOOKUP/ IVTAM
C    /MYCODE/ MY,JDX,LDXSY,LMYRVT
C    /SIZCAL/ CSIZE
C
C  Output on return:
C
C    common blocks:
C    /EGSCAL/ EGS
C    /LOOKUP/ IQG,IPG,JPGD,IGCSF
C    /MYCODE/ IAY
C    /SIZCAL/ TGSUSE,CSAE
C
C  Local array subscripts:
C
C  CSF1ST(7,2,3) -  CSF1ST ( IC7, IPG, IGCSF )
C
C  Local variable / array dictionary:
C
C   Name    Type              Description
C  ------  ----  ------------------------------------------------------
C  CSF1ST    R    category size factor for 1st calculation of CSIZE, expressed
C                 as <overlap case's CSF> = <o.c. freq> / <base case freq>,
C                 where <base case> = AorE for IC7=1-3, CATS for IC7=4-7
C
C  Notes:
C
C  EFFGRP was modified for MOBILE4.1 v5 to expand CSF1ST to 3 MYGs & updates
C  its rates.  Tampering effects are stored in array BSIZE for CEM4.1.
C
C
      DIMENSION CSF1ST(7,2,3)
C
      COMMON /EGSCAL/ AER(11,11,2,2),TGS(11,6,4),EGS(7,2)
      COMMON /LOOKUP/ IVTAM,IQG,IPG,JPGD,IHG,IGCSF
      COMMON /MYCODE/ MY,IDX,JDX,LDXSY,LMYRVT,IAY,IMDXSY,IMKINK
      COMMON /SIZCAL/ ATR(5,2),TGSUSE,CSIZE(12,2),CSAE(12)
C...
      COMMON /COST32/ BSIZE(4,25,2,6,17,2),TRAT(9)
C
C  Continuation code is IPG = H (HC & CO) & N (NOx)
C  MYG 1 applies to all MY for HDGV; the indicated ranges are for LDGV/T.
C
      DATA CSF1ST/
C                              CSIZE
C          1       2       3       4       5       6       7
C  MYG 1 (pre-1981)
     H   .0708, .1420, .1538, .5529, .0000, .1513, .2500,
     N   .0948, .1209, .0033, .3059, .0039, .3843, .0118,
C  MYG 2 (1981-83)
     H   .1421, .0519, .0364, .2840, .0406, .1917, .1469,
     N   .0698, .0233, .0116, .2727, .0260, .2338, .0130,
C  MYG 3 (1984+)
     H   .1739, .0750, .0938, .1011, .0000, .0470, .0556,
     N   .1212, .0000, .0000, .0000, .0000, .0588, .0000/
C
C  Zero out tampering effects group sizes (EGS) array.
C
      DO 20 IPG=1,2
      DO 10 IEG=1,7
      EGS(IEG,IPG)=0.0
   10 CONTINUE
   20 CONTINUE
C
```

```
C  Add in each equipment (technology) group's before and after anti-tampering
C  program (ATP) start year contribution to each EGS category for each
C  pollutant group.
C
      DO 80 IPG=1,2
C
C  Set ATR pointer for 1st 3 sizes: HC/CO => use AIRS, NOX => use EGRS.
C
      IF(IPG.EQ.1) JPGD=1
      IF(IPG.EQ.2) JPGD=5
C
      DO 70 IQG=1,6
C
C  Lookup technology group size to be used on this pass.
C
      IG1=ITAMPT(1)
      TGSUSE=TGS(IG1,IQG,IVTAM)
C
C  Check how technology type & size affect tampering rates.
C
      CALL TECH0(*70)
C
C  HC & CO effects category sizes are identical => only 2 pollutant passes.
C
      DO 65 IAY=1,2
C
C  Skip to end of loop if no mileage accumulated (hence no tampering)
C  for the pre/post ATP year case being checked.
C
      IF(IAY.EQ.1.AND.LMYRVT.EQ.2.AND.LDXSY.GT.JDX) GOTO 64
      IF(IAY.EQ.2.AND.LMYRVT.EQ.1) GOTO 64
C
      IGCSF=ITAMPT(6)
      CALL C1TO7(CSF1ST(1,IPG,IGCSF))
      CALL C8TO12
C
C  The first calculation pass can produce negative sizes for the no
C  overlap (8-11) and the no effects (12) categories.  Correct these
C  by calling A8TO11 and ADJ12, respectively.
C
      DO 30 IC=8,11
      IF(CSIZE(IC,IAY).LT.0) CALL A8TO11(IC)
   30 CONTINUE
      IF(CSIZE(12,IAY).LT.0) CALL ADJ12(CSF1ST)
C
C  "Subsequent" (to ATP start year) pass + have split mileage case =>
C  "subsequent" category size = overall size - "previous" size
C
C  I.e., in the split mileage case, the program computes the previous to
C  ATP start year and overall values up to this point.  After this next
C  loop assigns the subsequent values as residuals, the program works
C  directly with the previous and subsequent cases in the calls to ATPEFF
C  and SETEGS.
C
      IF(IAY.EQ.1.OR.LMYRVT.EQ.1.OR.LDXSY.GT.JDX) GOTO 50
      DO 40 IC=1,12
      CSIZE(IC,2)=CSIZE(IC,2)-CSIZE(IC,1)
   40 CONTINUE
C
C  If ATP covers this MY, apply effectiveness factors to the category sizes.
C
   50 IF(LMYRVT.EQ.2) CALL ATPEFF(*60)
C
C  Otherwise just shift IAY's sizes to CSAE without modification.
C
      DO 55 IC=1,12
      CSAE(IC)=CSIZE(IC,IAY)
   55 CONTINUE
C
C  Set the effects group sizes.
C
   60 CALL SETEGS
C...
   64 DO 61 IC=1,12
        BSIZE(IVTAM,JDX,IPG,IQG,IC,IAY) = CSAE(IC)
   61 CONTINUE
   65 CONTINUE
   70 CONTINUE
   80 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE EVPEME
C
C  EVPEME serves the same functions for evaporative (evap = hot soak + diurnal)
C  and crankcase (cc) HC as EFFGRP, EMIRAT and BAGEME do for exhaust IP,
C  producing hs & du HC tampering rates & cc HC offset.  The task is simplified
C  into one subroutine because there is no overlap categorization or
C  weighting.  The appropriate numbers are looked up and multiplied
C  together with only anti-tampering effectiveness reductions (if any) applied.
C
C  Called by TAMPER.
C
C  Calls ITAMPT,OTCALC.
C
C  Input on call:
C
C    common blocks:
C    /EVPDAT/ EVPAER,EVPTGS,CCEMI
C    /LOOKUP/ IVTAM
C    /MYCODE/ IDX,JDX,LDXSY,LMYRVT
C    /TAMEQ4/ BTR
C
C  Output on return:
C
C    common blocks:
C    /IM240P/ DSIZE
C    /LOOKUP/ IHG
C    /TAMOUT/ THS,TDU,TCC
C    /TAMOU2/ TOB,GCONLY
C
C  Local variable dictionary:
C
C   Name    Type              Description
C  ------   ----  ------------------------------------------------------
C  OTR       R    overall (previous + subsequent my ranges) tampering rate
C  OTRCAR    R    carbureted hot soak affecting overall tampering rate
C  OTRINJ    R    fuel injected hot soak affecting overall tampering rate
C  PCTEQP    R    percentage of IVTAM fleet equipped with IHG technology,
C                 given IG3
C
C  Notes:
C
C  EVPEME modified for MOBILE4.1 to store diurnal and crankcase
C  tampering rates in DSIZE.
C
      INTEGER ATPFLG,TPDFLG,RLFLAG,TEMFLG,OUTFMT
C
      COMMON /EVPDAT/ EVPAER(3,2),EVPTGS(3,2,4),CCEMI(7,4)
      COMMON /FLAGS3/ ATPFLG,TPDFLG,RLFLAG,LOCFLG,TEMFLG,OUTFMT
      COMMON /IM240P/ DSIZE(25,4),IM24YR,IPRGYR,IPRSYR
      COMMON /LOOKUP/ IVTAM,IQG,IPG,JPGD,IHG,IGCSF
      COMMON /MYCODE/ MY,IDX,JDX,LDXSY,LMYRVT,IAY,IMDXSY,IMKINK
      COMMON /TAMEQ4/ BTR(9,2)
      COMMON /TAMOUT/ TAMBAG(3,3,25,4),THS(2,25,4),TDU(25,4),TCC(25,4)
      COMMON /TAMOU2/ TOB(25,4),GCONLY(25,4)
      COMMON /COST32/ BSIZE(4,25,2,6,17,2),TRAT(9)
C
C  For MOBILE4, crankcase (IH = 3) processing does not change.
C  Diurnal processing only changes in its selection of the new evaporative
C  cannister + gas cap tampering (ID = 8) instead of the previously used
C  evaporative cannister only (ID = 6).  Since aside from data point selection,
C  the procedures for calculating the diurnal and crankcase offsets are the
C  same, a loop structure remains the convenient way to program the procedure
C  Hot soak, on the other hand, has become more complicated and has therefore
C  been pulled from the old IH loop and treated separately, after the diurnal
C  and crankcase offsets have been computed.
C
C  MOBILE4 defers HS and DU tampering offset calculation to CCEVRT,
C  returning only the % equipped * overall tampering rates instead.
C
C  The Diurnal and Crankcase tampering rates are stored in BSIZE for CEM4.1.
C
C  Store the non-ATP rates.
C
      DSIZE(IDX,IVTAM)=BTR(8,1)+BTR(8,2)
C
      DO 10 IH=2,3
C
```

```
C  There are only two evaporative cases, not three, when indexing the
C  anti-tampering effectiveness rates, evaporative technology group sizes,
C  and the model year groups for the group sizes and the evaporative emission
C  impact rates:  for these arrays, the hot soak and diurnal numbers are
C  identical.  For convenience we use IHG instead of IH in these arrays.
C
      IHG=IH-1
C
C  Assign the tampering index (see paragraph preceding DO statement).
C
      ID=9-IHG
C
C  Get the overall tampering rate.  As in DISATP, there are 3 cases:
C
C    (1) No ATP or its start year is after ICY or IDX is not in affected my
C        range: use the "previous" base rate without applying the
C        effectiveness rates.
C
      IF(LMYRVT.EQ.1) OTR=BTR(ID,1)
C
C    (2) There is an ATP and its start year is before IDX and IDX is in the
C        affected my range: use the "subsequent" rate * the effectiveness
C        rate.
C
      IF(LMYRVT.EQ.2.AND.LDXSY.GT.JDX.AND.ID.EQ.7)
     *  OTR=OTCALC(ID,2,IHG,2)
      IF(LMYRVT.EQ.2.AND.LDXSY.GT.JDX.AND.ID.EQ.8)
     *  OTR=OTCALC(ID-2,2,IHG,2)+OTCALC(ID,2,3,2)-OTCALC(ID-2,2,3,2)
C
C    (3) There is an ATP and its start year is at or after IDX but before ICY
C        and IDX is in the affected my range: sum the rates * their
C        corresponding effectiveness rates.  Note that in this case, BTR holds
C        the "previous" and overall rates => subtract 1st from 2nd to get the
C        "subsequent" rates.
C
      IF(LMYRVT.EQ.2.AND.LDXSY.LE.JDX.AND.ID.EQ.7)
     *  OTR=OTCALC(ID,1,IHG,1)+OTCALC(ID,2,IHG,2)-OTCALC(ID,1,IHG,2)
      IF(LMYRVT.EQ.2.AND.LDXSY.LE.JDX.AND.ID.EQ.8)
     *  OTR=OTCALC(ID-2,1,IHG,1)+OTCALC(ID,1,3,1)-OTCALC(ID-2,1,3,1)
     *     +OTCALC(ID-2,2,IHG,2)+OTCALC(ID,2,3,2)-OTCALC(ID-2,2,3,2)
     *    -(OTCALC(ID-2,1,IHG,2)+OTCALC(ID,1,3,2)-OTCALC(ID-2,1,3,2))
C...
C  Save for CEM via EBSIZE...
C
      CALL EBSIZE(ID,OTR)
C
C  Lookup model year group pointers.
C
      IG3=ITAMPT(3)
C
      IF(IH.EQ.3) IG4=ITAMPT(4)
C
C  Lookup and apply the percentage equipped and emission impact factors.
C
      PCTEQP=EVPTGS(IG3,IHG,IVTAM)
      IF(IH.EQ.2) TDU(IDX,IVTAM)=OTR*PCTEQP
      IF(IH.EQ.3) TCC(IDX,IVTAM)=OTR*PCTEQP*CCEMI(IG4,IVTAM)
   10 CONTINUE
C
C  Now calculate the hot soak offset.  This case is complicated by both the
C  usage of 2 tampering types (evaporative cannister only and evaporative
C  cannister plus gas caps) and the weighting together of fuel injected and
C  carbureted emission impact rates.
C
      IH=1
      IHG=IH
C
C  Assign the carbureted tampering index = evaporative cannister only, since
C  carbureted hot soak HC is not affected by gas cap tampering.  The fuel
C  injected index is ID+2 = 8 = cannister + gas caps.
C
      ID=6
C
C  Get the overall tampering rates.  As with diurnal and crankcase, there are
C  3 cases, but now 2 rates are computed.
C
C    (1) No ATP or its start year is after ICY or IDX is not in affected my
C        range: use the "previous" base rate without applying the
C        effectiveness rates.
C
      IF(LMYRVT.NE.1) GOTO 20
```

```
      OTRCAR=BTR(ID,1)
      OTRINJ=BTR(ID+2,1)
      GOTO 40
C
C     (2) There is an ATP and its start year is before IDX and IDX is in the
C         affected my range: use the "subsequent" rate * the effectiveness
C         rate.
C
   20 IF(LDXSY.LE.JDX) GOTO 30
      OTRCAR=OTCALC(ID,2,IHG,2)
      OTRINJ=OTCALC(ID,2,IHG,2)+OTCALC(ID+2,2,3,2)-OTCALC(ID,2,3,2)
      GOTO 40
C
C     (3) There is an ATP and its start year is at or after IDX but before ICY
C         and IDX is in the affected my range: sum the rates * their
C         corresponding effectiveness rates.  Note that in this case, BTR holds
C         the "previous" and overall rates => subtract 1st from 2nd to get the
C         "subsequent" rates.
C
   30 OTRCAR=OTCALC(ID,1,IHG,1)+OTCALC(ID,2,IHG,2)-OTCALC(ID,1,IHG,2)
      OTRINJ=OTCALC(ID,1,IHG,1)+OTCALC(ID+2,1,3,1)-OTCALC(ID,1,3,1)
     *       +OTCALC(ID,2,IHG,2)+OTCALC(ID+2,2,3,2)-OTCALC(ID,2,3,2)
     *      -(OTCALC(ID,1,IHG,2)+OTCALC(ID+2,1,3,2)-OTCALC(ID,1,3,2))
C
C  Save the unweighted (by PCTEQP) Evaporative Cannister (EC) Only tampering
C  rate for figuring the On Board (OB) EC tampering impact on refueling losses.
C  Lookup model year group pointer for the percentage equipped table.
C
   40 TOB(IDX,IVTAM)=OTRCAR
      IG3=ITAMPT(3)
C
C  Lookup the percentage equipped with canisters factor and apply it to
C  the otr's to get the tampered percentage of carbureted and fuel injected
C  cases for hot soak.
C
      PCTEQP=EVPTGS(IG3,IHG,IVTAM)
      THS(1,IDX,IVTAM)=PCTEQP*OTRCAR
      THS(2,IDX,IVTAM)=PCTEQP*OTRINJ
C
C  Store the gas cap only tampering values for running loss weighting.
C
      GCONLY(IDX,IVTAM)=OTRINJ-OTRCAR
      IF(GCONLY(IDX,IVTAM).LT.0.0) GCONLY(IDX,IVTAM)=0.0
C
      RETURN
C  End EVPEME
      END
```

```
      FUNCTION FAIL(MYR,KDX,IV,IK)
C
C  FAIL handles the effect of Purge and Pressure failures as well as
C  evap system tampering, returning a fraction for purge/pressure.
C  Revised for CEM to save P/P failure rates for an in-place
C  inspection program (i.e., fail rates lower than for M4.1).
C
C  Called by HCCALX.
C
C  Calls ENFORC, ITAMPT.
C
C  Input on call:
C
C    parameter list: MYR,KDX,IV,IK,IG3
C    common blocks:
C    /EVPDAT/ PCTEQP
C    /FLAGS3/ ATPFLG
C    /IMPAR1/ CRIM
C    /IMPAR2/ ILDT
C    /IMPAR6/ INTYP
C    /IM240P/ DSIZE,IPRGYR,IPRSYR
C    /LOOKUP/ IVTAM
C    /MAXIMA/ MAXYRS
C    /MYCODE/ MY
C    /TAMOUT/ TDU
C
C  Output on return:
C
C    function: FAIL
C
C  Notes.
C
C  FAIL was added for MOBILE4.1.
C
C... for CEM...
C  ------------------------------------------------------------
C  PPFAIL  Block    Recurring (lower) repair rates for Purge, Press,
C                   Purge+Press for each MY & IV for Repair Costs.
C  PPFIXR  Block    Purge/Pressure Fix rates = Full non-program fail
C                   rate minus w/program failure rate for FE benefits.
C  ISRECR  Local    Flag "Is Recurring" to loop again with lower
C                   P/P fail rates.
C  ------------------------------------------------------------
C
C
      INTEGER ATPFLG,TPDFLG,RLFLAG,TEMFLG,OUTFMT
C
      COMMON /EVPDAT/ EVPAER(3,2),EVPTGS(3,2,4),CCEMI(7,4)
      COMMON /FLAGS3/ ATPFLG,TPDFLG,RLFLAG,LOCFLG,TEMFLG,OUTFMT
      COMMON /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER(2),CRIM
      COMMON /IMPAR2/ ILDT(4),ITEST,NUDATA(2),NLIM,IMNAME(20,9)
      COMMON /IMPAR6/ IFREQ,INTYP
      COMMON /IM240P/ DSIZE(25,4),IM24YR,IPRGYR,IPRSYR
      COMMON /LOOKUP/ IVTAM,IQG,IPG,JPGD,IHG,IGCSF
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
      COMMON /MYCODE/ MY,IDX,JDX,LDXSY,LMYRVT,IAY,IMDXSY,IMKINK
      COMMON /TAMOUT/ TAMBAG(3,3,25,4),THS(2,25,4),TDU(25,4),TCC(25,4)
C...
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
      COMMON /COST47/ PPFAIL(25,3,10,4),PPFIXR(25,10,4)
C
      DIMENSION RATE(3,13),OVLP(5),OVLR(5),PPEFF(25,2)
C
C  Revised Purge/Pressure Failure Rate calc's, 3/26/91
      DATA RATE   / .043, .043, .080,
     *              .043, .043, .080,
     *              .043, .043, .080,
     *              .060, .053, .096,
     *              .060, .053, .103,
     *              .069, .053, .120,
     *              .094, .053, .150,
     *              .094, .106, .188,
     *              .142, .152, .258,
     *              .214, .171, .323,
     *              .224, .236, .389,
     *              .229, .336, .442,
     *              .229, .336, .451   /
C
      DATA FACTOR,DEFF / 0.50, 0.50 /
C
```

```
C
C  Purge/Pressure Check Effectiveness
C
C  Purge/Pressure Check Effectiveness, Annual, Biennial
C
      DATA PPEFF /
     * .000,.238,.853,.910,.836,.789,.765,.732,.798,.837,
     * .903,.967,.992,.981,.967,.958,.922,.928,.927,.941,
     * .972,.992,.981,.967,.958,
     * .000,.238,.853,.910,.779,.789,.612,.732,.582,.837,
     * .733,.967,.945,.973,.947,.925,.849,.850,.701,.853,
     * .705,.972,.945,.973,.947 /
C
C  Initialize variables
C
      FAIL=0.0
      PRGR=0.0
      PRSR=0.0
      PPRT=0.0
      DO 10 I=1,5
        OVLP(I)=0.0
        OVLR(I)=0.0
   10 CONTINUE
C...
      ISRECR = 1
C
C  For diesel & motorcycles, return 0.0 for FAIL
C
      IF(IV.GT.4) RETURN
C
C  Determine percent of vehicles equipped with evap systems
C  (Use KDX and MYR to avoid problems with common block MYCODE)
C
      MY=MYR
      IDX=KDX
C
      IHG=1
      IVTAM=IV
      IG3=ITAMPT(3)
      PCTEQP=EVPTGS(IG3,1,IV)
C
C  Determine overall Pressure and Purge failure rates
C
      JDX=(MAXYRS+1)-IDX
      JDXX = JDX
      IF(JDXX.GT.13) JDXX=13
      PRGR=RATE(1,JDXX)*PCTEQP
      PRSR=RATE(2,JDXX)*PCTEQP
      PPRT=RATE(3,JDXX)*PCTEQP
C
      TRAT=DSIZE(IDX,IV)*PCTEQP
C...
C  This is where we jump in for the recurring rate loop...
C
   15 SUM=PRGR+PRSR
      IF(PPRT.GT.SUM) PPRT=SUM
C
C  Determine proportion of overall in each overlap
C
       OVLP(4)=TRAT*FACTOR
       OVLP(5)=TRAT*(1.0-FACTOR)
       OVLP(1)=PPRT-PRGR-OVLP(4)
      IF(OVLP(1).LT.0.0) OVLP(1)=0.0
       OVLP(2)=PRSR-OVLP(1)-OVLP(4)-OVLP(5)
      IF(OVLP(2).LT.0.0) THEN
        OVLP(2)=0.0
        OVLP(5)=PRGR-(PPRT-PRSR)
        OVLP(4)=OVLP(4)+TRAT*(1.0-FACTOR)-OVLP(5)
      ENDIF
       OVLP(3)=PRGR-OVLP(2)-OVLP(5)
      IF(OVLP(3).LT.0.0) OVLP(3)=0.0
C
C  Initialize rates in overlaps
C
      DO 20 I=1,5
        OVLR(I)=OVLP(I)
   20 CONTINUE
C
C... 10/30/91 change to skip over program reductions with
C    recurring repairs for ongoing program (already part of
C    recurring RATEs)
```

```
C
      IF(ISRECR.EQ.2) GOTO 40
C
C  Adjust rates to reflect programs
C
      EADJ=1.0 - ENFORC(CRIM,1)*PPEFF(JDX,IFREQ)
      ADJ=1.0-EADJ
C
C Purge Check Alone
C
      IF(MY.GE.IPRGYR.AND.ILDT(IV).EQ.2) THEN
        IF(INTYP.EQ.1) THEN
          OVLR(2)=EADJ*OVLP(2)
          OVLR(3)=EADJ*OVLP(3)
          OVLR(5)=EADJ*OVLP(5)
        ENDIF
        IF(INTYP.GT.1) THEN
          OVLR(2)=DEFF*ADJ*OVLP(2)+EADJ*OVLP(2)
          OVLR(3)=DEFF*ADJ*OVLP(3)+EADJ*OVLP(3)
          OVLR(5)=DEFF*ADJ*OVLP(5)+EADJ*OVLP(5)
        ENDIF
          OVLR(1)=OVLP(1)+OVLP(2)-OVLR(2)
          OVLR(4)=OVLP(4)+OVLP(5)-OVLR(5)
      ENDIF
C
C Pressure Check Alone
C
      IF(MY.GE.IPRSYR.AND.ILDT(IV).EQ.2) THEN
        IF(INTYP.EQ.1) THEN
          OVLR(1)=EADJ*OVLP(1)
          OVLR(2)=EADJ*OVLP(2)
          OVLR(4)=EADJ*OVLP(4)
          OVLR(5)=EADJ*OVLP(5)
        ENDIF
        IF(INTYP.GT.1) THEN
          OVLR(1)=DEFF*ADJ*OVLP(1)+EADJ*OVLP(1)
          OVLR(2)=DEFF*ADJ*OVLP(2)+EADJ*OVLP(2)
          OVLR(4)=DEFF*ADJ*OVLP(4)+EADJ*OVLP(4)
          OVLR(5)=DEFF*ADJ*OVLP(5)+EADJ*OVLP(5)
        ENDIF
          OVLR(3)=OVLP(3)+OVLP(2)-OVLR(2)+OVLP(5)-OVLR(5)
      ENDIF
C
C Combined Purge/Pressure Checks
C
      IF(INTYP.NE.3.
     *    AND.MY.GE.IPRSYR.
     *    AND.MY.GE.IPRGYR.
     *    AND.ILDT(IV).EQ.2) THEN
        IF(INTYP.EQ.1) THEN
          OVLR(1)=EADJ*OVLP(1)
          OVLR(2)=EADJ*OVLP(2)
          OVLR(3)=EADJ*OVLP(3)
          OVLR(4)=EADJ*OVLP(4)
          OVLR(5)=EADJ*OVLP(5)
        ENDIF
        IF(INTYP.GT.1) THEN
          OVLR(1)=DEFF*ADJ*OVLP(1)+EADJ*OVLP(1)
          OVLR(2)=DEFF*ADJ*OVLP(2)+EADJ*OVLP(2)
          OVLR(3)=DEFF*ADJ*OVLP(3)+EADJ*OVLP(3)
          OVLR(4)=DEFF*ADJ*OVLP(4)+EADJ*OVLP(4)
          OVLR(5)=DEFF*ADJ*OVLP(5)+EADJ*OVLP(5)
        ENDIF
      ENDIF
C
C Anti-tampering program effects
C
      IF(ATPFLG.EQ.2.AND.ILDT(IV).EQ.2) THEN
        IF(MY.LT.IPRSYR.OR.ILDT(IV).NE.2) THEN
          OVLR(4)=TDU(IDX,IV)*FACTOR
          OVLR(5)=TDU(IDX,IV)*(1.0-FACTOR)
        ENDIF
      ENDIF
C
C  Return adjusted overall Pressure/Purge rate
C
C  IK = 1 : Purge only effects
C       2 : Pressure effects
C
      IF(IK.EQ.1) FAIL=OVLR(3)
      IF(IK.EQ.2) FAIL=OVLR(1)+OVLR(2)+OVLR(4)+OVLR(5)
```

```
C...
C  Only need CEM info for full ATP run...
C
      IF(ISCEN.NE.4) GOTO 99
C
C
C  Save difference between no pgm & with pgm total failure rate
C  for FE benefit calcs (PPFEB) in PPFIXR...
C
      IF(ISCEN.EQ.4) PPFIXR(IDX,JCYDX,IV) =
     *   OVLP(1)+OVLP(2)+OVLP(3)+OVLP(4)+OVLP(5)
     *  -OVLR(1)-OVLR(2)-OVLR(3)-OVLR(4)-OVLR(5)
C
C  Force lower "recurring" failure rates for in-place program...
C
      PRGR = 0.03
      PRSR = 0.025
      PPRT = 0.05
      ISRECR = 2
C
C  Go back and recalc overlaps for recurring failures...
C
      GOTO 15
C
C  Adjusted overall Pressure/Purge rate
C
C     Store Purge & Pressure Repair rates for later repair cost calcs
C
C     OVLR(1) = Press fail only (no tampering)
C     OVLR(2) = Press & Purge fail (no tampering)
C     OVLR(3) = Purge fail only (no tampering)
C     OVLR(4) = Press fail due to tampering
C     OVLR(5) = Purge & Press fail due to tampering
C
C  Save recurring Purge/Press failure & fix rates from loop with ATP...
C
C   PPFAIL(x,1,x,x) = Entire PURGE failure rate
C   PPFAIL(x,2,x,x) = Entire PRESSURE failure rate
C   PPFAIL(x,3,x,x) = Total PURGE & PRESSURE failure rate
C   i.e., overlap would need to be computed by:
C   PPFAIL(1) + PPFAIL(2) - PPFAIL(3)
C
   40 IF(ISCEN.EQ.4 .AND. IV.LE.4) THEN
        PPFAIL(IDX,1,JCYDX,IV) = OVLP(2) + OVLP(3)
     *                         + OVLP(5)
        PPFAIL(IDX,2,JCYDX,IV) = OVLP(1) + OVLP(2)
     *                         + OVLP(4) + OVLP(5)
        PPFAIL(IDX,3,JCYDX,IV) = OVLP(1) + OVLP(2)
     *                         + OVLP(3) + OVLP(4)
     *                         + OVLP(5)
      ENDIF
C
   99 RETURN
C  End FAIL
      END
```

```
      FUNCTION PCLEFT(MY,ICY,IP,IV)
C
C  PCLEFT determines the basic emission factor multiplicative adjustment
C  ( = percentage left of BEF = PCLEFT ) for the effects of an inspection /
C  maintanance (I/M) program, after checking whether or not I/M applies to the
C  factor being computed by the calling function.
C
C  Called by BEF.
C
C  Calls IMPTR.
C
C  Input on call:
C
C    parameter list: MY,ICY,IP,IV
C    common blocks:
C    /FLAGS2/ IMFLAG
C    /ICR4VA/ CRD4VA
C    /ICR4VB/ CRD4VB
C    /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER,CRIM
C    /IMPAR2/ ILDT,ITEST
C    /IMPAR5/ CRHDGV,DISCNT
C    /IMPAR6/ IFREQ,INTYP
C    /IM12HC/ CR12HC
C    /IM12CO/ CR12CO
C    /IM240P/ IM24YR
C
C  Output on return:
C
C    function: PCLEFT
C
C  Local variable / array dictionary:
C
C   Name    Type              Description
C  ------   ----  ------------------------------------------------------
C  AGE1ST     I    age of the vehicle at first inspection
C  BY         I    benefit year for technology 1 or 2 vehicle
C  IBY        I    benefit year for technology 4 plus vehicle
C  IREM       I    remainder = stringency - greatest multiple of 10 < stringency
C  ISTRN      I    stringency index into technology 1 or 2 credits array
C  ITESTL     I    local version of ITEST used for IM240 check
C  REM        R    IREM converted to REAL value
C  WAIV       R    waiver rate used on this call, depends on MY
C
C  Notes:
C
C  Non-TECH4+ vehicles use 19th value for 20-24 benefit year.
C  TECH4+ vehicles have arrays expanded to MAXYRS-1.
C  PCLEFT was modified to include the IM240 check.
C
C
      CHARACTER*4 IMNAME
      INTEGER ALHFLG
C
      COMMON /FLAGS2/ MYMRFG,NEWFLG,IMFLAG,ALHFLG
      COMMON /IM12HC/ CR12HC(19,20,5,2)
      COMMON /IM12CO/ CR12CO(19,20,5,2)
      COMMON /IM240P/ DSIZE(25,4),IM24YR,IPRGYR,IPRSYR
      COMMON /ICR4VA/ CRD4VA(24,2,12,3)
      COMMON /ICR4VB/ CRD4VB(24,2,12,3)
      COMMON /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER(2),CRIM
      COMMON /IMPAR2/ ILDT(4),ITEST,NUDATA(2),NLIM,IMNAME(20,9)
      COMMON /IMPAR5/ MYGIM2(3,3),LBIM4P,CRHDGV(2,2),DISCNT(3)
      COMMON /IMPAR6/ IFREQ,INTYP
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
C
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
C
      INTEGER BY,AGE1ST
C
C  Initialize PCLEFT to "no reduction" value = 1.0.
C
      PCLEFT=1.0
C
C  If factor being calculated by BEF is not covered by I/M, then RETURN.
C
      IF(IMFLAG.EQ.1.OR.IP.EQ.3.OR.IV.GT.4) GOTO 99
C...
      IF(ILDT(IV).EQ.1.OR.
     *   ICY.EQ.MY.OR.ICY.LE.IMSTRT.OR.
     *   MY.LT.MODYR1.OR.MY.GT.MODYR2) GOTO 99
C
```

```
C  Assign waiver rates
C  Control WAIV (waver rates) for INTYP (I/M program type). INTYP 2=
C  I/M Decentralized/Computerized, & 3= Decentralized/Manual, if INTYP is
C   Not a 1= Centralized I/M and the WAIV is LE 50%,  WAIV is set to zero.
C
      IF(MY.LE.1980) WAIV=WAIVER(1)
      IF(MY.GT.1980) WAIV=WAIVER(2)
      IF(WAIV.LE.0.50.AND.INTYP.GT.1) WAIV=0.0
C
      IF(IV.EQ.4) GOTO 50
C
C  Selecting I/M reduction for LDGV or LDGT.  Several parameters must be set.
C
C  Determine technology by model year and vehicle type.
C
      ITECH=IMPTR(MY,IV)
C
C  Find the benefit year:
C  Limit value according to technology type.
C
C     BY=ICY-ICYIM
C...  IF(MY.GT.ICYIM) BY=ICY-MY
      BY=ICY-IMSTRT
      IF(MY.GT.IMSTRT) BY=ICY-MY
      IF(ITECH.LE.3.AND.BY.GT.19) BY=19
      IF(ITECH.GE.4.AND.BY.GT.MAXYRS-1) BY=MAXYRS-1
C
C  Find the age of the vehicle at first inspection.
C  Limit value according to technology type.
C
      AGE1ST=1
C...
      IF(MY.LT.IMSTRT) AGE1ST=IMSTRT-MY+1
C
      IF(ITECH.LE.3) THEN
        IF(AGE1ST.GT.19) AGE1ST=19
        IF(BY+AGE1ST.GT.19) BY=20-AGE1ST
      ENDIF
C
C  For now, continue MOBILE3 policy of using technology 2 credits for ITECH=3.
C
      IF(ITECH.EQ.3) ITECH=2
C
C  Branch on technology type: TECH 1 & 2 form 1 group, TECH 4+ another.
C
      IF(ITECH.GE.4) GOTO 40
C
C  Select correct I/M credits for TECH 1 & 2.  The same credits array is used
C  for LDGV and LDGT, but the ITECH mygs differ, so that the same MY may yield
C  a different credit for LDGV than for LDGT.
C
C  Interpolate between 10,20,30,40 & 30% stringency.
C
      IREM=ISTRIN-(ISTRIN/10)*10
      REM=IREM*.1
      ISTRN=(ISTRIN-IREM)/10
C
      IF(IFREQ.EQ.1) THEN
        IF(IP.EQ.1) THEN
          PCRED=CR12HC(BY,AGE1ST,ISTRN,ITECH)
          IF(ISTRN.LT.5.AND.IREM.GT.0)  PCRED=
     *       (CR12HC(BY,AGE1ST,ISTRN+1,ITECH)-PCRED)*REM+PCRED
        ELSE IF(IP.EQ.2) THEN
          PCRED=CR12CO(BY,AGE1ST,ISTRN,ITECH)
          IF(ISTRN.LT.5.AND.IREM.GT.0)  PCRED=
     *       (CR12CO(BY,AGE1ST,ISTRN+1,ITECH)-PCRED)*REM+PCRED
        ENDIF
C
       ELSE IF(IFREQ.EQ.2) THEN
        IF(IP.EQ.1) THEN
          PCRED=CR12HC(20-BY,21-AGE1ST,ISTRN,ITECH)
          IF(ISTRN.LT.5.AND.IREM.GT.0)  PCRED=
     *       (CR12HC(20-BY,21-AGE1ST,ISTRN+1,ITECH)-PCRED)*REM+PCRED
        ELSE IF(IP.EQ.2) THEN
          PCRED=CR12CO(20-BY,21-AGE1ST,ISTRN,ITECH)
          IF(ISTRN.LT.5.AND.IREM.GT.0)  PCRED=
     *       (CR12CO(20-BY,21-AGE1ST,ISTRN+1,ITECH)-PCRED)*REM+PCRED
        ENDIF
C
       ENDIF
C
```

```
      GOTO 60
C
C  Select I/M credits for TECH 4+ vehicles.  For TECH 4+, there are separate
C  credits arrays, one for annual and one for biennial inspection programs.
C  Use the Loaded/Idle Test for IM240 check.
C
   40 IBY=BY+AGE1ST-1
C
      ITESTL=ITEST
      IF(MY.GE.IM24YR.AND.MY.GE.1981) ITESTL=3
C
      IF(IFREQ.EQ.1) PCRED=CRD4VA(IBY,IP,ITECH-3,ITESTL)
      IF(IFREQ.EQ.2) PCRED=CRD4VB(IBY,IP,ITECH-3,ITESTL)
      GOTO 60
C
C  Assign HDGV I/M credit.
C
   50 PCRED=CRHDGV(IP,IFREQ)
C
C  Set I/M benefit adjusted for waivers and enforcement and discount
C
   60 PCLEFT=1.0-(PCRED*(1.0-WAIV)*ENFORC(CRIM,1)*DISCNT(INTYP))
C
   99 RETURN
C  End PCLEFT
      END
```

```
C     MAIN
C
C..Main Driver for modified MOBILE4/Cost Effectiveness
C  Model.
C
C..Calls M4MAIN,SETUP,INTWDW,FLEET,TBASE,LOOP,SUMWDW and PRINT
C
C..Variable Dictionary:
C
C   Name     Source   Description
C   ----     ------   -----------------------------------------------
C
C   IATPLP   Block    Flag indicating whether an ATP only scenario
C                     is to be run.
C   INERR    Param    MOBILE4 error counter in subroutine QUITER
C   ISIZE1   Param    Variable containing either the size of the
C                     floating model year window for the I/M coverage
C                     or the earliest model year inspected in I/M.
C   ISIZE2   Param    Variable containing either the size of the
C                     floating model year window for the ATP coverage
C                     or the earliest model year inspected in an ATP.
C   PPFAIL   Block    Failure rates for Purge, Press, Purge+Press for
C                     each model year and each IVGAS
C
C
      REAL    JULMYR
      INTEGER PROMPT
      CHARACTER*20 M4IN,M4OUT
      CHARACTER*8 USNAME
      CHARACTER*4 NOYES,COMMA,PERIOD
      CHARACTER*1 COLON
C
      COMMON /COST01/ ATPFEE
      COMMON /COST02/ IFEVYR,ILEVYR
      COMMON /COST03/ STRNGY,RMAXF,REPEAT,FFACT
      COMMON /COST04/ TAMPER(25,6,4,10,4)
      COMMON /COST05/ REPLCE(25,6,10,4)
      COMMON /COST06/ STOAER
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
      COMMON /COST08/ FAILRT(2,25,39,4)
      COMMON /COST09/ DRSTRN(5),ZMSTRN(5)
      COMMON /COST10/ FEBNFT(25,10,4),FECNMY(20,4)
      COMMON /COST11/ PCNTSV(4)
      COMMON /COST12/ IMFXFG,IAFXFG,IMCSFG,IAFEFG,IALDV
      COMMON /COST13/ CIMFEE(25,10,4),CIMREP(25,10,4)
      COMMON /COST14/ TONRED(25,2,10,4),COST(25,10,4)
      COMMON /COST15/ TOTCST(2),TOTRED(2),TCOST
      COMMON /COST16/ DATPFE,DIMFEE,DIMREP,DATPRE,AATPFE,AIMFEE
      COMMON /COST17/ DETER(25,2,10,4),TDETER(25,2,10,4)
      COMMON /COST18/ AIMREP,AATPRE,CFACTR,CATPFE(25,10,4)
      COMMON /COST19/ ICOV1,ICOV2,INDVL1,INDVL2
      COMMON /COST20/ TDUCT(25,2,3,10,4),TEVAP(25,10,4)
      COMMON /COST21/ CATPRE(25,10,4),FULBEN(25,20,4)
      COMMON /COST22/ ATCOST(2,8)
      COMMON /COST23/ VCNT(39,8),GSDSCT(8,10),HDDCUM(25,10)
      COMMON /COST24/ ATEQP(20,5,4)
      COMMON /COST25/ FRLOSS(25,4,4,10),FREF(25,4,4,10)
      COMMON /COST26/ FRSTLS(25,8,4,10),YRSTLS(10),BRSTLS
      COMMON /COST27/ IGRFLG,IATPLP,IDIFF,OUTPRF
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
      COMMON /COST30/ EVAP(25,8,4,10),FER(3,25,8,4,10)
      COMMON /COST31/ SAER(11,11,2,2),SEVP(2,2),ZAER(11,11,2,2)
      COMMON /COST32/ BSIZE(4,25,2,6,17,2),TRAT(9)
      COMMON /COST33/ EMCAL4(7,3,3),EVPD1(3,2,4),EVPD2(7,4)
      COMMON /COST34/ TCOUNT,BYEAR,VGRORT
      COMMON /COST35/ TCST,TBEN(2),ADFBEN,ADIM(2),ADAT(2),ADET(2)
      COMMON /COST36/ YTONS(2,10),BTONS(2),BIDTON(2),AEVAP
      COMMON /COST37/ YRCOST(10),YRBEN(10,2),YCOUNT(39),ACOUNT
      COMMON /COST38/ STOCK(12,8),CLDIST(8)
      COMMON /COST40/ YEVTON(10),BEVTON,YEREF(10),BEREF
      COMMON /COST41/ YERLOS(10),BERLOS
      COMMON /COST42/ ECAL02(10,6,4),ECAL03(7,2),ECAL04(20,4)
      COMMON /COST43/ EMCAL1(3,3,3),EMCAL2(3,3,3),EMCAL3(4,3,3)
      COMMON /COST44/ LOOK1(5),MYCD1(8),TAM3Q1(6)
      COMMON /COST45/ TAMD1(8,3,3),TAMD2(8,3,3),TAMD3(8,4,3)
      COMMON /COST46/ REDIM(25,2,10,4),REDATP(25,2,10,4)
      COMMON /COST47/ PPFAIL(25,3,10,4),PPFIXR(25,10,4)
      COMMON /COST48/ PRGFEE,PRSFEE,CEVFEE(25,10,4),TRNFEE
      COMMON /COST49/ PPFEB(25,10,4),APFBEN
C
      COMMON /COSTXX/ JMYR1,JMYR2
```

```
      COMMON /IONAME/ M4IN,M4OUT,M4IMC,C4IN
C
C     ..... Common block with names other than COST?? originate in
C           the MOBILE4 section of this program.
C
      COMMON /ALUHIN/ AC,XLOAD(3),TRAILR(3),ABSHUM,DB,WB
      COMMON /ATPAR1/ LAPSY,LAP1ST,LAPLST,LVTFLG(4)
      COMMON /ATPAR2/ ATPPGM,ATPFQT,CRATP,DISTYP(8)
      COMMON /CITPAR/ SCNAME(4)
      COMMON /CITRV1/ RVPBAS,RVPIUS,RVPICY,IUSESY,RVPUWX
      COMMON /CUMCOM/ CUMMIL(25,8)
      COMMON /FLAGS1/ PROMPT,TAMFLG,SPDFLG,VMFLAG,OXYFLG,DSFLAG
      COMMON /FLAGS2/ MYMRFG,NEWFLG,IMFLAG,ALHFLG
      COMMON /FLAGS3/ ATPFLG,TPDFLG,RLFLAG,LOCFLG,TEMFLG,OUTFMT
      COMMON /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER(2),CRIM
      COMMON /IMPAR2/ ILDT(4),ITEST,NUDATA(2),NLIM,IMNAME(20,9)
      COMMON /IMPAR6/ IFREQ,INTYP
      COMMON /IM240P/ DSIZE(25,4),IM24YR,IPRGYR,IPRSYR
      COMMON /IOUCOM/ IOUIMD,IOUGEN,IOUREP,IOUERR,IOUASK
      COMMON /LOOKUP/ IVTAM,IQG,IPG,JPGD,IHG,IGCSF
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
      COMMON /MYCODE/ MY,IDX,JDX,LDXSY,LMYRVT,IAY,IMDXSY,IMKINK
      COMMON /MYRSAV/ AMAR(25,8),JULMYR(25,8),NEWCUM
      COMMON /PROJEC/ PROJID(20)
      COMMON /REGION/ FEET(2),IREJN,ALT,INITPR
C     COMMON /SAVE01/ JCALL,VA001(15,3,8,2),VA002(15,3,8,2)
      COMMON /SCENE1/ SPD(8),PCCN,PCHC,PCCC
      COMMON /STRING/ NOYES(2),COMMA,PERIOD,COLON
      COMMON /TAMEQ4/ BTR(9,2)
      COMMON /TEMPS/  AMBT,TEMMIN,TEMMAX,TEMEXH(3),TEMEVP(6)
      COMMON /USDATA/ USNAME(4,4),NUSD,IUSD(4)
C
      COMMON /VMXCOM/ REGMIX(8),TFNORM(8),VMTMIX(8),VCOUNT(39,8)
      COMMON /YEARS4/ IY1941,IY1960,IY2020
C
C
C  DRIVER (as of 08/07/91):
C
C  DRIVER demonstrates how to call the subroutine version of
C  MOBILE4.1
C
C  Calls MOBILE.
C
C  Local variable / array dictionary:
C
C   Name    Type              Description
C  ------  ----  ------------------------------------------------------
C  INTER    C    flag for interactive mode ('Y') vs. batch mode ('N')
C  M4CALL   I    loop index for MOBILE4.1 call loop
C
C
C     PROGRAM DRIVER
C
C
C     IFPRMT IsFilePrompt:
C       1 = M4INPUT...C4OUTPUT
C       2 = Prompt for each of 4 I/O files for each run
C       3 = All I/O files for all runs listed in one given filename
C
      LOGICAL ISFILE,ISFLST
      CHARACTER*20 C4IN,C4OUT,M4IMC,TMPFIL,M4OUT1,C4OUT1
C     CHARACTER*1 INTER
C
      IOUGEN=5
C     IOUGEN=0
      IOUREP=6
      IOUASK=0
      IOUERR=6
      M4IMC = 'M4IMC'
      M4OUT1 = ' '
      C4OUT1 = ' '
C
      WRITE(IOUASK,300)
  300 FORMAT(' ****** CEM4.1 DRIVER for MOBILE4.1 *****'/)
C
      CALL GETCL(M4IN)
```

```
      IF(M4IN.EQ.' ') THEN
        IFPRMT = 1
        M4IN  = 'M4INPUT'
        M4OUT = 'M4OUTPUT'
        C4IN  = 'C4INPUT'
        C4OUT = 'C4OUTPUT'
      ELSE IF(M4IN.EQ.' /'.OR.M4IN.EQ.'/'
     *    .OR.M4IN.EQ.'?'.OR.M4IN.EQ.' ?') THEN
C  Filename request mode...
        IFPRMT = 2
      ELSE
C  File list mode...
        INQUIRE(FILE = M4IN,EXIST = ISFLST)
        IF(ISFLST) THEN
          IFPRMT = 3
          OPEN(UNIT=3, FILE=M4IN, STATUS='OLD')
        ELSE
          WRITE(0,200) M4IN
  200     FORMAT(' File list not found: ',A20)
        ENDIF
      ENDIF
C
      M4CALL=0
C
C  *****************************************************
C  BEGIN Driver LOOP To run each input/output file set...
C  *****************************************************
C
   50 IF(IFPRMT.EQ.3) THEN
        READ(3,220,ERR=98,END=99) M4IN,M4OUT,C4IN,C4OUT,M4IMC
  220   FORMAT(5(A20/) )
      ELSE IF(IFPRMT.EQ.2) THEN
  230   FORMAT(A20)
        WRITE(IOUASK,240)
  240   FORMAT(' ','Please enter the MOBILE4.1 Input filename',
     *    ' (Return Quits):')
        READ(IOUASK,230,END=99) M4IN
        IF(M4IN.EQ.' ') GOTO 99
        WRITE(IOUASK,250)
  250   FORMAT('&','Please enter the MOBILE4.1 Output filename:')
        READ(IOUASK,230,END=99) M4OUT
        WRITE(IOUASK,260)
  260   FORMAT('&','Please enter the CEM4.1 Input filename:')
        READ(IOUASK,230,END=99) C4IN
        WRITE(IOUASK,270)
  270   FORMAT('&','Please enter the CEM4.1 Output filename:')
        READ(IOUASK,230,END=99) C4OUT
        WRITE(IOUASK,280)
  280   FORMAT('&','Enter the MOBILE4.1 Credits filename (if any):')
        READ(IOUASK,230,END=99) M4IMC
      ENDIF
      IF(M4IMC.EQ.' ') M4IMC = 'M4IMC'
      WRITE(0,390) M4IN,M4OUT,C4IN,C4OUT,M4IMC
  390 FORMAT(' I/O Files: ',5(/' ',A20)/ )
C
C  Now check existence of chosen M41 & CEM41 input files...
C
      TMPFIL = M4IN
      INQUIRE(FILE = TMPFIL,EXIST = ISFILE)
      IF(ISFILE) THEN
        TMPFIL = C4IN
        INQUIRE(FILE = TMPFIL,EXIST = ISFILE)
C       IF(ISFILE) THEN
C         TMPFIL = M4IMC
C         INQUIRE(FILE = TMPFIL,EXIST = ISFILE)
C       ENDIF
      ENDIF
      IF(ISFILE) THEN
CC
        OPEN(UNIT=IOUGEN, FILE=M4IN, STATUS='OLD')
        OPEN(UNIT=7, FILE=C4IN, STATUS='OLD')
C
C  Append if different output files are not given
C
        OPEN(UNIT=IOUREP, FILE=M4OUT, STATUS='UNKNOWN',
     *      CARRIAGE CONTROL="FORTRAN", POSITION="APPEND")
        OPEN(UNIT=8, FILE=C4OUT, STATUS='UNKNOWN',
     *      CARRIAGE CONTROL="FORTRAN", POSITION="APPEND")
```

```
      ELSE
        WRITE(0,290) TMPFIL
  290   FORMAT(' File not found: ',A20)
        GOTO 99
      ENDIF
C
      M4CALL=M4CALL+1
C
C *********************************
C
C  Get Cost Effective Inputs
C
      CALL GETCEI
C       ..... M4MAIN is the modified MOBILE4 driver.  It automatically
C             runs MOBILE4 four times for each evaluation date.
C             The runs are:
C
C              1. An I/M and ATP run
C              2. An I/M run
C              3. An I/M Deterence run
C              4. A no I/M and no ATP program run (baseline)
C
      ICALL = 1
   10 JCALL = 1
      IF(ICALL.EQ.1) CALL MOBILE(INERR,*98)
CC
      IF(ICALL.GT.1 .AND. ICALL.LT.50) CALL MOBNXT(INERR,*98)
      IF(ICALL.GE.50 .OR. INERR.GT.0) GOTO 98
      ICALL = ICALL + 1
C     CALL MOBILE(INERR,*99)
C
      WRITE(0,310) M4CALL,INERR
  310 FORMAT(/' ','Run #',I3,'  INERR =',I2/)
C
C
C  Calculate or assign the default cost and benefit assumptions...
C
        CALL SETUP(ISIZE1,ISIZE2,INERR)
C
C  Initialize all cost and benefit arrays to zero...
C
        CALL INTWDW
C
C
C  Normalize the vehicle fleet to the first evaluation year requested
C  by the user.  The default fleet is a total nationwide fleet based on
C  in-use vehicle counts done by MVMA...
C
        CALL FLEET
C
C  Calculate the emissions in tons for a given fleet with no
C  control program in place...
C
        CALL TBASE
C
C
C  Compute fuel economy benefits for scenarios with I/M...
C
        IF(IATPLP.NE.2) CALL CPFUEL
C
C
C  Calculate costs and benefits for each model year and vehicle
C  type in each calendar year...
C
C
        CALL LOOP(ISIZE1,ISIZE2)
```

```
C
C       ..... SUMWDW sums the cost and benefits over all calendar
C             years.
C
        CALL SUMWDW
C
C       ..... Output the programs results.
C
        CALL PRINT(ISIZE1,ISIZE2)
C
      GOTO 10
C
C  Close any no longer needed files...
C
   98   CLOSE(5)
        CLOSE(6)
        CLOSE(7)
        CLOSE(8)
C       CLOSE(4)
C
      IF(IFPRMT.GT.1) GOTO 50
C
   99 WRITE(0,320)
  320 FORMAT(' ','DRIVER calls completed.')
C
      STOP
C  End Main Driver
      END
```

```
      SUBROUTINE PPINIT
C
C  Initializes PPFIXR and PPFAIL arrays to zero, needed for MacFortran
C
C  Called by MOBILE.
C
C  Calls none.
C
C  Input on call:
C
C    common blocks:
C
C    /BYMYC2/ BYBEF4,BYTAM,BYFER
C    /BYMYC3/BYEVAP,BYRUNL,BYREFL,BYRSTL
C
C
C  Output on return:
C
C    common blocks:
C
C    /COST47/ PPFAIL(25,3,10,4),PPFIXR(25,10,4)
C
C  Notes:
C
C  PPINIT was added for CEM4.1 9/27/91 for better MacFortran use
C
C
      COMMON /COST47/ PPFAIL(25,3,10,4),PPFIXR(25,10,4)
C
C  Init PPFIXR,PPFAIL
C
      DO 50 I3=1,4
        DO 50 I2=1,10
          DO 50 I1=1,25
            PPFIXR(I1,I2,I3) = 0.0
            DO 50 I4=1,3
              PPFAIL(I1,I4,I2,I3) = 0.0
   50 CONTINUE
C
   99 RETURN
C  End PPINIT
      END
```

```
      SUBROUTINE EFSAVE(ISCEN,JCYDX)
C
C  EFSAVE stores the emission factors for each CE senario and
C  evaluation year.
C
C  Called by MOBILE.
C
C  Calls none.
C
C  Input on call:
C
C    parameter list: ISCEN,JCYDX
C    common blocks:
C
C    /BYMYC2/ BYBEF4,BYTAM,BYFER
C    /BYMYC3/BYEVAP,BYRUNL,BYREFL,BYRSTL
C
C
C  Output on return:
C
C    common blocks:
C
C    /COST25/ FRLOSS,FREF
C    /COST26/ FRSTLS
C    /COST30/ EVAP,FER
C
C  Notes:
C
C  EFSAVE was added for CEM4.1 VERSION 2
C
C
C
      COMMON /BYMYC2/ BYBEF4(3,25,8),BYTAM(3,25,4),BYFER(3,25,8)
      COMMON /BYMYC3/BYEVAP(25,8),BYRUNL(25,4),BYREFL(25,4),BYRSTL(25,8)
      COMMON /COST25/ FRLOSS(25,4,4,10),FREF(25,4,4,10)
      COMMON /COST26/ FRSTLS(25,8,4,10),YRSTLS(10),BRSTLS
      COMMON /COST30/ EVAP(25,8,4,10),FER(3,25,8,4,10)
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
      COMMON /SPEED6/ SALHCF(25,3,8),SCFIDL(25,4),SCIADJ(25,3,8)
C
C
      DO 10 IDX=1,MAXYRS
      DO 10 IV=1,MAXVEH
        DO 20 IP=1,MAXPOL
          JDX = MAXYRS + 1 - IDX
C
          FER(IP,IDX,IV,ISCEN,JCYDX) = BYBEF4(IP,JDX,IV)
          IF(IV.LE.4)
     *      FER(IP,IDX,IV,ISCEN,JCYDX)=FER(IP,IDX,IV,ISCEN,JCYDX) +
     *      BYTAM(IP,JDX,IV)
          FER(IP,IDX,IV,ISCEN,JCYDX) =
     *      FER(IP,IDX,IV,ISCEN,JCYDX)*SALHCF(IDX,IP,IV)
C
   20   CONTINUE
C
        EVAP(IDX,IV,ISCEN,JCYDX) = BYEVAP(JDX,IV)
        FRSTLS(IDX,IV,ISCEN,JCYDX) = BYRSTL(JDX,IV)
C
   10 CONTINUE
C
C
      DO 30 IDX=1,MAXYRS
      DO 30 IV=1,4
        JDX = MAXYRS + 1 - IDX
C
        FRLOSS(IDX,IV,ISCEN,JCYDX) = BYRUNL(JDX,IV)
        FREF(IDX,IV,ISCEN,JCYDX) = BYREFL(JDX,IV)
C
  30  CONTINUE
      RETURN
C  End EFSAVE
      END
```

```
      SUBROUTINE SAVER(ICY)
C
C..SAVER saves the Emission Factors and Tampering Rates generated
C..from each of the four (or two) MOBILE4 runs in the appropriate
C..variables.
C
C..Called by M4MAIN
C
C..Calls None
C
C..Array Subscripts:
C
C..BSIZE(4,25,2,6,15,2)        - BSIZE(IV,IDX,IPG,IQG,IC,IAY)
C..TAMPER(25,6,4,10,4)         - TAMPER(MYDX,IP,IISCEN,ICYDX,IV)
C..FER(3,25,8)                 - FER(IP,IDX,IV)
C..TRAT(7)                     - TRAT(IEG)
C
C..Variable Dictionary:
C
C.. Name     Source   Description
C   ----     ------   --------------------------------------------------
C  BSIZE     Block    Tampering rates in each overlap section from
C                     MOBILE4
C  EFALL     Block    Emission factors from MOBILE4.
C  FER       Block    MOBILE4 array variable which originally contains
C                     the emission factors.
C  ICY       Param    Calendar year.
C  ICYDX     Local    Absolute calendar year 1975=1.
C  IDX       Local    Forward model year index (ascending model years).
C  IP        Local    Pollutant type index (1:HC 2:CO 3:NOx).
C  ISCEN     Param    Control program index.
C  IV        Local    Vehicle type index.
C  JDX       Local    Backward model year index (descending model
C                     years).
C  MY        Local    Model Year.
C  MYDX      Local    Absolute model year index (1950=1).
C  TAMPER    Block    Tampering rate factors from MOBILE4.
C  TRAT      Block    Intermediate array which contains the tampering
C                     rates.
C
C
      COMMON /COST04/ TAMPER(25,6,4,10,4)
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
      COMMON /COST32/ BSIZE(4,25,2,6,17,2),TRAT(9)
      COMMON /COST40/ YEVTON(10),BEVTON,YEREF(10),BEREF
      COMMON /COST41/ YERLOS(10),BERLOS
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
C
C
C
      DO 40 IDX = 1,MAXYRS
        JDX   = MAXYRS + 1 - IDX
C       ICYDX = ICY - 1974
C       ICYDX = ICY - 1981
C       MYDX  = MAXYRS + ICYDX - JDX
C       MY    = MYDX + 1950
C
      DO 30 IV=1,4
C
       TRAT(1)=BSIZE(IV,JDX,1,1,1,1)+BSIZE(IV,JDX,1,1,1,2)
     *         + BSIZE(IV,JDX,1,1,2,1) + BSIZE(IV,JDX,1,1,2,2)
     *         + BSIZE(IV,JDX,1,1,3,1) + BSIZE(IV,JDX,1,1,3,2)
     *         + BSIZE(IV,JDX,1,1,4,1) + BSIZE(IV,JDX,1,1,4,2)
     *         + BSIZE(IV,JDX,1,1,5,1) + BSIZE(IV,JDX,1,1,5,2)
     *         + BSIZE(IV,JDX,1,1,8,1) + BSIZE(IV,JDX,1,1,8,2)
       IF(TRAT(1).EQ.0.0)
     *  TRAT(1)=BSIZE(IV,JDX,1,2,1,1)+BSIZE(IV,JDX,1,2,1,2)
     *          + BSIZE(IV,JDX,1,2,2,1) + BSIZE(IV,JDX,1,2,2,2)
     *          + BSIZE(IV,JDX,1,2,3,1) + BSIZE(IV,JDX,1,2,3,2)
     *          + BSIZE(IV,JDX,1,2,4,1) + BSIZE(IV,JDX,1,2,4,2)
     *          + BSIZE(IV,JDX,1,2,5,1) + BSIZE(IV,JDX,1,2,5,2)
     *          + BSIZE(IV,JDX,1,2,8,1) + BSIZE(IV,JDX,1,2,8,2)
       TRAT(2)=BSIZE(IV,JDX,1,3,1,1)+BSIZE(IV,JDX,1,3,1,2)
     *         + BSIZE(IV,JDX,1,3,9,1) + BSIZE(IV,JDX,1,3,9,2)
       TRAT(3)=BSIZE(IV,JDX,1,3,2,1)+BSIZE(IV,JDX,1,3,2,2)
     *         + BSIZE(IV,JDX,1,3,4,1) + BSIZE(IV,JDX,1,3,4,2)
     *         + BSIZE(IV,JDX,1,3,6,1) + BSIZE(IV,JDX,1,3,6,2)
     *         + BSIZE(IV,JDX,1,3,10,1) +BSIZE(IV,JDX,1,3,10,2)
```

```
      TRAT(4)=BSIZE(IV,JDX,1,3,3,1)+BSIZE(IV,JDX,1,3,3,2)
     *         + BSIZE(IV,JDX,1,3,5,1) + BSIZE(IV,JDX,1,3,5,2)
     *         + BSIZE(IV,JDX,1,3,7,1) + BSIZE(IV,JDX,1,3,7,2)
     *         + BSIZE(IV,JDX,1,3,11,1) +BSIZE(IV,JDX,1,3,11,2)
      TRAT(5)=BSIZE(IV,JDX,2,4,1,1)+BSIZE(IV,JDX,2,4,1,2)
     *         + BSIZE(IV,JDX,2,4,2,1) + BSIZE(IV,JDX,2,4,2,2)
     *         + BSIZE(IV,JDX,2,4,3,1) + BSIZE(IV,JDX,2,4,3,2)
     *         + BSIZE(IV,JDX,2,4,4,1) + BSIZE(IV,JDX,2,4,4,2)
     *         + BSIZE(IV,JDX,2,4,5,1) + BSIZE(IV,JDX,2,4,5,2)
     *         + BSIZE(IV,JDX,2,4,8,1) + BSIZE(IV,JDX,2,4,8,2)
      TRAT(6) = BSIZE(IV,JDX,1,1,13,1)
      TRAT(7) = BSIZE(IV,JDX,1,1,14,1)
      TRAT(8) = BSIZE(IV,JDX,1,1,15,1)
C
C
C  Store fleet variables for current IM program case
C  TAMPER/2nd subscript: 1=air, 2=cat missing/no misfueling,
C                        3=misfueled   4=pcv, 5=evap, 6=gas cap
C
C
      TAMPER(IDX,1,ISCEN,JCYDX,IV)=TRAT(1)
      TAMPER(IDX,2,ISCEN,JCYDX,IV)=TRAT(2)
      TAMPER(IDX,3,ISCEN,JCYDX,IV)=TRAT(3)+TRAT(4)
      TAMPER(IDX,4,ISCEN,JCYDX,IV)=TRAT(7)
      TAMPER(IDX,5,ISCEN,JCYDX,IV)=TRAT(6)
      TAMPER(IDX,6,ISCEN,JCYDX,IV)=TRAT(8)
C
   30 CONTINUE
   40 CONTINUE
C
   99 RETURN
C  End SAVER
      END
```

```
      SUBROUTINE ATPSAV(ICY)
C
C..ATPSAV is called if an ATP only program is to be modeled.  It
C  allows M4MAIN to be run only twice and stores the EFALL and
C  TAMPER array elements for the no control program situation and
C  the ATP only program.
C
C..Called by M4MAIN
C
C..Calls None
C
C..Array Subscript:
C
C..TAMPER(25,6,4,10,4)        - TAMPER(IDX,IVTAM,IISCEN,JCYDX,IV)
C
C..Varialbe Dictionary:
C
C.. Name    Source   Description
C   ----    ------   -----------------------------------------------
C  ICY      Param    Calendar year.
C  ICYDX    Local    Absolute calendar year index 1975=1.
C  IDX      Local    Forward model year index (ascending model
C                    years).
C  IISCEN   Local    Mobile3 run index(1:No program, 2:Deterrence,
C                    3:I/M only, 4:I/M;ATP).
C  IP       Local    Pollutant type index (1:HC 2:CO,3:NOx).
C  IV       Local    Vehicle type index.
C  IVTAM    Local    Emission control device tampering type index
C                    (1:AIR,2:CAT,3:MISF,4:EVAP 5:PCV).
C  JDX      Local    Backward model year index (descending model
C                    years).
C  MY       Local    Model year
C  MYDX     Local    Absolute model year index (1950=1).
C  TAMPER   Block    Tampering rate factors from MOBILE4.
C
C
      COMMON /COST04/ TAMPER(25,6,4,10,4)
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
      COMMON /COST30/ EVAP(25,8,4,10),FER(3,25,8,4,10)
      COMMON /COST25/ FRLOSS(25,4,4,10),FREF(25,4,4,10)
      COMMON /COST26/ FRSTLS(25,8,4,10),YRSTLS(10),BRSTLS
      COMMON /COST40/ YEVTON(10),BEVTON,YEREF(10),BEREF
      COMMON /COST41/ YERLOS(10),BERLOS
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
C
      DO 40 IDX = 1,MAXYRS
        JDX    = MAXYRS + 1 - IDX
C       ICYDX  = ICY - 1974
C       ICYDX  = ICY - 1981
C       MYDX   = MAXYRS + ICYDX - JDX
C       MY     = MYDX + 1950
        DO 40 IV = 1,8
          IF(IV .GT. 4) GOTO 20
            DO 10 IVTAM = 1,5
            DO 10 IISCEN = 1,2
              TAMPER(IDX,IVTAM,IISCEN,JCYDX,IV) =
     *           TAMPER(IDX,IVTAM,3,JCYDX,IV)
   10       CONTINUE
C
   20     DO 30 IISCEN = 1,2
            DO 25 IP = 1,2
              FER(IP,IDX,IV,IISCEN,JCYDX)=FER(IP,IDX,IV,3,JCYDX)
   25       CONTINUE
            EVAP(IDX,IV,IISCEN,JCYDX)=EVAP(IDX,IV,3,JCYDX)
            FREF(IDX,IV,IISCEN,JCYDX)=FREF(IDX,IV,3,JCYDX)
            FRLOSS(IDX,IV,IISCEN,JCYDX)=FRLOSS(IDX,IV,3,JCYDX)
            FRSTLS(IDX,IV,IISCEN,JCYDX)=FRSTLS(IDX,IV,3,JCYDX)
   30     CONTINUE
C
   40 CONTINUE
C
   99 RETURN
C  End ATPSAV
      END
```

```
      SUBROUTINE RESET
C
C..RESET resets the IMFLAG and ATPFLG for each MOBILE4 call in M4MAIN.
C..Now also resets IPRGYR & IPRSYR
C
C..Called by M4MAIN
C
C..Calls None
C
C..Array Subscripts:
C
C..AER(11,11,2,2)              - AER(I4,I3,I2,I1)
C..BSIZE(4,25,2,6,15,2)        - BSIZE(I1,I2,I3,I4,I5,I6)
C..SAER(11,11,2,2)             - SAER(I4,I3,I2,I1)
C..SEVP(2,2)                   - SEVP(2,2)
C..VAO23(11,11,2,2)            - VAO23(I4,I3,I2,I1)
C..VAO24(2,2)                  - VAO24(I2,I1)
C
C..Variable Dictionary:
C
C.. Name     Source   Description
C   ----     ------   -----------------------------------------------
C  AER       Block    The ATP effectiveness rates for non-evaporative
C                     exhaust emission tampering.
C  ATPFLG    Block    The anti-tampering flag  (1:No ATP, 2:ATP)
C  BSIZE     Block    Tampering rates from MOBILE4
C  IMFLAG    Block    The I/M flag  (1:No I/M, 2:I/M program)
C  ICYIM    Param    I/M start variable as read in MOBILE4
C  ISCEN     Param    Control program index (1: No control program,
C                                             2: I/M deterrence only,
C                                             3: I/M program run,
C                                             4: I/M and ATP run)
C  ISTRT     Param    I/M start storage variable.
C  JATP      Param    Storage of the ATP flag.
C  JIM       Param    Storage of the I/M flag.
C  JPRGYR    Param    Storage of the Purge coverage start model year.
C  JPRSYR    Param    Storage of the Press. coverage start model year.
C  SAER      Block    Storage of the exhaust ATP effectiveness
C  SEVP      Block    Storage of the non-exhaust ATP effectiveness
C
C
      INTEGER ATPFLG
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
      COMMON /COST31/ SAER(11,11,2,2),SEVP(2,2),ZAER(11,11,2,2)
      COMMON /COST32/ BSIZE(4,25,2,6,17,2),TRAT(9)
C
      COMMON /COSTXX/ JMYR1,JMYR2
C
      COMMON /ATPAR2/ ATPPGM,ATPFQT,CRATP,DISTYP(8)
      COMMON /FLAGS2/ MYMRFG,NEWFLG,IMFLAG,ALHFLG
      COMMON /FLAGS3/ ATPFLG,TPDFLG,RLFLAG,LOCFLG,TEMFLG,OUTFMT
      COMMON /IM240P/ DSIZE(25,4),IM24YR,IPRGYR,IPRSYR
      COMMON /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER(2),CRIM
      COMMON /SIZCAL/ ATR(5,2),TGSUSE,CSIZE(12,2),CSAE(12)
C
C  Initialize the tampering rates...
C
      DO 10 I1=1,4
      DO 10 I2=1,25
      DO 10 I3=1,2
      DO 10 I4=1,6
      DO 10 I5=1,17
      DO 10 I6=1,2
        BSIZE(I1,I2,I3,I4,I5,I6) = 0.0
   10 CONTINUE
C
      DO 20 I1=1,2
      DO 20 I2=1,12
        CSIZE(I2,I1)=0.0
   20 CONTINUE
C
C     ..... This routine checks to see if I/M and ATP exists.
C           and set FLAGS accordingly.
C
C  First set "defaults" for scenario 2, & modify as needed for others
      ATPFLG = 1
      IMFLAG  = JIM
      IMSTRT = 2020
      IPRGYR = 2020
      IPRSYR = 2020
```

```
      MODYR1 = JMYR1
      MODYR2 = JMYR2
C  Now set per scenario
      IF(ISCEN.EQ.4) THEN
        ATPFLG = JATP
        IF(JIM.EQ.2) IMSTRT = ISTRT
        IPRGYR = JPRGYR
        IPRSYR = JPRSYR
      ELSE IF(ISCEN.EQ.3) THEN
        IF(JIM.EQ.2) IMSTRT = ISTRT
CC
C       ELSE IF(ISCEN.EQ.2) THEN       ! No changes needed.
C        MODYR1 = 2020
C        MODYR2 = 2020
CC
      ELSE IF(ISCEN.EQ.1) THEN
C        IMFLAG = 1
        MODYR1 = 2020
        MODYR2 = 2020
      ENDIF
C
   99 RETURN
C  End RESET
      END
```

```
      SUBROUTINE SETUP(ISIZE1,ISIZE2,INERR)
C
C..SETUP defines most of the default cost and benefit assumptions
C..used in the model.
C
C..Called by MAIN
C
C..Calls QUITER
C
C..Variable Dictionary
C
C.. Name     Source   Description
C   ----     ------   -----------------------------------------------
C   ATCOST   Block    Cost of Replacing emission control devices as a
C                     result of failing a tampering inspection. The
C                     default assumptions are:  ATCOST(TECH,TYPE)
C                     TYPE = 1 : Air Pump System
C                          = 2 : Catalyst Removal
C                          = 3 : Misfueled Catalyst
C                          = 4 : Evaporative Control System
C                          = 5 : PCV System
C                          = 6 : Gas Cap
C   ATPFEE   Block    Anti-tampering inspection fee
C   BYEAR    Block    Fleet size and growth base year default = 1986
C   CSTIM    Block    Inspection Maintenance I/M inspection fee
C   FFACT    Block    Fraction of annual fuel economy benefit achieved
C                     by biennial I/M (based on HC emission reduction)
C   GASCST   Block    Cost of one gallon of unleaded gasoline
C   IAFEFG   Block    Flag indicating whether user is inputting
C                     optional ATP fees and costs or using the defaults
C                     1 = defaults   2 = user inputs
C   IAFXFG   Block    Flag indicating whether the ATP has a fixed or
C                     floating model year coverage
C   IALDV    Local    Variable indicating which vehicle classes are
C                     to be inspected by ATP. Must be the same as
C                     those inspected by I/M.
C   IATPLP   Block    Flag indicating whether an ATP only scenario is
C                     to be run
C   IFREQ    Block    Flag indicating whether the I/M program is
C                     annual or biennial
C   IGRFLG   Block    Flag indicating whether user is inputting the
C                     vehicle fleet distribution and the fleet growth
C                     rate or is using the built-in defaults
C   ILDT     Block    Parameter data from MOBILE4 indicating the
C                     number of vehicle classes inspected by I/M
C   IMCSFG   Block    Flag indicating whether user is inputting
C                     optional I/M repair cost and fees or is using
C                     the defaults
C   IMFXFG   Block    Flag indicating whether the I/M program has a
C                     fixed or floating model year coverage
C   INERR    Param    MOBILE4 error counter in subroutine QUITER
C   ISIZE1   Block    Variable containing either the size of the
C                     floating model year window for I/M coverage or
C                     the earliest model year inspected in an I/M
C                     program
C   ISIZE2   Block    Variable containing either the size of the
C                     floating modely year window for I/M coverage or
C                     the earliest model year inspected in an I/M
C                     program
C   DISTYP   Block    Array of flags indicating which emission
C                     control components are to be inspected by the ATP
C   IVTYP    Local    Vehicle class index for all eight vehicle classes
C   ATPFQT    Block    Flag indicating whether ATP program is annual
C                     or biennial
C   LAP1ST   Block    Variable containing the oldest model year
C                     covered by an ATP if a fixed model year program
C                     is run
C   MODYR1   Block    Variable containing the oldest model year
C                     covered by I/M if a fixed model year program is
C                     run
C   MOVATP   Block    Number of model years covered in an ATP if a
C                     floating model year program is run
C   MOVIM    Block    Number of model years covered in I/M if a
C                     floating model year program is run
C   REPEAT   Block    Fraction of I/M failures which fail in the
C                     subsequent year also
C   REPIM    Block    Array containing the I/M repair costs
C                      REPIM(1) = Old Tech  ;  REPIM(2) = New Tech
C                      REPIM(3) = IM240 ; REPIM(4) = NOx (IM240)
C   RMAXF    Block    Maximum I/M failure rate that 1981 and later
C                     vehicles are allowed
```

```
C    TCOUNT  Block    Vehicle fleet size in base year
C    VGRORT  Block    Array containing the growth rates for each
C                     vehicle class
C
      INTEGER BYEAR,ATPFLG,PROMPT,ATPFQT,DISTYP
C
C     ..... COMMON BLOCK DEFINITIONS
C
      COMMON /COST01/ ATPFEE
      COMMON /COST02/ IFEVYR,ILEVYR
      COMMON /COST03/ STRNGY,RMAXF,REPEAT,FFACT
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
      COMMON /COST12/ IMFXFG,IAFXFG,IMCSFG,IAFEFG,IALDV
      COMMON /COST22/ ATCOST(2,8)
      COMMON /COST27/ IGRFLG,IATPLP,IDIFF,OUTPRF
      COMMON /COST34/ TCOUNT,BYEAR,VGRORT
      COMMON /COST48/ PRGFEE,PRSFEE,CEVFEE(25,10,4),TRNFEE
C
      COMMON /COSTXX/ JMYR1,JMYR2
C
      COMMON /ATPAR1/ LAPSY,LAP1ST,LAPLST,LVTFLG(4)
      COMMON /FLAGS1/ PROMPT,TAMFLG,SPDFLG,VMFLAG,OXYFLG,DSFLAG
      COMMON /FLAGS2/ MYMRFG,NEWFLG,IMFLAG,ALHFLG
      COMMON /ATPAR2/ ATPPGM,ATPFQT,CRATP,DISTYP(8)
      COMMON /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER(2),CRIM
      COMMON /IMPAR6/ IFREQ,INTYP
C
CC
      MODYR1 = JMYR1
      MODYR2 = JMYR2
CC
C  I/M program defaults
C
      RMAXF  = .25
      REPEAT = .20
C
C.. FFACT was 0.70 in CEM4, changed 8/14/91
C
      FFACT  = .90
C
C  Default I/M cost assumptions:
C
      IF(IMCSFG.EQ.2) GOTO 10
      IF(IFREQ.EQ.1)  CSTIM = 10.00
      IF(IFREQ.EQ.2)  CSTIM = 12.00
          GASCST   =  1.25
          REPIM(1) =  50.00
          REPIM(2) =  75.00
          REPIM(3) = 150.00
          REPIM(4) = 100.00
C
C  Default Purge/Pressure Inspection costs...
C
          PRGFEE =  6.53
          PRSFEE =  0.69
C    TRNFEE is just increment for IM240 over Purge insp fee.  6/24/91
          TRNFEE =  0.67
C
C  Default ATP cost assumptions:
C
   10 IF(IAFEFG.EQ.2)     GOTO 20
          ATCOST(1,1) =  15.00
          ATCOST(2,1) =  15.00
          ATCOST(1,2) = 150.00
          ATCOST(2,2) = 165.00
          ATCOST(1,3) = 175.00
          ATCOST(2,3) = 190.00
          ATCOST(1,4) =   5.00
          ATCOST(2,4) =   5.00
          ATCOST(1,5) =   5.00
          ATCOST(2,5) =   5.00
          ATCOST(1,6) =   5.00
          ATCOST(2,6) =   5.00
          ATCOST(1,7) =  70.00
          ATCOST(2,7) =  70.00
          ATCOST(1,8) =  38.00
          ATCOST(2,8) =  38.00
C
```

```
C  ATPFEE is the inspection cost for the ATP.
C  The default assumes any underhood inspection will cost
C  $1.00 regrardless of the number of items inspected, a
C  lead deposit test will cost an additional $0.50, and an exterior
C  vehicle inspection of either catalyst, fuel inlet restrictor,
C  or gas cap will cost an additional $0.25. Max cost of $1.75.
C
   20 IF(IAFEFG.EQ.2)              GOTO 30
                                   ATPFEE = 0.0
      IF( DISTYP(1).EQ.2  .OR.
     *    DISTYP(5).EQ.2  .OR.
     *    DISTYP(6).EQ.2  .OR.
     *    DISTYP(7).EQ.2 )
     *                             ATPFEE = 1.00
      IF( DISTYP(2).EQ.2  .OR.
     *    DISTYP(3).EQ.2  .OR.
     *    DISTYP(8).EQ.2 )
     *                             ATPFEE = ATPFEE + 0.25
      IF( DISTYP(4).EQ.2 )         ATPFEE = ATPFEE + 0.50
C
C  The default fleet distribution and growth rates by vehicle type.
C
   30 IF(IGRFLG.EQ.2) GOTO 45
C
C... default growth rate used to be 2.0
C
      VGRORT = 0.0
C
      BYEAR  = 1986
      TCOUNT = 1000000.
C
C
C  This block determines whether a fixed or floating
C  program is to be run and transfers the model year
C  window size or program start date.
C
C           IMFXFG = 1   Moving Model Year Coverage
C           IAFXFG = 1
C           IMFXFG = 2   Fixed Model Year Coverage
C           IAFXFG = 2
C
   45 IF(IMFXFG.EQ.1) ISIZE1 = MOVIM
      IF(IAFXFG.EQ.1) ISIZE2 = MOVATP
      IF(IMFXFG.EQ.2) ISIZE1 = MODYR1
      IF(IAFXFG.EQ.2) ISIZE2 = LAP1ST
C
C
   99 RETURN
C  End SETUP
      END
```

```
      SUBROUTINE INTWDW
C
C..INTWDW initializes window scenario array elements to zero
C
C..Called by MAIN
C
C..Array Subscripts
C
C..CATPFE(25,10,4)              - CATPFE(IDX,JCYDX,IV)
C..CATPRE(25,10,4)              - CATPRE(IDX,JCYDX,IV)
C..CIMFEE(25,10,4)              - CIMFEE(IDX,JCYDX,IV)
C..CIMREP(25,10,4)              - CIMREP(IDX,JCYDX,IV)
C..COST(25,10,4)                - COST(IDX,JCYDX,IV)
C..DETER(25,2,10,4)             - DETER(IDX,IP,JCYDX,IV)
C..FULBEN(25,10,4)              - FULBEN(IDX,JCYDX,IV)
C..REDATP(25,2,10,4)            - REDATP(IDX,IP,JCYDX,IV)
C..REDIM(25,2,10,4)             - REDIM(IDX,IP,JCYDX,IV)
C..TDETER(25,2,10,4)            - TDETER(IDX,IP,JCYDX,IV)
C..TONRED(25,2,10,4)            - TONRED(IDX,IP,JCYDX,IV)
C..TOTCST(2)                    - TOTCST(IP)
C..TOTRED(2)                    - TOTRED(IP)
C
C
C
C..Name   Type                Dictionary
C  ----   ----   -------------------------------
C
C  CATPFE Block  Array which holds and sums the ATP fees for each
C                model year, calendar year and vehicle type
C  CATPRE Block  Array which holds and sums the ATP repair costs
C                for each model year, calendar year and vehicle type
C  CIMFEE Block  Array which holds and sums the I/M fees for each
C                model year, calendar year and vehicle type
C  CIMREP Block  Array which holds and sums the I/M repair costs
C                for each model year, calendar year and vehicle type
C  COST   Block  Array which holds and sums the total cost
C                for each model year, calendar year and vehicle type
C  DETER  Block  Array which holds and sums the deterence benefit
C                for each model year, calendar year and vehicle type
C  FULBEN Block  Array which holds and sums the fuel economy benefit
C                for each model year, calendar year and vehicle type
C  ICYDX  Local  Calendar year index    1 = 1975
C  IP     Local  Pollutant index  1 = HC   2 = CO
C  IV     Local  Vehicle class index
C  MYDX   Local  Model year index       1 = 1950
C  REDATP Block  Array which holds and sums the ATP benefit for each
C                model year, calendar year and vehicle type
C  REDIM  Block  Array which holds and sums the I/M benefit for each
C                model year, calendar year and vehicle type
C  TCOST  Block  Array which passes the total cost of control programs
C  TDETER Block  Array which passes the total deterence benefit
C  TONRED Block  Array which passes the total benefit
C  TOTCST Block  Array which passes the total cost of control programs
C
C
      COMMON /COST10/ FEBNFT(25,10,4),FECNMY(20,4)
      COMMON /COST13/ CIMFEE(25,10,4),CIMREP(25,10,4)
      COMMON /COST14/ TONRED(25,2,10,4),COST(25,10,4)
      COMMON /COST15/ TOTCST(2),TOTRED(2),TCOST
      COMMON /COST16/ DATPFE,DIMFEE,DIMREP,DATPRE,AATPFE,AIMFEE
      COMMON /COST17/ DETER(25,2,10,4),TDETER(25,2,10,4)
      COMMON /COST18/ AIMREP,AATPRE,CFACTR,CATPFE(25,10,4)
      COMMON /COST21/ CATPRE(25,10,4),FULBEN(25,20,4)
      COMMON /COST20/ TDUCT(25,2,3,10,4),TEVAP(25,10,4)
      COMMON /COST46/ REDIM(25,2,10,4),REDATP(25,2,10,4)
      COMMON /COST47/ PPFAIL(25,3,10,4),PPFIXR(25,10,4)
      COMMON /COST49/ PPFEB(25,10,4),APFBEN
C
      COMMON /COST50/ TRLOSS(25,4,3),TREVAP(25,4,3)
C     COMMON /COST50/ TRLOSS(25,4,3),TREVAP(25,4,3),TRSTLS(25,4,3)
C
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
C
C
      TCOST=0.0
C
      DO 10 IP=1,2
       TOTCST(IP)=0.0
       TOTRED(IP)=0.0
   10 CONTINUE
C
```

```
      DO 20 IV=1,4
        DO 20 JCYDX=1,10
          DO 20 IDX = 1,MAXYRS
            COST(IDX,JCYDX,IV)=0.0
            CIMFEE(IDX,JCYDX,IV)=0.0
            CATPFE(IDX,JCYDX,IV)=0.0
            CIMREP(IDX,JCYDX,IV)=0.0
            CATPRE(IDX,JCYDX,IV)=0.0
            FULBEN(IDX,JCYDX,IV)=0.0
            FEBNFT(IDX,JCYDX,IV)=0.0
            PPFEB(IDX,JCYDX,IV)=0.0
            TEVAP(IDX,JCYDX,IV)=0.0
            DO 20 IP=1,2
              TONRED(IDX,IP,JCYDX,IV)=0.0
              REDIM(IDX,IP,JCYDX,IV) =0.0
              REDATP(IDX,IP,JCYDX,IV)=0.0
              DETER(IDX,IP,JCYDX,IV) =0.0
              TDETER(IDX,IP,JCYDX,IV)=0.0
              DO 20 IMC=1,3
                TDUCT(IDX,IP,IMC,JCYDX,IV)=0.0
C               TRSTLS(IDX,IV,IMC)=0.0
                TREVAP(IDX,IV,IMC)=0.0
                TRLOSS(IDX,IV,IMC)=0.0
   20 CONTINUE
C
      RETURN
C  End INTWDW
      END
```

```
      SUBROUTINE FLEET
C
C
C..FLEET determines the number of vehicles in each vehicle
C..class in each calendar year.  FLEET also sums the total
C..number of vehicles in each calendar year.
C
C..Called by MAIN
C
C..Array Subscripts
C
C..STOCK(12,8)              - STOCK(JBY,IV)
C..VCNT(46,8)               - VCNT(IY,IV)
C..VGRORT(8)                - VGRORT(IV)
C
C..Variable Dictionary
C
C.. Name     Source   Description
C   ----     ------   -----------------------------------------------
C   ACOUNT   Param    The average number of vehicles over all the
C                     calendar years selected in the scenario records.
C   BCOUNT   Local    Sum of MOBILE VCOUNT for 1st eval year
C   BYEAR    Param    The fleet size base year
C   CLDIST   Block    Vehicle class registration distribution
C   ICYDX    Local    The absolute calendar year index 1 = 1975
C   IV       Local    Vehicle class index
C   JEXP     Local    Exponent index
C   NCOUNT   Block    Desired vehicle fleet size in 1st evaluation year
C   TCOUNT   Block    Vehicle fleet size in base year
C   VCNT     Block    Number of vehicles of each type in each
C                     calendar year
C   VGRORT   Block    Array containing the fleet growth rates for each
C                     vehicle class
C   YCOUNT   Block    The total number of vehicles in a given calendar
C                     year
C
C
      INTEGER BYEAR
C
C
      COMMON /COST02/ IFEVYR,ILEVYR
      COMMON /COST23/ VCNT(39,8),GSDSCT(8,10),HDDCUM(25,10)
      COMMON /COST34/ TCOUNT,BYEAR,VGRORT
      COMMON /COST37/ YRCOST(10),YRBEN(10,2),YCOUNT(39),ACOUNT
      COMMON /REGISF/ GSFVCT(8),USRGSF(25,2)
      COMMON /VMXCOM/ REGMIX(8),TFNORM(8),VMTMIX(8),VCOUNT(39,8)

      DIMENSION OLDCNT (39)
C
C  Determine base year index
C
      IBY = BYEAR - 1981
C
C  Adjust YCOUNT from given base year to current IFEVYR...
C  Leave TCOUNT as the base year count
C  and use YCOUNT as the new count for current eval year
C
      DO 20 ICYDX = 1,39
        YCOUNT(ICYDX) = TCOUNT
        IF(VGRORT.NE.0.0 .AND. ICYDX.NE.IBY) THEN
          IF(ICYDX.LT.IBY) THEN
            JEXP = IBY - ICYDX
            YCOUNT(ICYDX) = TCOUNT / ((1.0+(VGRORT/100.))**JEXP)
          ELSE IF(ICYDX.GT.IBY) THEN
            JEXP = ICYDX - IBY
            YCOUNT(ICYDX) = TCOUNT * ((1.0+(VGRORT/100.))**JEXP)
          ENDIF
        ENDIF
        OLDCNT(ICYDX) = 0.0
        DO 10 IV=1,8
          VCNT(ICYDX,IV) = VCOUNT(ICYDX,IV) * GSFVCT(IV)
          OLDCNT(ICYDX) = OLDCNT(ICYDX) + VCNT(ICYDX,IV)
   10   CONTINUE
C
```

```
C  normalize VCNT by Desired YCOUNT/(Old VCOUNT from M.41)
C
      DO 50 ICYDX = 1,39
        ADJCNT = YCOUNT(ICYDX)/OLDCNT(ICYDX)
        DO 40 IV = 1,8
          VCNT(ICYDX,IV) = VCNT(ICYDX,IV)*ADJCNT
   40   CONTINUE
   50 CONTINUE
C
C  Sum up YCOUNT and ACOUNT...
C
  105 IFICY = IFEVYR - 1981
      ILICY = ILEVYR - 1981
C
      ACOUNT=0.0
      DO 120 ICYDX=IFICY,ILICY
        ACOUNT = ACOUNT + YCOUNT(ICYDX)
  120 CONTINUE
C
      ACOUNT = ACOUNT / ( ILEVYR - IFEVYR + 1 )
C
  999 RETURN
C  End FLEET
      END
```

```
      SUBROUTINE TBASE
C
C..TBASE calculate the non-program emission levels for each
C..calendar year.
C
C..Called by MAIN
C
C..Calls CAMIL
C
C..Array Subscripts:
C
C..YTONS(2,10)              - YTONS(IP,JCYDX)
C..JULMYR(25,8)             - JULMYR(JDX,IV)
C..BTONS(2)                 - BTONS(IP)
C..VCNT(39,8)               - VCNT(ICYDX,IV)
C
C..Variable Dictionary:
C
C.. Name    Source   Description
C   ----    ------   -------------------------------------------------
C  ACCMIL   Param    The average accumulated mileage in a one year
C                    period.
C  BTONS    Block    Average benefits over all evaluated calendar
C                    years.
C  EFALL    Block    Emission factors from MOBILE4.
C  ICYDX    Local    Absolute Calendar year index (1975=1).
C  IDX      Local    Forward model year index (ascending model years)
C  IFEVYR   Local    First calendar year evaluated.
C  IFICY    Local    First evaluated calendar year index (1975=1).
C  ILEVYR   Local    Last calendar year evaluated.
C  ILICY    Local    Last evaluated calendar year index (1975 =1).
C  IP       Local    Pollutant type index (1:HC,2:CO,3:NOx).
C  IV       Param    Vehicle type index.
C  JDX      Param    Backward model year index (descending model
C                    year).
C  JULMYR   Block    Fraction of vehicles in each model year from
C                    MOBILE4.
C  MY       Local    Model year.
C  MYDX     Local    Absolute model year index (1955=1).
C  NUMCY    Local    The number of calendar years being evaluated.
C  VCNT     Block    Total number of vehicles in a vehilce class in a
C                    calendar year.
C  VMT      Param    Total vehicle miles traveled in a calendar year.
C  YTONS    Block    Total benefits in each evaluted calendar year.
C
C
      REAL JULMYR
      COMMON /COST02/ IFEVYR,ILEVYR
      COMMON /COST04/ TAMPER(25,6,4,10,4)
      COMMON /COST23/ VCNT(39,8),GSDSCT(8,10),HDDCUM(25,10)
      COMMON /COST25/ FRLOSS(25,4,4,10),FREF(25,4,4,10)
C...
      COMMON /COST26/ FRSTLS(25,8,4,10),YRSTLS(10),BRSTLS
      COMMON /COST27/ IGRFLG,IATPLP,IDIFF,OUTPRF
C
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
C   Add AEVAP 6/3/91
      COMMON /COST36/ YTONS(2,10),BTONS(2),BIDTON(2),AEVAP
      COMMON /COST30/ EVAP(25,8,4,10),FER(3,25,8,4,10)
      COMMON /COST40/ YEVTON(10),BEVTON,YEREF(10),BEREF
      COMMON /COST41/ YERLOS(10),BERLOS

      COMMON /CUMCOM/ CUMMIL(25,8)

      COMMON /MYRSAV/ AMAR(25,8),JULMYR(25,8),NEWCUM
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
      COMMON /REGISF/ GSFVCT(8),USRGSF(25,2)
C
      DIMENSION YHCFTP(10)
C
C     IFICY = IFEVYR - 1974
      IFICY = IFEVYR - 1981
C     IDIFF = ILEVYR - IFEVYR + 1
C
C     ..... Compute the number of calendar years analyzed.
C
C
      DO 5 IPP = 1,2
        BTONS(IPP) = 0.0
        BIDTON(IPP) = 0.0
    5 CONTINUE
```

```
        BEVTON  = 0.0
        BEREF   = 0.0
        BERLOS  = 0.0
C...
        BRSTLS  = 0.0
        BFTP    = 0.0
C
      DO 30 JCYDX = 1,IDIFF
C
C       ICYDX = (IFEVYR-1974) + JCYDX - 1
        ICYDX = (IFEVYR-1981) + JCYDX - 1
C
        YTONS(1,JCYDX) = 0.0
        YTONS(2,JCYDX) = 0.0
        YEVTON(JCYDX)  = 0.0
        YEREF(JCYDX)   = 0.0
        YERLOS(JCYDX)  = 0.0
        YRSTLS(JCYDX)  = 0.0
C... add 8/12/91...
        YHCFTP(JCYDX)  = 0.0
C
        DO 20 IV = 1,8
C...
          DO 10 IDX = 1,MAXYRS
            JDX = MAXYRS + 1 - IDX
C           MYDX = MAXYRS + ICYDX - JDX
C           MY   = MYDX + 1950
C
C     ..... Determine the vehicle miles traveled (VMT)
C    VCNT now already has GSFVCT incorporated into it...
C
            CALL CALMIL(JDX,IV,ACCMIL,VMT)
C
            VADJ = VCNT(ICYDX,IV)*JULMYR(JDX,IV)*1.1025E-6*.001*VMT
C
          TMP=VADJ*(EVAP(IDX,IV,1,JCYDX)+EVAP(IDX,IV,1,JCYDX+1))/2.0
              YEVTON(JCYDX) = YEVTON(JCYDX) + TMP
C     *          (EVAP(IDX,IV,1,JCYDX)+EVAP(IDX,IV,1,JCYDX+1))/2 *
C     *                        VADJ
              BEVTON        = BEVTON + TMP
C     *          (EVAP(IDX,IV,1,JCYDX)+EVAP(IDX,IV,1,JCYDX+1))/2 *
C     *                        VADJ
C...
          TMP=VADJ*(FRSTLS(IDX,IV,1,JCYDX)+FRSTLS(IDX,IV,1,JCYDX+1))/2.0
              YRSTLS(JCYDX) = YRSTLS(JCYDX) + TMP
C
              BRSTLS        = BRSTLS + TMP
C
          TMP=VADJ*(FER(1,IDX,IV,1,JCYDX)+FER(1,IDX,IV,1,JCYDX+1))/2.0
              YHCFTP(JCYDX) = YHCFTP(JCYDX) + TMP
C
              BFTP          = BFTP + TMP
C
          TMP=VADJ*(FER(2,IDX,IV,1,JCYDX)+FER(2,IDX,IV,1,JCYDX+1))/2.0
              YTONS(2,JCYDX)= YTONS(2,JCYDX) + TMP
C
              BTONS(2)      = BTONS(2) + TMP
C
        IF(IV.LE.4) THEN
          TMP=VADJ*(FREF(IDX,IV,1,JCYDX)+FREF(IDX,IV,1,JCYDX+1))/2.0
              YEREF(JCYDX)  = YEREF(JCYDX) + TMP
C
              BEREF         = BEREF + TMP
C
          TMP=VADJ*(FRLOSS(IDX,IV,1,JCYDX)+FRLOSS(IDX,IV,1,JCYDX+1))/2.0
                YERLOS(JCYDX) = YERLOS(JCYDX) + TMP
C
                BERLOS        = BERLOS + TMP
C
        ENDIF
C
   10 CONTINUE
C
   20 CONTINUE
C...
            YTONS(1,JCYDX) = YHCFTP(JCYDX)
     *                     + YEVTON(JCYDX) + YEREF(JCYDX)
     *                     + YERLOS(JCYDX) + YRSTLS(JCYDX)
C
   30 CONTINUE
C
```

```
C...
            BTONS(1)  = BFTP + BEVTON + BEREF + BERLOS + BRSTLS
C
            DO 40 I=1,2
              BTONS(I) = (BTONS(I) / IDIFF)
   40       CONTINUE
C
            BEVTON = BEVTON / IDIFF
            BEREF  = BEREF  / IDIFF
            BERLOS = BERLOS / IDIFF
C...
            BRSTLS = BRSTLS / IDIFF
            BFTP   = BFTP   / IDIFF
C
C
   99 RETURN
C  End TBASE
      END
```

```
      SUBROUTINE CPFUEL
C
C..CPFUEL computes the fuel economy benefits due to car
C..repairs.  This routine is called only if an I/M
C..program is selected. If this is the case, this routine
C..calculates the fuel savings accumulated from I/M
C..repairs over the life of the I/M program. It is assumed
C..that a given vehicle receives only one fuel economy
C..benefit over its entire life and that once received
C..this benefit is permanent.
C
C..Because this subroutine may have the largest calendar
C..year coverage (the ICYDX looping begins at the I/M
C..start year not the first scenario year (IFEVYR)), the
C..I/M failure rate calculation is performed in this
C..subroutine.
C
C..Called by MAIN
C
C..Calls CALMIL
C
C..Array Subscripts:
C
C..DRSTRN(3)                - DRSTRN(ITEST)
C..FAILRT(25,10,4)           - FAILRT(IDX,JCYDX,IV)
C..FEBNFT(25,10,4)            - FEBNFT(IDX,ICYDX,IV)
C..FECNMY(20,4)               - FECNMY(IDX,IV)
C..JULMYR(25,8)               - JULMYR(IDX,IV)
C..NEWSTR(4,100)              - NEWSTR(4,IM)
C..PCNTSV(4)                  - PCNTSV(ITECH+IM24+P/P)
C..PPFEB(25,10,4)             - PPFEB(IDX,ICYDX,IV)
C..WAIVER(2)                  - WAIVER(ITECH)
C..ZMSTRN(3)                - ZMSTRN(ITEST)
C
C..Variable Dictionary
C
C..  Name     Source     Description
C    ----     ------     -----------------------------------------------
C    ACCMIL   Param      Accumulated mileage at a given age for each
C                        vehicle class
C    DRSTRN   Block      Growth in the I/M failure as a function of
C                        mileage for new tech vehicles
C    FAIL     Block      Calculated I/M failure rate (1=HC/CO, 2=NOx)
C    FAIL1    Local      I/M failure rate for next year
C    FAIL2    Local      I/M failure rate for current year among cars
C                        which were OK after last year's repairs
C    FEBNFT   Block      Final fuel economy benefit for exhaust repairs
C    FECARS   Local      Number of cars for which fuel economy credits
C                        should be claimed
C    FECNMY   Block      Fuel economy of each vehicle type for each
C                        model year in miles per gallon
C    FFACT    Block      Fraction of annual fuel economy benefit achieved
C                        by biennial I/M (based on HC emission reduction)
C    GASCST   Block      Cost of one gallon of unleaded gasoline
C    ICUTS    Block      I/M cutpoint index from MOBILE4
C    ICYDX    Local      Calendar year index  1 = 1975
C    ICYDX2   Local      Subsequent calendar year index ICYDX2=ICYDX + 1
C    ICY      Local      Calendar year
C    IDX      Local      Model year index (forward counter 1 - 25)
C    IFEVYR   Block      First calendar year evaluated
C    IFICY    Local      First calendar year index
C    IFREQ    Block      Flag indicating whether the I/M program is
C                        annual or biennial
C    ILEVYR   Block      Last calendar year evaluated
C    ILICY    Local      Last calendar year index
C    IMICY    Local      Calendar year index in which I/M starts.
C                        Only used if I/M start precedes first calendar
C                        evaluated.
C    ISTRIN   Block      Number of input stringency groups
C    ISTRT    Block      I/M start year
C    ITECH    Block      Technology group  1 = old tech , 2 = new tech
C                         Old = myr 1951-1980 LDGV , myr 1951-1983 LDT's
C                         New = myr 1981+     LDGV , myr 1984+     LDT's
C    ITEST    Block      I/M test type from MOBILE4
C    IV       Local      Vehicle class index
C    JDX      Local      Model year index (backwards counter 20 - 1)
C    MY       Local      Model year
C    MYDX     Local      Model year index
C    NEWSTR   Block      Array containing information read from the
C                        stringency records.
C                            NEWSTR(1,IM)  1 = Vehicle class
```

```
C                              NEWSTR(2,IM)  2 = First model year in group
C                              NEWSTR(3,IM)  3 = Last model year in group
C                              NEWSTR(4,IM)  4 = Group's stringency
C    NMYF      Local       First model year in group (from NEWSTR(2,IM)
C    NMYLL     Local       Last model year in group (from NEWSTR(3,IM)
C    NRPEAT    Local       Cars which are not part of the REPEAT failure
C                           category
C    PCNTSV    Block       Average fuel savings by technology group
C    PPCARS    Local       Number of cars for which Purge/Pressure repair
C                           fuel economy credits should be claimed
C    PPFEB     Block       Fuel economy benefit for Purge/Press repairs
C    PREVCY    Block       Values used in calculating the previous
C                           calendar year's fuel economy cars.  Used to
C                           calculate next year's cars
C    PREVNF    Block       Cars repaired in previous years which have not
C                           yet failed again
C    REPEAT    Block       Fraction of I/M failures which fail in the
C                           subsequent year also.
C    RMAXF     Block       Maximum failure rate that 1981 and later
C                           vehicles are allowed
C    VMT       Param       Vehicle miles travelled in a given year
C    WAIVER    Block       Array containing the waiver rates for old
C                           and new technology vehicles
C    ZMSTRN    Block       Failure rate of new technology vehicles at
C                           zero miles.
C
C    NOTES: EVPFEB added 7/11/91 could be done away with and the
C           results simply added in with FEBNFT if we didn't want
C           to see it separately in the printout.
C      9/8/91  Add NOx to FAIL array FAILRT(IPOL,JDX,ICYDX,IV), where
C      IPOL: HC,CO=1, NOx=2
C
C
       COMMON /COST01/ ATPFEE
       COMMON /COST02/ IFEVYR,ILEVYR
       COMMON /COST03/ STRNGY,RMAXF,REPEAT,FFACT
       COMMON /COST05/ REPLCE(25,6,10,4)
       COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
C...
       COMMON /COST08/ FAILRT(2,25,39,4)
       COMMON /COST09/ DRSTRN(5),ZMSTRN(5)
       COMMON /COST10/ FEBNFT(25,10,4),FECNMY(20,4)
       COMMON /COST11/ PCNTSV(4)
       COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
       COMMON /COST47/ PPFAIL(25,3,10,4),PPFIXR(25,10,4)
       COMMON /COST49/ PPFEB(25,10,4),APFBEN
C
       COMMON /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER(2),CRIM
       COMMON /IMPAR2/ ILDT(4),ITEST,NUDATA(2),NLIM,IMNAME(20,9)
       COMMON /IMPAR6/ IFREQ,INTYP
       COMMON /IM240P/ DSIZE(25,4),IM24YR,IPRGYR,IPRSYR
       COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
C
       IFICY = IFEVYR - 1981
       ILICY = ILEVYR - 1981
       IMICY = ISTRT  - 1981
C
C      ..... The IMICY allows this subroutine to loop for calendar
C            earlier than the first calendar evaluated (IFEVYR).
C
       ISICY = IMICY
       IF((ILICY-IMICY).GT.19) ISICY = ILICY - 19
C
       DO 52 IV=1,4
         IF(ILDT(IV) .NE. 2) GOTO 52
         DO 51 ICYDX=ISICY,ILICY
           JCYDX=ICYDX-IFICY+1
           ICYDX2=ICYDX+1
           ICY = 1981 + ICYDX
           DO 50 IDX = 1,MAXYRS
             JDX = MAXYRS + 1 - IDX
             MYDX = MAXYRS + ICYDX - JDX
             MY  = MYDX + 1957
C
C      ..... Get vehicle miles traveled (VMT) that year
C
             CALL CALMIL(JDX,IV,ACCMIL,VMT)
C
C      ..... Determine technology group
C
             ITECH=1
```

```
            IF(IV.EQ.1.AND.MY.GE.1981)    ITECH=2
            IF(IV.GT.1.AND.MY.GE.1984)    ITECH=2
C
C     ..... Compute IM failure rate
C
            IF(ITECH .EQ. 2) GOTO 20
C
            IF(MY.GE.MODYR1.AND.MY.LE.MODYR2.AND.IMFLAG.GT.1)
     *        FAILRT(1,IDX,ICYDX,IV) = ISTRIN/100.0
C
C     Add separate IM240 failure rates, 6/6/91, & adjusted for time
C     by factor of 0.01/0.0187... 0.0199 put into DRSTRN(4) 9/9/91
C       0.4/15 : 0.0750 ... 0.0401
C       0.8/15 : 0.0373 ... 0.0199
C   Revise 12/10/91, to use half of flat zero mile
C   and half of sloped DR.
C       0.8/30 : 0.0324 ... 0.0173
C       1.6/30 : 0.0148 ... 0.0079
C
   20       IF(ITECH .EQ. 2) THEN
              IF(MY .GE. IM24YR) THEN
C               FAILRT(1,IDX,ICYDX,IV) = ZMSTRN(4)
C    *            + DRSTRN(4)*ACCMIL*0.0001
C  12/10/91...
                FAILRT(1,IDX,ICYDX,IV) =
     *            DRSTRN(4)/2.0 + (DRSTRN(4)/(2.0*1.87))*ACCMIL*0.0001

                FAILRT(2,IDX,ICYDX,IV) = ZMSTRN(5)
     *            + DRSTRN(5)*ACCMIL*0.0001
              ELSE
                FAILRT(1,IDX,ICYDX,IV) =
     *            ZMSTRN(ITEST)+(DRSTRN(ITEST)*(ACCMIL*.0001))
                FAILRT(2,IDX,ICYDX,IV) = 0.0
              ENDIF
              IF(FAILRT(1,IDX,ICYDX,IV).GT.RMAXF)
     *          FAILRT(1,IDX,ICYDX,IV)=RMAXF
            ELSE
              FAILRT(2,IDX,ICYDX,IV) = 0.0
            ENDIF
C
C   Add check for negative failure rate, 6/6/91 ...
C
            IF(FAILRT(1,IDX,ICYDX,IV).LT.0.0) FAILRT(1,IDX,ICYDX,IV) = 0.0
C
C   FAIL1 is used only for FE benefit calcs
C
            IF(ITECH.EQ.2 .AND. MY.GE.IM24YR) THEN
              FAIL1 = ZMSTRN(4) + DRSTRN(4)*ACCMIL*0.0001
            ELSE
              FAIL1  = FAILRT(1,IDX,ICYDX,IV)*1.87
            ENDIF
C
C  Removed all code regarding NRPEAT, FAIL2, PREVCY & PREVNF since
C  we've been using different FE calc method since 6/19/91, 12/10/91...
C
C  Calculate the number of cars to get fuel economy benefit...
C
            FECARS = FAIL1*ENFORC(CRIM,1) * (1.0-WAIVER(ITECH))
            IF(FECARS.GT.1.) FECARS=1.0
C
C      ..... Calculate annual fuel economy benefits for a vehicle in
C            a given model year.
C
            IDXP1=MY-1967
            IF(IDXP1.LE.0)  IDXP1=1
            IF(IDXP1.GE.20) IDXP1=20
C
C     ..... Calculate fuel economy benefit in each calendar year.
C
            IF(ICYDX.GE.IFICY) THEN
              IF(ITECH.EQ.2 .AND. MY.GE.IM24YR) THEN
                FEBNFT(IDX,JCYDX,IV) =
     *            (PCNTSV(3)*GASCST*VMT/FECNMY(IDXP1,IV))*FECARS
              ELSE
                FEBNFT(IDX,JCYDX,IV) =
     *            (PCNTSV(ITECH)*GASCST*VMT/FECNMY(IDXP1,IV))*FECARS
              ENDIF
C           ENDIF
C
```

```
C     Add FE benefit calc for Purge/Pressure Repairs 7/11/91...
C     PPFIXR already includes ENFORC(CRIM,1), but not WAIVER
C     since no waivers are expected for P/P repairs.
C
              IF(MY.GE.JPRSYR .OR. MY.GE.JPRGYR) THEN
C               PPCARS = PPFIXR(IDX,JCYDX,IV)
                PPFEB(IDX,JCYDX,IV) =
     *            PCNTSV(4)*GASCST*VMT/FECNMY(IDXP1,IV)*
     *            PPFIXR(IDX,JCYDX,IV)
              ENDIF
            ENDIF
C
C     ..... Adjust annual FE benefit if the inspection is biennial.
C
            IF(IFREQ.EQ.2 .AND. ICYDX.GE.IFICY) THEN
              FEBNFT(IDX,JCYDX,IV)=FEBNFT(IDX,JCYDX,IV)*FFACT
            ENDIF
C
C     ..... Save current values calculated. These are used to
C           calculate next year's benefits.
C
   50     CONTINUE
   51   CONTINUE
   52 CONTINUE
C
   99 RETURN
C  End CPFUEL
      END
```

```
      SUBROUTINE CALMIL(JDX,IV,ACCMIL,VMT)
C
C..CALMIL calculates the mileage statistics for each model year in
C..each vehicle class in each calendar year.
C
C..Called by CMPUTE,CPFUEL,SMCOST,TBASE
C
C..Calls None
C
C..Array Subscripts:
C
C..CUMMIL(25,8)          - CUMMIL(JDX,IV)
C
C..Variable Dictionary:
C
C.. Name     Source   Description
C   ----     ------   -------------------------------------------
C  ACCMIL    Param    The average accumulated mileage in a one year
C                     period.
C  CUMMIL    Block    The average accumulated mileage at a given
C                     vehicle age.
C  IV        Param    Vehicle type index.
C  JDX       Param    Backward model year index (decending model
C                     years).
C  VMT       Param    Total vehicle miles traveled in a calendar
C                     year.
C
C
      COMMON /COST23/ VCNT(39,8),GSDSCT(8,10),HDDCUM(25,10)
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
      COMMON /CUMCOM/ CUMMIL(25,8)
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
C
      IF(JDX.NE.25) ACCMIL = (CUMMIL(JDX,IV)+CUMMIL(JDX+1,IV))/2.0
      IF(JDX.EQ.25) ACCMIL =  CUMMIL(JDX,IV)
C
      IF(JDX.NE.25) VMT = CUMMIL(JDX+1,IV) - CUMMIL(JDX,IV)
      IF(JDX.EQ.25) VMT = CUMMIL(JDX,IV)   - CUMMIL(JDX-1,IV)
C
C
      RETURN
C  End CALMIL
      END
```

```
      SUBROUTINE LOOP(ISIZE1,ISIZE2)
C
C..LOOP does the vehicle type, calendar year, model year and
C..pollutant looping.  Inside these loops the subroutines
C..COVER, CMPUTE, CMPREP, POLL, REDUC, and SMCOST are
C..called.
C
C..Called by MAIN
C
C..Calls COVER,CMPUTE,POLL,CMPREP and SMCOST
C
C..Array Subscriptes
C
C..Variable Dictionary
C
C.. Name    Source   Description
C   ----    ------   -------------------------------------------------
C   IATPLP  Block    Flag indicating whether an ATP only scenario is
C                    to be run
C   ICOV1   Local    Variable indicating whether a given calendar year
C                    is covered by I/M
C   ICOV2   Local    Variable indicating whether a given calendar year
C                    is covered by an ATP
C   ICY     Local    Calendar year
C   ICYDX   Local    Calendar year index
C   IDX     Local    Model year index (forward 1 - 25)
C   IFEVYR  Block    First calendar year evaluated
C   IFICY   Local    Index of first calendar year evaluated
C   ILEVYR  Block    Last calendar year evaluated
C   ILICY   Local    Index of last calendar year evaluated
C   INDVL1  Local    Variable indicating whether a given model year
C                    is covered by I/M
C   INDVL2  Local    Variable indicating whether a given model year
C                    is covered by an ATP
C   IP      Local    Pollutant index
C   ISIZE1  Param    Variable containing either the size of the
C                    floating model year window for I/M coverage or
C                    the earliest model year inspected in an I/M
C                    program.
C   ISIZE2  Param    Variable containing either the size of the
C                    floating model year window for ATP coverage
C                    or the earliest model year inspected in an ATP.
C   ISTRT   Block    I/M program start year
C   IV      Local    Vehicle class index
C   JDX     Local    Model year index (backwards counter 20 - 1)
C   LAPSY   Block    ATP start year
C   MY      Local    Model year
C   MYDX    Local    Model year index
C
C
      INTEGER PROMPT
C
C
      COMMON /COST02/ IFEVYR,ILEVYR
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
      COMMON /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER(2),CRIM
      COMMON /COST12/ IMFXFG,IAFXFG,IMCSFG,IAFEFG,IALDV
      COMMON /COST19/ ICOV1,ICOV2,INDVL1,INDVL2
      COMMON /COST27/ IGRFLG,IATPLP,IDIFF,OUTPRF
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
C
      COMMON /ATPAR1/ LAPSY,LAP1ST,LAPLST,LVTFLG(4)
      COMMON /FLAGS1/ PROMPT,TAMFLG,SPDFLG,VMFLAG,OXYFLG,DSFLAG
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
C
C
C     IDIFF = ILEVYR - IFEVYR + 1
C     IFICY = IFEVYR - 1974
C     ILICY = ILEVYR - 1974
      IFICY = IFEVYR - 1981
      ILICY = ILEVYR - 1981
C
      DO 22 IV = 1,4
        DO 21 JCYDX = 1,IDIFF
C         ICYDX = (IFEVYR-1974) + JCYDX - 1
C         ICY = ICYDX + 1974
          ICYDX = (IFEVYR-1981) + JCYDX - 1
          ICY = ICYDX + 1981
          ICOV1 = 0
          ICOV2 = 0
          IF(IATPLP .EQ. 2) ISTRT = 2020
```

```
C
          IF(ICY.LT.ISTRT .AND. ICY.LT.LAPSY) GOTO 21
          IF(ICY.GE.ISTRT)    ICOV1 = 1
          IF(ICY.GE.LAPSY)    ICOV2 = 1
C
          DO 20 IDX = 1,MAXYRS
            JDX = MAXYRS + 1 - IDX
            MYDX = MAXYRS + ICYDX -JDX
C           MY = MYDX + 1950
            MY = MYDX + 1957
C
            INDVL1 = 0
            INDVL2 = 0
C
C     ..... Determine the vehicles covered by an inspection program.
C
            CALL COVER(MYDX,ICY,IV,ISIZE1,ISIZE2)
C
C     ..... Compute emission reduction benefits and
C           failure rates.
C
            DO 10 IP = 1,2
              CALL CMPUTE(IV,ICYDX,MYDX,IP,IDX,JDX,JCYDX)
              CALL POLL(MYDX,IP,IV,IDX,JCYDX)
   10       CONTINUE
C
C     ..... Compute overall anti-tampering failure/replacement
C           rates.
C
            CALL CMPREP(IV,ICY,MYDX,IDX,JDX,JCYDX)
C
            CALL SMCOST(MYDX,ICYDX,IV,JDX,IDX)
C
   20     CONTINUE
   21   CONTINUE
   22 CONTINUE
C
   99 RETURN
C  End LOOP
      END
```

```
      SUBROUTINE COVER(MYDX,ICY,IV,ISIZE1,ISIZE2)
C
C..COVER determines whether a given model year or calendar year
C..is covered by an I/M or ATP program.
C
C..Called by Loop
C
C..Variable Dictionary
C
C.. Name     Source   Description
C   ----     ------   -----------------------------------------------
C   IAFXFG   Block    Flag determining whether the ATP has a fixed or
C                     floating model year coverage
C   IATPLP   Block    Flag indicating whether an ATP only scenario is
C                     to be run
C   ICOV1    Local    Variable indicating whether a given calendar year
C                     is covered by I/M
C   ICOV2    Local    Variable indicating whether a given calendar year
C                     is covered by an ATP
C   ICY      Local    Calendar year
C   ICYDX    Local    Calendar year index
C   IMFXFG   Block    Flag indicating whether the I/M program has a
C                     fixed or floating model year coverage
C   INDVL1   Local    Variable indicating whether a given model year
C                     is covered by I/M
C   INDVL2   Local    Variable indicating whether a given model year
C                     is covered by an ATP
C   ISIZE1   Param    Variable containing either the size of the
C                     floating model year window for I/M coverage or
C                     the earliest model year inspected in an I/M
C                     program.
C   ISIZE2   Param    Variable containing either the size of the
C                     floating model year window for ATP coverage
C                     or the earliest model year inspected in an ATP.
C   ISTRT    Block    I/M program start year
C   LAPSY    Block    ATP start year
C   MY       Local    Model year
C   MYDX     Local    Model year index
C
      INTEGER PROMPT
C
      COMMON /COST05/ REPLCE(25,6,10,4)
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
      COMMON /COST12/ IMFXFG,IAFXFG,IMCSFG,IAFEFG,IALDV
      COMMON /COST15/ TOTCST(2),TOTRED(2),TCOST
      COMMON /COST19/ ICOV1,ICOV2,INDVL1,INDVL2
      COMMON /COST27/ IGRFLG,IATPLP,IDIFF,OUTPRF
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
      COMMON /ATPAR1/ LAPSY,LAP1ST,LAPLST,LVTFLG(4)
      COMMON /FLAGS1/ PROMPT,TAMFLG,SPDFLG,VMFLAG,OXYFLG,DSFLAG
      COMMON /IMPAR2/ ILDT(4),ITEST,NUDATA(2),NLIM,IMNAME(20,9)
C
      MY = MYDX + 1957
C
      IF(IATPLP.EQ.2)                          GOTO 30
      IF((IMFXFG.EQ.1) .AND. (ICOV1.EQ.1)) GOTO 10
      IF((IMFXFG.EQ.2) .AND. (ICOV1.EQ.1)) GOTO 20
      GOTO 30
C
C     ..... Sets coverage for floating I/M programs.
C
   10 IF(MY.GT.ICY)                                  INDVL1 = 1
      IF((MY.LE.ICY) .AND. (MY.GT.(ICY-ISIZE1)))     INDVL1 = 2
      IF(MY.EQ.(ICY-ISIZE1))                         INDVL1 = 3
      IF((MY.EQ.(ICY-ISIZE1-1)) .AND. ((ICY-ISTRT).GT.1))
     *                                               INDVL1 = 4
      IF((MY.EQ.(ICY-ISIZE1-2)) .AND. ((ICY-ISTRT).GT.2))
     *                                               INDVL1 = 5
      IF(MY .LE. (ICY-ISIZE1-3))                     INDVL1 = 6
      GOTO 30
C
C     ..... Sets coverage for fixed I/M programs.
C
   20 IF(MY.GT.ICY)                                  INDVL1 = 1
      IF(MY.LE.ICY .AND. (MY.GE.ISIZE1))             INDVL1 = 2
C
C
   30 IF(IATPLP.EQ.2)                                INDVL1 = 6
      IF(IAFXFG.EQ.1 .AND. ICOV2.EQ.1) GOTO 40
      IF(IAFXFG.EQ.2 .AND. ICOV2.EQ.1) GOTO 50
      GOTO 98
```

```
C
C     ..... Sets coverage for floating ATPs.
C
   40 IF(MY.GT.ICY)                                    INDVL2 = 1
      IF((MY.LE.ICY) .AND. (MY.GT.(ICY-ISIZE2)))       INDVL2 = 2
      IF(MY.EQ.(ICY-ISIZE2))                           INDVL2 = 3
      IF((MY.EQ.(ICY-ISIZE2-1)) .AND. ((ICY-LAPSY).GT.1))
     *                                                 INDVL2 = 4
      IF((MY.EQ.(ICY-ISIZE2-2)) .AND. ((ICY-LAPSY).GT.2))
     *                                                 INDVL2 = 5
      IF(MY .LE. (ICY-ISIZE2-3))                       INDVL2 = 6
      GOTO 98
C
C     ..... Sets coverage for fixed ATPs.
C
   50 IF(MY.GT.ICY)                                    INDVL2 = 1
      IF(MY.LE.ICY .AND. (MY.GE.ISIZE2))               INDVL2 = 2
C
   98 IF(ILDT(IV)  .EQ.1) INDVL1=1
      IF(LVTFLG(IV).EQ.1) INDVL2=1
C
   99 RETURN
C  End COVER
      END
```

```
      SUBROUTINE CMPUTE(IV,ICYDX,MYDX,IP,IDX,JDX,JCYDX)
C
C..CMPUTE computes the overall emission reduction
C..benefits by computing the differences in the MOBILE4
C..EFALL arrays.
C
C..Called by LOOP
C
C..Array Subscripts
C
C..JULMYR(25,8)              - JULMYR(JDX,IV)
C..TDUCT(25,2,3,10,4)        - TDUCT(25,2,3,10,4)
C..VCNT(46,8)                - VCNT(ICYDX,IV)
C..WAIVER(2)                 - WAIVER(ITECH)
C
C..Variable dictionary
C
C.. Name   Source     Description
C   ----   ------     -----------------------------
C   ICY    Local      Calendar year
C   ICYDX  Local      Calendar year index
C   IETYP  Local      Control program reduction type index
C   IMC    Local      Control program reduction type index
C   IMCAS1 Local      Control program reduction type counter
C   IMCAS2 Local      Second control program reduction type counter
C   IP     Local      Pollutant index  1 = HC  2 = CO
C   ITECH  Local      Technology type index  1 = old tech 2 = new tech
C   IV     Local      Vehicle class index
C   JDX    Local      Model year index (backwards 20 - 1)
C   JULMYR Block      Distribution of vehicle fleet by model year.
C                     One distribution per vehicle class
C   MY     Local      Model year
C   MYDX   Local      Model year index
C                     by calendar year by vehicle class as a result of
C                     a control program
C   RDUCT1 Local      Emissions of no control program or lesser
C                     control program
C   RDUCT2 Local      Emissions of greater control program
C   RDUCT  Local      Difference in emissions between RDUCT1 and
C                     RDUCT2       RDUCT = RDUCT1 - RDUCT2
C   TDUCT  Block      Array containing final emission factors.
C                     VMT weighting and fleet weighting have been done
C   VCNT   Block      Number of vehicles of each type in each
C                     calendar year
C   VMT    Param      Vehicle miles travelled in a given calendar year
C   WAIVER Block      Array containing waiver rates
C
C
C
      REAL JULMYR
C
      COMMON /COST01/ ATPFEE
      COMMON /COST04/ TAMPER(25,6,4,10,4)
      COMMON /COST05/ REPLCE(25,6,10,4)
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
      COMMON /COST20/ TDUCT(25,2,3,10,4),TEVAP(25,10,4)
      COMMON /COST23/ VCNT(39,8),GSDSCT(8,10),HDDCUM(25,10)
C...
      COMMON /COST25/ FRLOSS(25,4,4,10),FREF(25,4,4,10)
C     COMMON /COST26/ FRSTLS(25,8,4,10),YRSTLS(10),BRSTLS
C
      COMMON /COST50/ TRLOSS(25,4,3),TREVAP(25,4,3)
C     COMMON /COST50/ TRLOSS(25,4,3),TREVAP(25,4,3),TRSTLS(25,4,3)
C
      COMMON /COST30/ EVAP(25,8,4,10),FER(3,25,8,4,10)
      COMMON /COST40/ YEVTON(10),BEVTON,YEREF(10),BEREF
      COMMON /COST41/ YERLOS(10),BERLOS
      COMMON /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER(2),CRIM
C     COMMON /MYRCAL/ XMYM(25,8),JANMYR(25,8),TF(25,8),TFMYM(25,8)
      COMMON /MYRSAV/ AMAR(25,8),JULMYR(25,8),NEWCUM
      COMMON /REGISF/ GSFVCT(8),USRGSF(25,2)
C
C
      JCYDX2 = JCYDX + 1
      ICY    = 1981 + ICYDX
      MY = MYDX + 1957
C
C     ..... There are three cases (IMC) for which emission reductions
C           are calculated:
C
C           IMC = 1 : I/M tampering deterrence effect.
```

```
C           IMC = 2 : The effect of I/M repairs.
C           IMC = 3 : The effect of ATP repairs.
C
      DO 30 IMC=1,3
        IMCAS1=IMC
        IMCAS2=IMC+1
C
        IF(IDX.NE.1) GOTO 10
C
C     ..... Calculate basic emission reductions without losses.
C           for last model year index in given window,
C           set mid-year emissions equal to Jan 1 emissions,
C           otherwise interpolate between the Jan 1st emissions
C           from one calendar year to the next for the given
C           model year.
C
        RDUCT1=FER(IP,IDX,IV,IMCAS1,JCYDX)
        RDUCT2=FER(IP,IDX,IV,IMCAS2,JCYDX)
C
        REVAP1=EVAP(IDX,IV,IMCAS1,JCYDX)
        REVAP2=EVAP(IDX,IV,IMCAS2,JCYDX)
C
        RLOSS1=FRLOSS(IDX,IV,IMCAS1,JCYDX)
        RLOSS2=FRLOSS(IDX,IV,IMCAS2,JCYDX)
C...
C       RSTLS1=FRSTLS(IDX,IV,IMCAS1,JCYDX)
C       RSTLS2=FRSTLS(IDX,IV,IMCAS2,JCYDX)
C
        GOTO 20
C
C     ..... The January 1st EFALL value for a given calendar
C           year is averaged with the subsequent year's EFALL
C           value to arrive at a July 1st emission value.
C
   10   RDUCT1 = (FER(IP,IDX,IV,IMCAS1,JCYDX) +
     *             FER(IP,IDX,IV,IMCAS1,JCYDX2))/2.0
        RDUCT2 = (FER(IP,IDX,IV,IMCAS2,JCYDX) +
     *             FER(IP,IDX,IV,IMCAS2,JCYDX2))/2.0
C
        REVAP1 = (EVAP(IDX,IV,IMCAS1,JCYDX) +
     *             EVAP(IDX,IV,IMCAS1,JCYDX2))/2.0
        REVAP2 = (EVAP(IDX,IV,IMCAS2,JCYDX) +
     *             EVAP(IDX,IV,IMCAS2,JCYDX2))/2.0
C
        RLOSS1 = (FRLOSS(IDX,IV,IMCAS1,JCYDX) +
     *             FRLOSS(IDX,IV,IMCAS1,JCYDX2))/2.0
        RLOSS2 = (FRLOSS(IDX,IV,IMCAS2,JCYDX) +
     *             FRLOSS(IDX,IV,IMCAS2,JCYDX2))/2.0
C
C...
C       RSTLS1 = (FRSTLS(IDX,IV,IMCAS1,JCYDX) +
C    *             FRSTLS(IDX,IV,IMCAS1,JCYDX2))/2.0
C       RSTLS2 = (FRSTLS(IDX,IV,IMCAS2,JCYDX) +
C    *             FRSTLS(IDX,IV,IMCAS2,JCYDX2))/2.0
C
   20   RDUCT = RDUCT1 - RDUCT2
C
C...
        REVAP = (REVAP1-REVAP2) + (RLOSS1-RLOSS2)
C       REVAP = (REVAP1-REVAP2) + (RLOSS1-RLOSS2) + (RSTLS1-RSTLS2)
C
C     ..... Get the vehicle miles traveled (VMT)
C
        CALL CALMIL(JDX,IV,ACCMIL,VMT)
C
C     ..... Change emission reductions to WEIGHT (grams) reductions.
C           On a per vehicle basis, not a fleet basis.
C
C
C           TDUCT(IDX,IP,IMC,JCYDX,IV)
C           represents the I/M or ATP emission's benefit (tonnage) per
C           car per year and multiplies it by the appropriate fleet
C           size.  The units are then converted from tons to grams
C           when calculating TDUCT.
C
C  Save these 2 separately for debugging...
C
        VADJ = VCNT(ICYDX,IV) * JULMYR(JDX,IV) * 1.1025E-6 *
     *         VMT !* GSFVCT(IV) !GSDSCT(IV,JCYDX)
C
        TREVAP(IDX,IV,IMC) = (REVAP1-REVAP2) * VADJ
```

```
          TRLOSS(IDX,IV,IMC) = (RLOSS1-RLOSS2) * VADJ
C
          IF(IP.EQ.1)   TEVAP(IDX,JCYDX,IV) = REVAP * VADJ
C
          IF(IP.EQ.2) REVAP = 0.0
          TDUCT(IDX,IP,IMC,JCYDX,IV) = (RDUCT+REVAP) * VADJ
C
   30 CONTINUE
C
   99 RETURN
C  End CMPUTE
      END
```

```
      SUBROUTINE POLL(MYDX,IP,IV,IDX,JCYDX)
C
C..POLL transfers the contents from the array TDUCT into other arrays
C..which are specific to I/M, ATP or DETERRENCE.  These new arrays are
C..subsequently summed by model year, calendar year, pollutant and
C..vehicle class in subroutine SUMWDW.
C
C..Called by LOOP
C
C..Calls None
C
C..Array Subscripts:
C
C..CRDTAT(3,2)              - CRDTAT(IAYRDX,IP)
C..CRDTIM(3,2)              - CRDTIM(IMYRDX,IP)
C..DETER(25,2,10,4)         - DETER(IDX,IP,JCYDX,IV)
C..REDATP(25,2,10,4)        - REDATP(IDX,IP,JCYDX,IV)
C..REDIM(25,2,10,4)         - REDIM(IDX,IP,JCYDX,IV)
C..TDUCT(25,2,3,10,4)       - TDUCT(IDX,IP,3,JCYDX,IV)
C..TONRED(25,2,10,4)        - TONRED(IDX,IP,JCYDX,IV)
C
C..Variable Dictionary:
C
C.. Name     Source   Description
C   ----     ------   -----------------------------------------------
C  CRDTAT    Block    Fraction of ATP effectiveness for vehicles which
C                     are no longer inspected.
C  CRDTIM    Block    Fraction of I/M effectiveness for vehicles which
C                     no longer inspected.
C  DETER     Block    Array which contains the pollutant reductions for
C                     each model year, calendar year and vehicle type
C                     due to tampering deterence.
C  IAYRDX    Local    Index used in CRDTAT array. Relates INDVL2 to
C                     the model years which are no longer inspected.
C  IMYRDX    Local    Index used in CRDTIM array. Relates INDVL1 to the
C                     model years which are no longer inspected.
C  INDVL1    Local    Flag determining whether a given vehicle class
C                     with a given model year in a calendar year is
C                     covered by I/M.
C  INDVL2    Local    Flag determining whether a given vehicle class
C                     with a given model year in a calendar year is
C                     covered by ATP.
C  IP        Param    Pollutant type index (ascending model years).
C  IV        Param    Vehicle type index.
C  MY        Local    Model year.
C  MYDX      Param    Abolute model year index (1950=1).
C  REDATP    Block    Array which contains the pollutant reduction for
C                     each model year, calendar year and vehicle type
C                     due to ATP.
C  REDIM     Block    Array which contains the pollutant reductions
C                     for each model year, calendar year and vehicle
C                     type due to ATP.
C  TDUCT     Block    The emission factor after it has been multiplied
C                     by the fleet size and converted to units of tons.
C  TONRED    Block    Array which contains the pollutant reductions for
C                     each model year calendar year and vehicle type
C                     due to all control programs.
C  TONSAT    Block    Intermediate variable holding the pollutant
C                     reductions due to the ATP.
C  TONSDE    Local    Intermediate variable holding the pollutant
C                     redutions due to the deterence.
C  TONSIM    Local    Intermediate variable holding the pollutant
C                     reductions due to the I/M program.
C
C
      DIMENSION CRDTAT(3,2),CRDTIM(3,2)
C
      COMMON /COST01/ ATPFEE
      COMMON /COST14/ TONRED(25,2,10,4),COST(25,10,4)
      COMMON /COST16/ DATPFE,DIMFEE,DIMREP,DATPRE,AATPFE,AIMFEE
      COMMON /COST18/ AIMREP,AATPRE,CFACTR,CATPFE(25,10,4)
      COMMON /COST13/ CIMFEE(25,10,4),CIMREP(25,10,4)
      COMMON /COST21/ CATPRE(25,10,4),FULBEN(25,20,4)
      COMMON /COST46/ REDIM(25,2,10,4),REDATP(25,2,10,4)
      COMMON /COST17/ DETER(25,2,10,4),TDETER(25,2,10,4)
      COMMON /COST19/ ICOV1,ICOV2,INDVL1,INDVL2
      COMMON /COST20/ TDUCT(25,2,3,10,4),TEVAP(25,10,4)
C
      COMMON /COST50/ TRLOSS(25,4,3),TREVAP(25,4,3)
C     COMMON /COST50/ TRLOSS(25,4,3),TREVAP(25,4,3),TRSTLS(25,4,3)
C
```

```
      COMMON /ATPAR1/ LAPSY,LAP1ST,LAPLST,LVTFLG(4)
      COMMON /ATPAR2/ ATPPGM,ATPFQT,CRATP,DISTYP(8)
C
      DATA CRDTIM/.50,.25,.125, .50,.25,.125/
      DATA CRDTAT/.75,.50,.25,  .75,.50,.25 /
C
C     MY  = MYDX + 1950
      MY = MYDX + 1957
C     ICY = ICYDX + 1974
C
      TONSDE = 0.0
      TONSIM = 0.0
      TONSAT = 0.0
C
C     ..... Assign benefits for vehicle covered by a program.
C
      IF(INDVL1.EQ.2) TONSDE = TDUCT(IDX,IP,1,JCYDX,IV)
      IF(INDVL1.EQ.2) TONSIM = TDUCT(IDX,IP,2,JCYDX,IV)
      IF(INDVL2.EQ.2) TONSAT = TDUCT(IDX,IP,3,JCYDX,IV)
C
C
      IMYRDX = INDVL1 - 2
      IAYRDX = INDVL2 - 2
C
      IF(INDVL1.GE.3.AND.INDVL1.LT.6)
     *  TONSDE=TDUCT(IDX,IP,1,JCYDX,IV)*CRDTIM(IMYRDX,IP)
      IF(INDVL1.GE.3.AND.INDVL1.LT.6)
     *  TONSIM=TDUCT(IDX,IP,2,JCYDX,IV)*CRDTIM(IMYRDX,IP)
      IF(INDVL2.GE.3.AND.INDVL2.LT.6)
     *  TONSAT=TDUCT(IDX,IP,3,JCYDX,IV)*CRDTAT(IAYRDX,IP)
C
      IF(INDVL1.GE.3.AND.INDVL1.LT.6) THEN
        TEVAP(IDX,JCYDX,IV) = TEVAP(IDX,JCYDX,IV)*CRDTAT(IMYRDX,IP)
        TREVAP(IDX,JCYDX,IV) = TREVAP(IDX,JCYDX,IV)*CRDTAT(IMYRDX,IP)
        TRLOSS(IDX,JCYDX,IV) = TRLOSS(IDX,JCYDX,IV)*CRDTAT(IMYRDX,IP)
      ENDIF
      IF(INDVL1.EQ.1 .OR. INDVL1.GE.6) THEN
        TEVAP(IDX,JCYDX,IV) = 0.0
        IF(IV.LE.4) THEN
          DO 20 IMC=1,3
            TREVAP(IDX,IV,IMC) = 0.0
            TRLOSS(IDX,IV,IMC) = 0.0
20        CONTINUE
        ENDIF
      ENDIF
C
C     ..... Add IM tons to ATP tons to get total.
C
      TONRED(IDX,IP,JCYDX,IV)=TONSIM+TONSAT+TONSDE
      REDIM(IDX,IP,JCYDX,IV)=TONSIM
      REDATP(IDX,IP,JCYDX,IV)=TONSAT
      DETER(IDX,IP,JCYDX,IV)=TONSDE
C
      RETURN
C  End POLL
      END
```

```
      SUBROUTINE CMPREP(IV,ICY,MYDX,IDX,JDX,JCYDX)
C
C..CMPREP uses the differences in MOBILE4 I/M,ATP, and no
C..control program tampering rates and computes ATP
C..failure/replacements for five different tampering
C..situations.
C
C  Called by LOOP
C
C..Array Subscript
C
C..REPLCE(25,5,10,4)                - REPLCE(IDX,IT,JCYDX,IV)
C..TAMPER(25,6,4,10,4)              - TAMPER(MYDX,IT,3,ICYDX,IV)
C
C..Variable dictionary:
C
C.. Name   Source     Description
C   ----   ------     -----------------------------------------------
C
C   ICY    Local      Calendar year
C   ICYDX  Local      Calendar year index
C   ICYDX2 Local      Subsequent calendar year index ICYDX2 = ICYDX+1
C   IT     Local      Emission control tampering component index
C   IT2    Local      Tampering component index for DISTYP
C   DISTYP Block      Array of flags indicating which emission
C                     control components are to be inspected by the
C                     ATP
C   IV     Local      Vehicle class index
C   LAPSY  Block      ATP start year
C   MY     Local      Model year
C   MYDX   Local      Model year index
C   PBFAC  Local      Plumbtesmo efficiency factor
C   REFAIL Local      Percentage of vehicles which refail the
C                     tampering inspection the following year after
C                     being fixed the previous year
C   REPLCE Block      The difference in tampering rates as a result
C                     of a control program
C   STOAER Block      Condition determining if the Plumbtesmo
C                     efficiency is applied
C   TAMPER Block      The MOBILE4 tampering rates
C
      INTEGER DISTYP
      DIMENSION REFAIL(6)
C
      COMMON /COST01/ ATPFEE
      COMMON /COST04/ TAMPER(25,6,4,10,4)
      COMMON /COST05/ REPLCE(25,6,10,4)
      COMMON /COST06/ STOAER
      COMMON /COST40/ YEVTON(10),BEVTON,YEREF(10),BEREF
      COMMON /COST41/ YERLOS(10),BERLOS
      COMMON /ATPAR1/ LAPSY,LAP1ST,LAPLST,LVTFLG(4)
      COMMON /ATPAR2/ ATPPGM,ATPFQT,CRATP,DISTYP(8)
C
      DATA PBFAC  / 1.061 /
      DATA REFAIL / 0.05, 0.05, 0.10, 0.30, 0.30, 0.30 /
C
      JCYDX2 = JCYDX + 1
      IDX2   = IDX - 1
      MY = MYDX + 1957
C
      DO 30 IT=1,6
C
C  Compute initial year ATP
C  failure/replacement by substracting non-ATP (IM only)
C  from IM+ATP.
C
        IF(ICY .GT. LAPSY)  GOTO 10
C
C  NOTE: the tampering rate for the last model year in each
C  calendar year is always zero.
C
        REPLCE(IDX,IT,JCYDX,IV) = 0
        IF(IDX .EQ. 2) REPLCE(IDX,IT,JCYDX,IV) =
     *           (TAMPER(IDX,IT,3,JCYDX,IV)
     *         -  TAMPER(IDX,IT,4,JCYDX,IV))*ENFORC(CRATP,2)
        IF(IDX .GT. 2) REPLCE(IDX,IT,JCYDX,IV) =
     *           (TAMPER(IDX,IT,3,JCYDX,IV)
     *         -  TAMPER(IDX2,IT,4,JCYDX2,IV))*ENFORC(CRATP,2)
        GOTO 20
C
```

```
C  Calculate the number of replacements in subsequent years and
C  adjust replacements to account for enforcement problems.
C
   10   REPLCE(IDX,IT,JCYDX,IV) =
     *   TAMPER(IDX,IT,3,JCYDX,IV)*REFAIL(IT)*ENFORC(CRATP,2)
C
C  If a given emission control component is not inspected,
C  set the replacement rate to zero.
C
   20   IT2 = IT
        IF(IT .GT. 3) IT2 = IT + 2
        IF(DISTYP(IT2) .NE. 2) REPLCE(IDX,IT,JCYDX,IV) = 0.0
C
C  Replacement rates cannot be less than zero
C
        IF(REPLCE(IDX,IT,JCYDX,IV).LT.0.)
     *    REPLCE(IDX,IT,JCYDX,IV) = 0.0
C
C  30 CONTINUE
C
C  Adjust misfueling replacements to account for lead
C  deposit testing failures.
C
      IF(STOAER .LT. 1.0 .AND. IT .EQ. 3)
     *  REPLCE(IDX,3,JCYDX,IV)=REPLCE(IDX,3,JCYDX,IV)*PBFAC
C
   30 CONTINUE
C
   99 RETURN
C  End CMPREP
      END
```

```
      SUBROUTINE SMCOST(MYDX,ICYDX,IV,JDX,IDX)
C
C..Calculates and sums the I/M and ATP inspection and repair costs
C
C..Called by LOOP
C
C..Calls CAMIL
C
C..Array Subscripts
C
C..ATCOST(2,6)                - ATCOST(ITECH,ITAM5)
C..ATEQP(25,4,4)              - ATEQP(MYDX,ITAM4,IV)
C..CATPFE(25,10,4)            - CATPFE(MYDX,ICYDX,IV)
C..CATPRE(25,10,4)            - CATPRE(IDX,JCYDX,IV)
C..CIMFEE(25,10,4)            - CIMFEE(IDX,JCYDX,IV)
C..CIMREP(25,10,4)            - CIMREP(IDX,JCYDX,IV)
C..COST(25,10,4)              - COST(IDX,JCYDX,IV)
C..FAILRT(25,20,4)            - FAILRT(IDX,JCYDX,IV)
C..FEBNFT(25,20,4)            - FEBNFT(IDX,ICYDX,IV)
C..FULBEN(25,20,4)            - FULBEN(IDX,JCYDX,IV)
C..JULMYR(25,8)               - JULMYR(JDX,IV)
C..REPLCE(25,5,10,4)          - REPLCE(IDX,ITAM5,JCYDX,IV)
C..REPIM(3)                   - REPIM(ITECH)
C..VCNT(46,8)                 - VCNT(ICYDX,IV)
C
C..Variable Dictionary
C
C   Name     Source   Description
C   ----     ------   -----------------------------------------------
C   ACCMIL   Param    The average accumulated mileage in a one year
C                     period
C   ATCOST   Block    Cost of replacing emission control devices as a
C                     result of failing a tampering inspection.  The
C                     default assumptions are:  ATCOST(TECH,TYPE)
C                     TYPE = 1 : Air Pump System
C                          = 2 : Catalyst Removal
C                          = 3 : Misfueled Catalyst
C                          = 4 : Evaporative Control System
C                          = 5 : PCV System
C                          = 6 : Gas Cap
C                          = 7 : Purge Test
C                          = 8 : Pressure Test
C   ATEQP    Block    Array containing the fraction of each model year
C                     in each vehicle class equipped with each
C                     tampering component.
C   ATPFEE   Block    Anti-tampering inspection fee
C   CATPFE   Block    Array which holds and sums the ATP fees for each
C                     model year, calendar year and vehicle type
C   CATPRE   Block    Array which holds and sums the ATP repair costs
C                     for each model year, calendar year and vehicle
C                     type
C   CIMFEE   Block    Array which holds and sums the I/M fees for each
C                     model year, calendar year and vehicle type
C   CIMREP   Block    Array which holds and sums the I/M repair costs
C                     for each model year, calendar year and vehicle
C                     type
C   CNSPEC   Local    Variable which sums and holds the I/M and the
C                     ATP fees
C   COST     Block    Array which holds and sums the total cost for
C                     each model year, calendar year and vehicle type
C   CREPAT   Local    Holds the ATP repair cost
C   CREPIM   Local    Holds the I/M repair cost
C   CSTIM    Block    I/M inspection fee
C   FAIL     Block    Calculated I/M failure rate
C   FAIL2S   Local    Failure rate for 2speed test only
C   FEBNFT   Block    Final fuel economy benefit (before summing)
C   FULBEN   Block    Array which holds and sums the fuel economy
C                     benefit for each model year, calendar year and
C                     vehicle type
C   ICY      Local    Calendar year
C   ICYDX    Local    Calendar year index
C   INDVL1   Local    Variable indicating whether a given model year is
C                     covered by I/M
C   INDVL2   Local    Variable indicating whether a given model year is
C                     covered by ATP
C   ITAM4    Block    Emission control tampering component index
C   ITAM5    Block    Emission control tampering component index
C   ITECH    Block    Technology group  1 = old tech , 2 = new tech
C                      Old = myr 1951-1980 LDGV , myr 1951-1983 LDT's
C                      New = myr 1981+     LDGV , myr 1984+     LDT's
C   IV       Local    Vehicle class index
```

```
C    JDX      Local    Model year index (backwards 20 - 1)
C    JULMYR   Block    Fraction of vehicles in each model year from
C                      MOBILE4
C    MY       Local    Model year
C    MYDX     Local    Model year index
C    REPLCE   Block    The difference in tampering rates as a result of
C                      control programs.  See ATCOST above for elements
C    REPIM    Block    Array containing the I/M repair costs
C                       REPIM(1) = Old Tech  ;  REPIM(2) = New Tech
C                       REPIM(3) = IM240 ; REPIM(4) = NOx (IM240)
C    VCNT     Block    Array of the total number of vehicles in given
C                      calendar years
C
      REAL    JULMYR
      INTEGER BYEAR,ATPFLG,PROMPT,ATPFQT,DISTYP
C
      COMMON /COST01/ ATPFEE
      COMMON /COST03/ STRNGY,RMAXF,REPEAT,FFACT
      COMMON /COST05/ REPLCE(25,6,10,4)
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
      COMMON /COST08/ FAILRT(2,25,39,4)
      COMMON /COST09/ DRSTRN(5),ZMSTRN(5)
      COMMON /COST10/ FEBNFT(25,10,4),FECNMY(20,4)
      COMMON /COST12/ IMFXFG,IAFXFG,IMCSFG,IAFEFG,IALDV
      COMMON /COST13/ CIMFEE(25,10,4),CIMREP(25,10,4)
      COMMON /COST14/ TONRED(25,2,10,4),COST(25,10,4)
      COMMON /COST15/ TOTCST(2),TOTRED(2),TCOST
      COMMON /COST16/ DATPFE,DIMFEE,DIMREP,DATPRE,AATPFE,AIMFEE
      COMMON /COST18/ AIMREP,AATPRE,CFACTR,CATPFE(25,10,4)
      COMMON /COST19/ ICOV1,ICOV2,INDVL1,INDVL2
      COMMON /COST21/ CATPRE(25,10,4),FULBEN(25,20,4)
      COMMON /COST22/ ATCOST(2,8)
C     COMMON /COST23/ VCNT(46,8)
      COMMON /COST23/ VCNT(39,8),GSDSCT(8,10),HDDCUM(25,10)
      COMMON /COST24/ ATEQP(20,5,4)
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
C  add PPFAIL 6/19/91, and PPFEB,PPFIXR,APFBEN 7/11/91 ...
      COMMON /COST47/ PPFAIL(25,3,10,4),PPFIXR(25,10,4)
C  add Purge/Pressure inspection fees, 6/21/91 ...
      COMMON /COST48/ PRGFEE,PRSFEE,CEVFEE(25,10,4),TRNFEE
      COMMON /COST49/ PPFEB(25,10,4),APFBEN
C
      COMMON /ATPAR2/ ATPPGM,ATPFQT,CRATP,DISTYP(8)
      COMMON /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER(2),CRIM
      COMMON /IMPAR2/ ILDT(4),ITEST,NUDATA(2),NLIM,IMNAME(20,9)
      COMMON /IMPAR6/ IFREQ,INTYP
      COMMON /MYRSAV/ AMAR(25,8),JULMYR(25,8),NEWCUM
      COMMON /IM240P/ DSIZE(25,4),IM24YR,IPRGYR,IPRSYR
      COMMON /REGISF/ GSFVCT(8),USRGSF(25,2)
      COMMON /YEARS4/ IY1941,IY1960,IY2020
C
      MY = MYDX + 1957
C     ICY = ICYDX + 1974
      ICY = ICYDX + 1981
C
      CNSPEC = 0.0
      CREPIM = 0.0
      CREPAT = 0.0
C
C  to allow addition of Purge/Pressure inspection costs, 6/21/91...
C
      CATPRE(IDX,JCYDX,IV) = 0.0
      CEVFEE(IDX,JCYDX,IV) = 0.0
C
C     ..... Determine vehicle technology group.
C
      ITECH=1
      IF(IV.EQ.1.AND.MY.GE.1981) ITECH=2
      IF(IV.GT.1.AND.MY.GE.1984) ITECH=2
C
C     ..... Get average miles accumulated during the calendar
C           year, for the given model, and set I50K index.
C
      I50K=1
      CALL CALMIL(JDX,IV,ACCMIL,VMT)
      IF(ACCMIL.GT.50000.0) I50K=2
C
C     ..... Skip cost calculation if vehicle is not inspected.
C
      IF(INDVL1.NE.2 .AND. INDVL2.NE.2 .AND. MY.LT.JPRGYR .AND.
     *   MY.LT.JPRSYR) GOTO 30
```

```
      IF(INDVL1.NE.2.AND.INDVL2.NE.2) GOTO 5
C
C     ..... Inspection cost is the sum of the I/M fee plus the ATP
C           fee.
C
      FEE = CSTIM
C
C  TRNFEE is incremental transient inspection cost over purge
C  inspection cost, PRGFEE
C...
      IF(MY.GE.IM24YR) THEN
        FEE = FEE + TRNFEE
        IF(IM24YR.LT.JPRGYR .AND. MY.LT.JPRGYR) FEE = FEE + PRGFEE
      ENDIF
      IF(IFREQ.EQ.2) FEE=FEE/2.0
      IF(INDVL1.EQ.2)
     *  CIMFEE(IDX,JCYDX,IV) =
     *    VCNT(ICYDX,IV)*JULMYR(JDX,IV)*FEE
C
C     FEE=ATPFEE
C     IF(ATPFQT.EQ.2) FEE=FEE/2.0
      IF(INDVL2.EQ.2) THEN
        FEE = ATPFEE
        IF(ATPFQT.EQ.2) FEE = FEE/2.0
        CATPFE(IDX,JCYDX,IV) =
     *    VCNT(ICYDX,IV)*JULMYR(JDX,IV)*FEE
      ENDIF
C
C   Add Purge & Pressure Inspection cost calcs, 6/21/91 ...
C   using PRGFEE, PRSFEE, and CEVFEE
C
   5  IF(IV.LE.4 .AND. (MY.GE.JPRGYR .OR. MY.GE.JPRSYR)) THEN
C       IF(IV.LE.4) THEN
          IF(MY.GE.JPRGYR) THEN
            FEE = PRGFEE
            IF(IFREQ.EQ.2)  FEE = FEE/2.0
            CEVFEE(IDX,JCYDX,IV) = CEVFEE(IDX,JCYDX,IV) +
     *        VCNT(ICYDX,IV)*JULMYR(JDX,IV)*FEE
          ENDIF
          IF(MY.GE.JPRSYR) THEN
            FEE = PRSFEE
            IF(IFREQ.EQ.2) FEE = FEE/2.0
            CEVFEE(IDX,JCYDX,IV) = CEVFEE(IDX,JCYDX,IV) +
     *        VCNT(ICYDX,IV)*JULMYR(JDX,IV)*FEE
          ENDIF
C       ENDIF
      ENDIF
C     CNSPEC = CIMFEE(IDX,JCYDX,IV) + CATPFE(IDX,JCYDX,IV)
      CNSPEC = CIMFEE(IDX,JCYDX,IV) + CATPFE(IDX,JCYDX,IV)
     *  + CEVFEE(IDX,JCYDX,IV)
C
   8  IF(INDVL1.NE.2) GOTO 10
C
C     ..... IM repair cost.
C     For IM240 failures, use 2-spd repair cost for that fraction of
C     IM240 failures that would have failed the 2-speed test.
C
        IF(MY.GE.IM24YR) THEN
          FAIL2S = ZMSTRN(2)+(DRSTRN(2)*ACCMIL*0.0001)
          IF(FAIL2S.GT.RMAXF) FAIL2S = RMAXF
          IF(FAIL2S.LT.0.0) FAIL2S = 0.0
          IF(FAIL2S.LE.FAILRT(1,IDX,ICYDX,IV)) THEN
            CREPIM = FAIL2S*REPIM(2) +
     *        ((FAILRT(1,IDX,ICYDX,IV) - FAIL2S) * REPIM(3))
          ELSE
            CREPIM = FAIL2S*REPIM(2)
          ENDIF
C
C  Add NOx repair costs...
C
          CREPIM = CREPIM + FAILRT(2,IDX,ICYDX,IV)*REPIM(4)
C
        ELSE
          IF((MY.LE.1980) .OR. (MY.LE.1983 .AND. IV.GE.2))
     *      CREPIM=FAILRT(1,IDX,ICYDX,IV)*REPIM(1)
          IF((MY.GE.1984) .OR. (MY.GE.1981 .AND. IV.EQ.1))
     *      CREPIM=FAILRT(1,IDX,ICYDX,IV)*REPIM(2)
        ENDIF
C
      CREPIM = CREPIM*(CRIM/100) * VCNT(ICYDX,IV)*JULMYR(JDX,IV)
      CIMREP(IDX,JCYDX,IV) = CREPIM
```

```
C
   10 IF(INDVL2.NE.2) GOTO 21
C
C     ..... ATP repair cost.
C
      DO 20 ITAM5=1,6
        ITAM4=ITAM5
        IF(ITAM4.GT.2) ITAM4=ITAM4-1
C
        IDXP2 = MY - 1966
        IF(IDXP2.LE.0)  IDXP2=1
        IF(IDXP2.GE.20) IDXP2=20
          CREPAT = CREPAT+(ATEQP(IDXP2,ITAM4,IV)*
     *    REPLCE(IDX,ITAM5,JCYDX,IV)*ATCOST(ITECH,ITAM5)*
     *    (CRATP/100.))
C
   20 CONTINUE
C
   21 IF((MY.LT.JPRGYR .AND. MY.LT.JPRSYR).OR. IV.GT.4) GOTO 25
C
C     Fix Purge, Press repair costs including separate Prg+Prs cost
C     in new block PPFAIL, 6/21/91
C
      IF(MY.GE.JPRGYR) CREPAT = CREPAT+(PPFAIL(IDX,1,JCYDX,IV)*
     *  (ATCOST(ITECH,7))*(CRATP/100.))
      IF(MY.GE.JPRSYR) CREPAT = CREPAT+(PPFAIL(IDX,2,JCYDX,IV)*
     *  (ATCOST(ITECH,8))*(CRATP/100.))
C
   25 CREPAT = CREPAT*VCNT(ICYDX,IV)*JULMYR(JDX,IV)
      CATPRE(IDX,JCYDX,IV) = CREPAT
C
C  Sum inspection, I/M and ATP costs to get total.
C  Note: If fuel economy benefits are larger than the program
C        costs, then a negative cost is assumed for that model year.
C
   30 COST(IDX,JCYDX,IV) = CNSPEC + CREPIM + CREPAT
      IF(COST(IDX,JCYDX,IV).GT.0.0 .AND. INDVL1.EQ.2)
     *  COST(IDX,JCYDX,IV) =
     *  COST(IDX,JCYDX,IV) - ( FEBNFT(IDX,JCYDX,IV)*
     *  VCNT(ICYDX,IV)*JULMYR(JDX,IV) )
C
      IF(INDVL1.EQ.2)
     *  FULBEN(IDX,JCYDX,IV) = FEBNFT(IDX,JCYDX,IV)*
     *    VCNT(ICYDX,IV)*JULMYR(JDX,IV)
C
C  Add Purge/Press FE benefit summation...
C
      IF((MY.GE.JPRGYR .OR. MY.GE.JPRSYR) .AND. IV.LE.4) THEN
        PPFEB(IDX,JCYDX,IV) = PPFEB(IDX,JCYDX,IV)*
     *    VCNT(ICYDX,IV)*JULMYR(JDX,IV)
C
        IF(COST(IDX,JCYDX,IV).GT.0.0 .AND. INDVL1.EQ.2)
     *    COST(IDX,JCYDX,IV) =
     *    COST(IDX,JCYDX,IV) - PPFEB(IDX,JCYDX,IV)
      ENDIF
C
C
   99 RETURN
C  End SMCOST
      END
```

```
      SUBROUTINE SUMWDW
C
C..SUMWDW sums emission reductions and costs across model years
C..for each calendar year, and store in appropriate variable
C
C..Array Subscripts
C
C..ADAT(2)                    - ADAT(IP)
C..ADET(2)                    - ADET(IP)
C..ADIM(2)                    - ADIM(IP)
C..CATPFE(25,10,4)            - CATPFE(MYDX,JCYDX,IV)
C..CATPRE(25,10,4)            - CATPRE(MYDX,JCYDX,IV)
C..CIMFEE(25,10,4)            - CIMFEE(IDX,JCYDX,IV)
C..CIMREP(25,10,4)            - CIMREP(IDX,JCYDX,IV)
C..COST(25,10,4)              - COST(IDX,JCYDX,IV)
C..DETER(25,2,10,4)           - DETER(IDX,IP,JCYDX,IV)
C..FULBEN(25,20,4)            - FULBEN(MYDX,JCYDX,IV)
C..REDATP(25,2,10,4)          - REDATP(IDX,IP,JCYDX,IV)
C..REDIM(25,2,10,4)           - REDIM(IDX,IP,JCYDX,IV)
C..TBEN(2)                    - TBEN(IP)
C..TONRED(25,2,10,4)          - TONRED(MYDX,IP,JCYDX,IV)
C..YRBEN(10,2)                - YRBEN(JCYDX,IP)
C..YRCOST(10)                 - YRCOST(JCYDX)
C
C..Variable Dictionary
C
C   Name     Source   Description
C   ----     ------   -------------------------------------------------
C   AATPFE   Block    Final sum of the ATP inspection fees
C   AATPRE   Block    Final sum of the ATP repair costs
C   ADAT     Block    Array containing the final sum of the ATP
C                     benefits
C   ADET     Block    Array containing the final sum of the I/M
C                     deterence benefits
C   ADFBEN   Block    Contains the final sum of the fuel
C                     economy benefits
C   ADIM     Block    Array containing the final sum of the I/M benefit
C   AEVAP    Block    Final sum of the Evap+Runloss benefits in tons.
C   AIMFEE   Block    Final sum of the I/M inspection fees
C   AIMREP   Block    Final sum of the I/M repair costs
C   APFBEN   Block    Final sum of Purge/Pressure Fuel economy benefits
C   CATPFE   Block    Array which holds and sums the ATP fees for each
C                     model year, calendar year and vehicle type
C   CATPRE   Block    Array which holds and sums the ATP repair costs
C                     for each model year, calendar year and vehicle
C                     type
C   CIMFEE   Block    Array which holds and sums the I/M fees for each
C                     model year, calendar year and vehicle type
C   CIMREP   Block    Array which holds and sums the I/M repair costs
C                     for each model year, calendar year and vehicle
C                     type
C   COST     Block    Array which holds and sums the total cost for
C                     each model year, calendar year and vehicle type
C   DETER    Block    Array which contains the pollutant reductions for
C                     each model year, calendar year and vehicle type
C                     due to tamering deterence.
C   FULBEN   Block    Array which holds and sums the fuel economy
C                     benefit for each model year, calendar year and
C                     vehicle type
C   ICY      Local    Calendar year
C   JCYDX    Local    Calendar year index
C   IDX      Local    Model year index (forward 1 - 25)
C   IFEVYR   Block    First calendar year evaluated
C   IFICY    Local    Index of first calendar year evaluated
C   ILEVYR   Block    Last calendar year evaluated
C   ILICY    Local    Index of last calendar year evaluated
C   IP       Local    Pollutant index  (1 = HC ; 2 = CO)
C   IV       Local    Vehicle class index
C   JDX      Local    Model year index (backwards 20 - 1)
C   MY       Local    Model year
C   MYDX     Local    Model year index
C   NUMCY    Local    Number of calendar years which are being
C                     evaluated (number of scenario records - 1)
C   REDATP   Block    Array which holds and sums the ATP benefit for
C                     each model year, calendar year and vehicle type
C   REDIM    Block    Array which holds and sums the I/M benefit for
C                     each model year, calendar year and vehicle type
C   TBEN     Block    Array containing the final total benefit from
C                     I/M deterence, I/M and ATP
C   TCST     Block    Final total cost of all control programs
C   TONRED   Block    Array which passes the total benefit
```

```
C   YRBEN   Block    Array which contains the individual calendar
C                    year benefits
C   YRCOST  Block    Array which contains the individual calendar
C                    year costs
C
      REAL   JULMYR
C
      COMMON /COST02/ IFEVYR,ILEVYR
      COMMON /COST14/ TONRED(25,2,10,4),COST(25,10,4)
      COMMON /COST16/ DATPFE,DIMFEE,DIMREP,DATPRE,AATPFE,AIMFEE
      COMMON /COST17/ DETER(25,2,10,4),TDETER(25,2,10,4)
      COMMON /COST18/ AIMREP,AATPRE,CFACTR,CATPFE(25,10,4)
      COMMON /COST13/ CIMFEE(25,10,4),CIMREP(25,10,4)
      COMMON /COST21/ CATPRE(25,10,4),FULBEN(25,20,4)
      COMMON /COST20/ TDUCT(25,2,3,10,4),TEVAP(25,10,4)
      COMMON /COST27/ IGRFLG,IATPLP,IDIFF,OUTPRF
      COMMON /COST35/ TCST,TBEN(2),ADFBEN,ADIM(2),ADAT(2),ADET(2)
      COMMON /COST36/ YTONS(2,10),BTONS(2),BIDTON(2),AEVAP
      COMMON /COST37/ YRCOST(10),YRBEN(10,2),YCOUNT(39),ACOUNT
      COMMON /COST46/ REDIM(25,2,10,4),REDATP(25,2,10,4)
      COMMON /COST47/ PPFAIL(25,3,10,4),PPFIXR(25,10,4)
      COMMON /COST48/ PRGFEE,PRSFEE,CEVFEE(25,10,4),TRNFEE
      COMMON /COST49/ PPFEB(25,10,4),APFBEN
C
      COMMON /COST50/ TRLOSS(25,4,3),TREVAP(25,4,3)
C     COMMON /COST50/ TRLOSS(25,4,3),TREVAP(25,4,3),TRSTLS(25,4,3)
      COMMON /COST51/ ARLOSS,AREVAP,ARSTLS
C
C
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
C
      IFICY = IFEVYR - 1981
      ILICY = ILEVYR - 1981
C
C  Initialize summing variables
C
      TCST    = 0.0
      AIMFEE  = 0.0
      AIMREP  = 0.0
      AATPRE  = 0.0
      AATPFE  = 0.0
      ADFBEN  = 0.0
      APFBEN  = 0.0

      AEVAP   = 0.0
      ARLOSS  = 0.0
      AREVAP  = 0.0
C
      DO 10 IP = 1,2
        TBEN(IP) = 0.0
        ADIM(IP) = 0.0
        ADAT(IP) = 0.0
        ADET(IP) = 0.0
   10 CONTINUE
C
C     ..... Sum costs over vehicle type, model year and calendar year.
C
      DO 60 JCYDX=1,IDIFF
        YRCOST(JCYDX) = 0.0
        DO 12 IP = 1,2
          YRBEN(JCYDX,IP) = 0.0
   12   CONTINUE
        DO 50 IV=1,4
          ICYDX = (IFEVYR-1981) + JCYDX - 1
          ICY = 1981 + ICYDX
          DO 40 IDX = 1,MAXYRS
            JDX = MAXYRS + 1 - IDX
            MYDX = MAXYRS + ICYDX - JDX
            MY = MYDX + 1957
C
            TCST   = TCST   + COST(IDX,JCYDX,IV)
            AIMFEE = AIMFEE+CIMFEE(IDX,JCYDX,IV)+CEVFEE(IDX,JCYDX,IV)
            AIMREP = AIMREP + CIMREP(IDX,JCYDX,IV)
            AATPRE = AATPRE + CATPRE(IDX,JCYDX,IV)
            AATPFE = AATPFE + CATPFE(IDX,JCYDX,IV)
            ADFBEN = ADFBEN + FULBEN(IDX,JCYDX,IV)
            APFBEN = APFBEN + PPFEB(IDX,JCYDX,IV)
C
C  Sum cost over vehicle class and model year.
C  As of 10/7/91 this includes PP FE benefit
C
```

```
            YRCOST(JCYDX) = YRCOST(JCYDX) + COST(IDX,JCYDX,IV)
C
C  Sum benefits over vehicle class, model year and
C  calendar year for each pollutant.  Also sum over
C  vehicle class and model year only.
C
            DO 20 IP=1,2
              TBEN(IP) = TBEN(IP) + TONRED(IDX,IP,JCYDX,IV)
              ADIM(IP) = ADIM(IP) + REDIM(IDX,IP,JCYDX,IV)
              ADAT(IP) = ADAT(IP) + REDATP(IDX,IP,JCYDX,IV)
              ADET(IP) = ADET(IP) + DETER(IDX,IP,JCYDX,IV)
              YRBEN(JCYDX,IP) = YRBEN(JCYDX,IP)+TONRED(IDX,IP,JCYDX,IV)
   20       CONTINUE
C
C  Sum evaporative emission benefits
C
            AEVAP = AEVAP + TEVAP(IDX,JCYDX,IV)
C
            DO 15 IMC=1,3
              AREVAP = AREVAP + TREVAP(IDX,IV,IMC)
              ARLOSS = ARLOSS + TRLOSS(IDX,IV,IMC)
   15       CONTINUE
C
   40     CONTINUE
   50   CONTINUE
   60 CONTINUE
C
C  Compute annual averages changing to thousands of tons and
C  thousands of dollars.
C
      TBEN(1) = TBEN(1) * .001 / IDIFF
      TBEN(2) = TBEN(2) * .001 / IDIFF
      TCST    = TCST    * .001 / IDIFF
C
      AATPFE  = AATPFE * .001 / IDIFF
      AIMFEE  = AIMFEE * .001 / IDIFF
      AIMREP  = AIMREP * .001 / IDIFF
      AATPRE  = AATPRE * .001 / IDIFF
      ADFBEN  = ADFBEN * .001 / IDIFF
      APFBEN  = APFBEN * .001 / IDIFF
C
      AEVAP   = AEVAP   * .001 / IDIFF
      ADIM(1) = ADIM(1) * .001 / IDIFF
      ADIM(2) = ADIM(2) * .001 / IDIFF
      ADAT(1) = ADAT(1) * .001 / IDIFF
      ADAT(2) = ADAT(2) * .001 / IDIFF
      ADET(1) = ADET(1) * .001 / IDIFF
      ADET(2) = ADET(2) * .001 / IDIFF
C
      ARLOSS = ARLOSS * .001 / IDIFF
      AREVAP = AREVAP * .001 / IDIFF
C
      DO 30 JCYDX = 1,IDIFF
        YRCOST(JCYDX)  = YRCOST(JCYDX)  * .001
        YRBEN(JCYDX,1) = YRBEN(JCYDX,1) * .001
        YRBEN(JCYDX,2) = YRBEN(JCYDX,2) * .001
   30 CONTINUE
C
      RETURN
C  End SUMWDW
      END
```

```
      BLOCK DATA
C
      COMMON /COST09/ DRSTRN(5),ZMSTRN(5)
      COMMON /COST10/ FEBNFT(25,10,4),FECNMY(20,4)
      COMMON /COST11/ PCNTSV(4)
      COMMON /COST24/ ATEQP(20,5,4)
      COMMON /COST38/ STOCK(12,8),CLDIST(8)
C
C
C  ZMSTRN(ITEST,ICUT) is the zero-mile intercept used to calculate the
C  failure rates for 1981 and newer vehicles.  Idle, 2-Speed, Loaded,
C  IM240(.8/15),NOx(10% fail=1.69 MPFI & 2.50 TBI & 3.99 Carb)
C
      DATA ZMSTRN / 0.0,0.0,0.0252,0.0,0.032936/
C
C  DRSTRN(ITEST,ICUT) is the rate per 10k miles used to calculate the
C  failure rates for 1981 and newer vehicles.  Idle, 2-speed, Loaded,
C  IM240,NOx
C
C  Revise IM240 back to initial rate 11/18/91
C
      DATA DRSTRN / 0.01,0.01,0.01190,0.0373,0.0084805/
C
C  FECNMY is the miles-per-gallon average for each model year
C  by vehicle class.  (MY 1968 - 1987+)
C
      DATA FECNMY/
     1 13.9, 13.9, 13.2, 13.1, 12.9, 12.6, 13.9, 14.9, 15.6, 16.7,
     1 18.5, 19.6, 21.8, 23.3, 24.6, 26.0, 27.4, 28.8, 30.2, 31.6,
     2 10.6, 10.6, 10.4, 10.2,  9.9,  9.6, 12.0, 12.6, 13.8, 14.3,
     2 15.2, 16.3, 18.1, 18.4, 18.9, 19.5, 20.2, 21.1, 22.0, 22.9,
     3  7.9,  7.9,  7.7,  7.4,  7.0,  6.9,  8.8,  9.7,  9.4,  9.6,
     3  9.8, 11.5, 13.3, 13.8, 14.3, 14.9, 15.4, 16.0, 16.6, 17.2,
     4  7.9,  7.9,  7.7,  7.4,  7.0,  6.9,  8.8,  9.7,  9.4,  9.6,
     4  9.8, 11.5, 13.3, 13.8, 14.3, 14.9, 15.4, 16.0, 16.6, 17.2/
C
C  PCNTSV is the average fuel savings by technology group.
C   Pre-81 2spd/idle, 81+ 2spd/idle, 83+ IM240, Purge/Press Repair
C
      DATA PCNTSV/ 0.0, 0.080, 0.126, 0.059 /
C
C  ATEQP determines the fraction of each model year in each vehicle
C  class equipped with each tampering component.
C
C  ATEQP CODE:
C    1=air
C    2=cat
C    3=pcv
C    4=evap
C    5=gas cap
C
      DATA ATEQP/
C  LDGV
     1  .00, .05, .05, .05, .10, .30, .30, .45, .40, .30,
     1  .30, .30, .65, .85, .70, .60, .60, .40, .40, .30,
     2  .00, .00, .00, .00, .00, .00, .00, .80, .85, .85,
     2  .90, .90, .95,1.00,1.00,1.00,1.00,1.00,1.00,1.00,
     3  .00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,
     3 1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,
     4  .00, .00, .00, .00,1.00,1.00,1.00,1.00,1.00,1.00,
     4 1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,1.00,
     5   20*1.00,
C  LDGT1
     1  .00, .05, .05, .05, .10, .30, .30, .40, .40, .30,
     1  .30, .50, .50, .50, .50, .50, .50, .50, .50, .50,
     2  .00, .00, .00, .00, .00, .00, .00, .70, .80, .75,
     2  .75, .80, .80,1.00,1.00,1.00,1.00,1.00,1.00,1.00,
     3  .00, 19*1.00,
     4  .00, 19*1.00,  20*1.00,
C  LDGT2  IVTAM4=1     IVTAM4=2       IVTAM4=3        IVTAM4=4
     * 11*.00,9*.50, 11*.00,9*1.00, .00,19*1.00, 3*.00,8*.05,9*1.00,
     * 20*1.00,
C  HDGV   IVTAM4=1     IVTAM4=2       IVTAM4=3        IVTAM4=4
     * 11*.00,9*.50, 11*.00,9*1.00, .00,19*1.00, 3*.00,8*.05,9*1.00,
     * 20*1.00/
C
      END
```

```
      SUBROUTINE PRINT(ISIZE1,ISIZE2)
C
C..PRINT lists the overall emission benefits and costs for
C  the indicated calendar years combined. No discounting.
C
C..Called by MAIN
C
C..Calls PRNIM,PRNATP,PRNCST,PRNBEN
C
C..Array Subscripts
C
C..ADAT(2)                      - ADAT(IP)
C..ADET(2)                      - ADET(IP)
C..ADIM(2)                      - ADIM(IP)
C..BTONS(2)                     - BTONS(IP)
C..IVPRT(4)                     - IVPRT(NCOVER),IVPRT(I2ND)
C..KCOV(2,2)                    - KCOV(ICH,IAFXFG)
C..KCOVST(2,2)                  - KCOVST(ICH,IAFXFG)
C..KFREQ(2,2)                   - KFREQ(ICH,IFREQ)
C..KTYPE(4,2)                   - KTYPE(ICH,ATPPGM)
C..LVTFLG(4)                    - LVTFLG(IVTAM)
C..NOYES(2)                     - NOYES(IMTFLG)
C..TBEN(2)                      - TBEN(IP)
C..TTYPE(4,3)                   - TTYPE(ICH,ATPPGM)
C..VGRORT(8)                    - VGRORT(KI)
C..VNAME(4)                     - VNAME(IVPTR(NCOVER))
C..WAIVER(2)                    - WAIVER(ITECH)
C..YCOUNT(46)                   - YCOUNT(IY)
C..YRBEN(10,2)                  - YRBEN(IY,IP)
C..YRCOST(10)                   - YRCOST(IY)
C..YTONS(2,10)                  - YTONS(2,IY)
C
C..Variable dictionary
C
C   Name     Source   Description
C   ----     ------   -----------------------------------------------
C   AATPFE   Block    Final sum of the ATP inspection fees
C   AATPRE   Block    Final sum of the ATP repair costs
C   ACOUNT   Block    Total vehicle count over all scenario years
C   ADAT     Block    Array containing the final sum of the ATP
C                     benefits
C   ADET     Block    Array containing the final sum of the I/M
C                     deterence benefits
C   ADFBEN   Block    Contains the final sum of the fuel
C                     economy benefits
C   ADIM     Block    Array containing the final sum of the I/M benefit
C   AIMFEE   Block    Final sum of the I/M inspection fees
C   AIMREP   Block    Final sum of the I/M repair costs
C   ATPFEE   Block    Anti-tampering inspection fee
C   BTONS    Block    Array containing the number of tons of pollutant
C                     without a control program
C   BYEAR    Block    The fleet size base year
C   CLDIST   Block    Vehicle class registration distribution
C   COMMA    Local    Variable holding the character ','
C   CSTIM    Block    I/M inspection fee
C   CUTCO    Local    Variable holding character data pertaining to CO
C   CUTHC    Local    Variable holding character data pertaining to HC
C   GASCST   Block    The cost of one gallon of unleaded gasoline
C   GRORT    BLock    The vehicle fleet growth rate by vehicle class
C                     converted into percent for printing
C   IAFXFG   Block    Flag indicating whether ATP has fixed or floating
C                     model year coverage
C   IATPLP   Block    Flag indicating whether an ATP only scenario is
C                     to be run
C   ICH      Local    DO loop counter
C   ICO      Local    DO loop counter
C   ICUTS    Block    I/M cutpoint index from MOBILE4
C   ICYIM    Block    Tampering deterence start year
C   ICY2     Block    Calendar year
C   IFEVYR   Block    First calendar year evaluated
C   IFREQ    Block    Flag indicating whether the I/M program is
C                     annual or biennial
C   IFICY    Local    Index of first calendar year evaluated
C   ILEVYR   Block    Last calendar year evaluated
C   ILICY    Local    Index of last calendar year evaluated
C   IMFXFG   Block    Flag indicating whether the I/M program has a
C                     fixed or floating model year coverage
C   IMTFLG   Block    Mechanic Training flag
C   IOUREP   Block    Output Device number
C   ISIZE1   Block    Variable containing either the size of the
C                     floating model year window for I/M coverage or
```

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C                     the earliest model year inspected in an I/M
C                     program
C   ISIZE2  Block     Variable containing either the size of the
C                     floating model year window for I/M coverage or
C                     the earliest model year inspected in an I/M
C                     program
C   ISTRIN  Block     Number of input stringency groups
C   ISTRT   Block     I/M start year
C   IT      Local     DO loop counter calling subroutine ATPOUT
C   DISTYP  Block     Array of flags indicating which emission
C                     control components are to be inspected by the
C                     ATP
C   ITEST   Block     I/M test type from MOBILE4
C   INTYP   Block     I/M program type       1 = Centralized
C                                            2 = Decentralized
C   IVTAM   Local     DO loop index
C   ATPFQT   Block     Flag indicating whether ATP program is annual
C                     or biennial
C   KCOV    Local     Variable holding the character data :
C                      'floating' and 'fixed'
C   KCOVST  Local     Array holding a string of character data
C   KFREQ   Local     Array holding the character data :
C                      'annual' and 'biennial'
C   KII     Local     DO loop index
C   KTYPE   Local     Array holding the character data :
C                      'centralized' and 'decentralized'
C   LAPSY   Block     ATP start year
C   NCOVER  Local     Counter variable  1 - 4
C   NOYES   Block     Mechanic training program character string
C   PROJID  Block     Variable holding the project ID character
C                     string
C   TBEN    Block     Array containing the final total benefit from
C                     I/M deterence, I/M and ATP
C   TCOUNT  Block     Vehicle fleet size in base year
C   TCST    Block     Final total cost of all control programs
C   TTYPE   Local     Variable holding the character data 'idle'
C   VGRORT  Block     Array containing the growth rates for each
C                     vehicle class
C   VNAME   Local     Array holding character data
C   WAIVER  Block     Array containing the waiver rates for old
C                     and new technology vehicles
C   WAIV1   Local     Variable which contains the old tech waiver rate
C   WAIV2   Local     Variable which contains the new tech waiver rate
C   YCOUNT  Block     The fleet count in a particular calendar year.
C   YTONS   Block     Total benefits in each evaluted calendar year.
C   YRBEN   Block     Array which contains the individual calendar
C                     year benefits
C   YRCOST  Block     Array which contains the individual calendar
C                     year costs
C
C
      INTEGER ALHFLG,ATPFLG,TPDFLG,RLFLAG,OUTFMT
C
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
      COMMON /PROJEC/ PROJID(20)
C
C     DIMENSION IDATE(3),ITIME(3)
C
C     just use hh:mm:sec of time w/o hundreths of second
C
      CHARACTER*4 PROJID
      CHARACTER*8 CDATE,CTIME
C
      IREP = 8
C...
C  MTS date/time...
C
C     CALL ANSITM(ITIME)
C     WRITE(IREP,100) PROJID,IDATE(2),IDATE(3),IDATE(1),
C    *                ITIME(1),ITIME(2),ITIME(3)
C 100 FORMAT('1Cost Effect. Model (CEM4.1): ',20A4,
C     *        1X,'(',I2,'/',I2,'/',I4,') ',I2,':',I2,':',I2,/)
C
C  Lahey MSDOS date/time...
C
      CALL DATE(CDATE)
      CALL TIME(CTIME)
      WRITE(IREP,100) PROJID,CDATE,CTIME
  100 FORMAT('1Cost Effect. Model (CEM4.1): ',20A4,2(2X,A8) )
C
```

```
C  MacFortran date/time...
C
C     CALL DATE(IDATE(2),IDATE(3),IDATE(1))
C     CALL TIME(ISECS)
C     ITIME(1) = ISECS/3600
C     ISECS = ISECS - (ITIME(1)*3600)
C     ITIME(2) = ISECS/60
C     ITIME(3) = ISECS - ITIME(2)*60
C     WRITE(IREP,100) PROJID,IDATE(2),IDATE(3),IDATE(1),
C    *                          ITIME(1),ITIME(2),ITIME(3)
C 100 FORMAT('1Cost Effect. Model (CEM4.1): ',20A4,
C     *        1X,'(',I2,'/',I2,'/',I4,') ',I2,':',I2,':',I2,/)
C
C
      CALL PRNLAP(IREP)
C
      IF(JIM.EQ.2) CALL PRNIM(IREP,ISIZE1)
C
      IF(JATP.EQ.2) CALL PRNATP(IREP,ISIZE2)
C
      CALL PRNCST(IREP)
C
      CALL PRNBEN(IREP)
C
   99 RETURN
      END
```

```
      SUBROUTINE PRNIM(IREP,ISIZE1)
C
C..PRNIM lists the I/M program parameters
C
C..Called by PRINT
C
C..Array Subscripts
C
C..ILDT(4)                      - ILDT(IVTAM)
C..IMSTR(4,20)                  - IMSTR(IV,NMY)
C..IVPTR(4)                     - IVPTR(NCOVER),IVPTR(I2ND)
C..KCOV(2,2)                    - KCOV(ICH,IAFXFG)
C..KCOVST(2,2)                  - KCOVST(ICH,IAFXFG)
C..KFREQ(2,2)                   - KFREQ(ICH,IFREQ)
C..KTYPE(4,2)                   - KTYPE(ICH,ATPPGM)
C..NEWSTR(4,100)                - NEWSTR(IT,ISTRN)
C..TTYPE(4,3)                   - TTYPE(ICH,ITEST)
C..VNAME(4)                     - VNAME(IVPTR(NCOVER))
C..WAIVER(2)                    - WAIVER(ITECH)
C
C..Variable dictionary
C
C   Name     Source   Description
C   ----     ------   -----------------------------------------------
C   COMMA    Local    Variable holding the character ','
C   CRIM     Block    I/M program compliance rate
C   I        Local    DO loop counter
C   ICH      Local    DO loop counter
C   ICYIM    Block    Tampering deterence start year
C   IFREQ    Block    Flag indicating whether the I/M program is
C                     annual or biennial
C   IMFXFG   Block    Flag indicating whether the I/M program has a
C                     fixed or floating model year coverage
C   IMSTR    Local    Stringency by model year and vehicle type
C   INTYP    Block    I/M program type       1 = Centralized
C                                            2 = Decentralized
C   IREP     Local    Output device indicator
C   ISIZE1   Block    Variable containing either the size of the
C                     floating model year window for I/M coverage or
C                     the earliest model year inspected in an I/M
C                     program
C   ISTRIN   Block    Number of input stringency groups
C   ISTRT    Block    I/M start year
C   ITEST    Block    I/M test type from MOBILE4
C   IV       Local    Vehicle type           1 = LDGV
C                                            2 = LDGT1
C                                            3 = LDGT2
C                                            4 = HDGV
C   KCOV     Local    Variable holding the character data :
C                      'floating' and 'fixed'
C   KCOVST   Local    Array holding a string of character data
C   KFREQ    Local    Array holding the character data :
C                      'annual' and 'biennial'
C   KTYPE    Local    Array holding the character data :
C                      'centralized' and 'decentralized'
C   NEWSTR   Block    Contains stringency information
C                              1 : Contains vehicle class code
C                              2 : Contains first model year covered
C                              3 : Contains last model year covered
C                              4 : Contains stringency value
C   NCOVER   Local    Counter variable  1 - 4
C   TTYPE    Local    Variable holding the I/M test type character data
C   VNAME    Local    Array holding vehicle class character data
C   WAIVER   Block    Array containing the waiver rates for old
C                     and new technology vehicles
C   WAIV1    Local    Variable which contains the old tech waiver rate
C   WAIV2    Local    Variable which contains the new tech waiver rate
C
      CHARACTER*8 VNAME(4)
      CHARACTER*4 KTYPE(4,2),KCOV(2,2),KCOVST(8,2)
      CHARACTER*4 TTYPE(4,3),KFREQ(2,2)
      CHARACTER*4 NOYES,COMMA,PERIOD
      CHARACTER*1 COLON
C
      COMMON /COST12/ IMFXFG,IAFXFG,IMCSFG,IAFEFG,IALDV
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
      COMMON /IM240P/ DSIZE(25,4),IM24YR,IPRGYR,IPRSYR
      COMMON /IMPAR1/ ICYIM,ISTRIN,MODYR1,MODYR2,WAIVER(2),CRIM
      COMMON /IMPAR2/ ILDT(4),ITEST,NUDATA(2),NLIM,IMNAME(20,9)
      COMMON /IMPAR6/ IFREQ,INTYP
      COMMON /STRING/ NOYES(2),COMMA,PERIOD,COLON
```

```
C
      DIMENSION IVPTR(4)
      DIMENSION IMSTR(4,20)
C
      DATA KCOV /
     *  'Floa','ting',
     *  'Fixe','d   ' /
      DATA KCOVST /
     *  'Numb','er o','f mo','del ','year','s in',' win','dow:',
     *  'Olde','st m','odel',' yea','r co','vere','d:  ',',    ' /
      DATA KFREQ /
     * 'Annu','al  ',
     * 'Bien','nial' /
      DATA KTYPE /
     * 'Cent','rali','zed ',',    ',
     * 'Dece','ntra','lize','d   ' /
      DATA TTYPE/'Idle',',    ',',    ',',    ',
     2           '2500',' rpm',' / I','dle ',
     3           'Load','ed /',' Idl','e   '/
      DATA VNAME/'LDGV    ','LDGT1   ','LDGT2   ','HDGV    '/
C
C
      I1=MODYR1-1900
C     WRITE(IREP,100) ISTRT,(I,I=I1,83,1)
      WRITE(IREP,100) ISTRT,ISTRIN
  100 FORMAT('0',55X,'I/M Program Selected:'/
     *   130(' '),/,
     *   '    I/M start year (January 1):      ',I4,25X,
     *   'Stringency:',1X,I2 )
C
      I2=83-I1+1
      DO 20 IV=1,4
      DO 20 NMY=1,I2
        IMY=MODYR1+NMY-1
        IMSTR(IV,NMY)=0
        IF(IMY.GE.MODYR1.AND.IMY.LE.MODYR2)
     *    IMSTR(IV,NMY)=ISTRIN
   10   CONTINUE
   20 CONTINUE
      I3=80-I1+1
      WRITE(IREP,101) ICYIM
  101 FORMAT(' ',' Tampering deterrence start:      ',I4,30X)
C
      IF(IMFXFG.EQ.1) WRITE(IREP,102) (KCOVST(ICH,IMFXFG),ICH=1,8),
     *                ISIZE1,
     *                (KCOV(ICH,IMFXFG),ICH=1,2),
     *                (IMSTR(2,I),I=1,I2,1)
  102 FORMAT(4X,8A4,1X,I4,2X,2A4,20X,'LDGT1 ',16(I2,1X))
      IF(IMFXFG.EQ.2) WRITE(IREP,103) (KCOVST(ICH,IMFXFG),ICH=1,8),
     *                ISIZE1,MODYR2,
     *                (KCOV(ICH,IMFXFG),ICH=1,2)
C    *                (IMSTR(2,I),I=1,I2,1)
  103 FORMAT(4X,8A4,1X,I4,'-',I4,2X,2A4,15X)
C
C
      WRITE(IREP,104) (KFREQ(ICH,IFREQ),ICH=1,2)
C    *                (IMSTR(3,I),I=1,I2,1)
  104 FORMAT(' ',' I/M inspection frequency:        ',2A4,26X)
C    *          'LDGT2 ',16(I2,1X))
C
C
      WRITE(IREP,105) (KTYPE(ICH,INTYP),ICH=1,4)
  105 FORMAT(' ',' I/M program type:                ',4A4,8X)
C
C
      WRITE(IREP,106)(TTYPE(ICH,ITEST),ICH=1,4),IM24YR
  106 FORMAT(' ',' 1981 & later MYR test type:      ',4A4,
     * T75,'IM240 test model year coverage:     ',I4,'+')
C
C
      NCOVER=0
      DO 30 IV=1,4
        IF(ILDT(IV).EQ.1) GOTO 30
        NCOVER=NCOVER+1
        IVPTR(NCOVER)=IV
   30 CONTINUE
C
      IF(NCOVER.EQ.1) WRITE(IREP,107) VNAME(IVPTR(1)),JPRGYR
  107 FORMAT(' ',' Vehicle types covered:           ',A4,
     * T75,'Purge check model year coverage:    ',I4,'+')
      NCOMMA=NCOVER-1
```

```
      IF(NCOVER.EQ.2)
     *  WRITE(IREP,108)  VNAME(IVPTR(1)),COMMA,
     *                   VNAME(IVPTR(NCOVER)),JPRGYR
  108 FORMAT(' ','   Vehicle types covered:     ',7X,A4,A2,A5,
     * T75,'Purge check model year coverage:    ',I4,'+')
      IF(NCOVER.EQ.3)
     *  WRITE(IREP,109)  (VNAME(IVPTR(I)),COMMA,I=1,NCOMMA),
     *                   VNAME(IVPTR(NCOVER)),JPRGYR
  109 FORMAT(' ','   Vehicle types covered:     ',7X,A4,A2,A5,A2,A5,
     * T75,'Purge check model year coverage:    ',I4,'+')
      IF(NCOVER.EQ.4)
     *  WRITE(IREP,110)  (VNAME(IVPTR(I)),COMMA,I=1,NCOMMA),
     *                   VNAME(IVPTR(NCOVER)),JPRGYR
  110 FORMAT(' ','   Vehicle types covered:     ',7X,A4,A2,2(A5,A2),A5,
     * T75,'Purge check model year coverage:    ',I4,'+')
C
      WAIV1 = WAIVER(1) * 100.
      WAIV2 = WAIVER(2) * 100.
      WRITE(IREP,120) WAIV1,JPRSYR,WAIV2,CRIM
  120 FORMAT(  '    I/M waiver rate (pre-1981):       ',F5.1,'%',
     * T75,'Pressure check model year coverage: ',I4,'+',/,
     *         '    I/M waiver rate (post-1981):      ',F5.1,'%',/,
     *         '    I/M compliance rate:              ',F5.1,'%')
C
  999 RETURN
      END
```

```
      SUBROUTINE PRNATP(IREP,ISIZE2)
C
      INTEGER ATPPGM,ATPFQT,DISTYP
C
      CHARACTER*8 VNAME(4)
      CHARACTER*4 KTYPE(4,2),KCOV(2,2),KCOVST(8,2)
      CHARACTER*4 TINSP(3,8)
      CHARACTER*4 TTYPE(4,3),KFREQ(2,2)
      CHARACTER*4 NOYES,COMMA,PERIOD
      CHARACTER*1 COLON
C
      COMMON /COST12/ IMFXFG,IAFXFG,IMCSFG,IAFEFG,IALDV
      COMMON /ATPAR1/ LAPSY,LAP1ST,LAPLST,LVTFLG(4)
      COMMON /ATPAR2/ ATPPGM,ATPFQT,CRATP,DISTYP(8)
      COMMON /STRING/ NOYES(2),COMMA,PERIOD,COLON
C
      DIMENSION IVPTR(4),ITPTR(8)
C
      DATA KCOV /
     *  'Floa','ting',
     *  'Fixe','d   ' /
      DATA KCOVST /
     *  'Numb','er o','f mo','del ','year','s in',' win','dow:',
     *  'Olde','st m','odel',' yea','r co','vere','d:  ','    ' /
      DATA KFREQ /
     * 'Annu','al  ',
     * 'Bien','nial' /
      DATA KTYPE /
     * 'Cent','rali','zed ','    ',
     * 'Dece','ntra','lize','d   ' /
      DATA TINSP/'Air ','Pump','    ',
     *           'Cata','lyst','    ',
     *           'Fuel',' Inl','et  ',
     *           'Plum','btes','mo  ',
     *           'EGR ','Syst','em  ',
     *           'Evap',' Sys','tem ',
     *           'PCV ','Syst','em  ',
     *           'Gas ','Cap ','    '/
      DATA VNAME/'LDGV    ','LDGT1   ','LDGT2   ','HDGV    '/
C
C
      WRITE(IREP,101) LAPSY,CRATP
  101 FORMAT('0',50X,'Anti-Tampering Program Selected:',/,
     *  130('-'),/,
     *       '   ATP start year (January 1):      ',I4,25X,
     *       '   ATP compliance rate:               ',F5.1,'%')
C
C
      WRITE(IREP,102) (KFREQ(ICH,ATPFQT),ICH=1,2),
     *                (KTYPE(ICH,ATPPGM),ICH=1,4)
  102 FORMAT(' ',' ATP inspection frequency:        ',2A4,21X,
     *       ' ',' ATP program type:                  ',4A4)
C
C
      IF(IAFXFG.EQ.1) WRITE(IREP,103) (KCOVST(ICH,IAFXFG),ICH=1,8),
     *                                ISIZE2
  103 FORMAT(' ',' ',8A4,4X,I4,2X,2A4)
      IF(IAFXFG.EQ.2) WRITE(IREP,104) (KCOVST(ICH,IAFXFG),ICH=1,8),
     *                                ISIZE2,LAPLST,
     *                                (KCOV(ICH,IAFXFG),ICH=1,2)
  104 FORMAT(' ',' ',8A4,1X,I4,'-',I4,2X,2A4)
C
C
      NCOVER=0
      DO 10 IV=1,4
        IF(LVTFLG(IV).EQ.1) GOTO 10
        NCOVER=NCOVER+1
        IVPTR(NCOVER)=IV
   10 CONTINUE
C
      IF(NCOVER.EQ.1) WRITE(IREP,105) VNAME(IVPTR(1))
  105 FORMAT(' ',' Vehicle types covered:           ',A4,A4)
      NCOMMA=NCOVER-1
      IF(NCOVER.GT.1)
     *  WRITE(IREP,106) (VNAME(IVPTR(I)),COMMA,I=1,NCOMMA),
     *                  VNAME(IVPTR(NCOVER))
  106 FORMAT(' ',' Vehicle types covered:    ',7X,3(A5,A2),A5)
C
C
      NCOVER=0
```

```
      DO 20 IT=1,8
        IF(DISTYP(IT).EQ.1) GOTO 20
        NCOVER=NCOVER+1
        ITPTR(NCOVER)=IT
   20 CONTINUE
C
      IF(NCOVER.EQ.1) WRITE(IREP,107) (TINSP(J,ITPTR(1)),J=1,3)
  107 FORMAT(4X,'Parameters covered by ATP:',7X,3A4)
      NCOMMA=NCOVER-1
      IF(NCOVER.GT.1) WRITE(IREP,108)
     *                ((TINSP(J,ITPTR(I)),J=1,3),I=1,NCOMMA),
     *                 (TINSP(J,ITPTR(NCOVER)),J=1,3)
  108 FORMAT(4X,'Parameters covered by ATP:',7X,4(3A4,'/ '),/,
     *                                       37X,3(3A4,'/ '),3A4)
C
C
  999 RETURN
      END
```

```
      SUBROUTINE PRNCST(IREP)
C
      INTEGER BYEAR
      INTEGER PROMPT,TAMFLG,SPDFLG,VMFLAG
C
      COMMON /VMXCOM/ REGMIX(8),TFNORM(8),VMTMIX(8),VCOUNT(39,8)
C
      COMMON /COST01/ ATPFEE
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
      COMMON /COST22/ ATCOST(2,8)
      COMMON /COST27/ IGRFLG,IATPLP,IDIFF,OUTPRF
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
      COMMON /COST34/ TCOUNT,BYEAR,VGRORT
      COMMON /COST38/ STOCK(12,8),CLDIST(8)
      COMMON /FLAGS1/ PROMPT,TAMFLG,SPDFLG,VMFLAG,OXYFLG,DSFLAG
      COMMON /COST48/ PRGFEE,PRSFEE,CEVFEE(25,10,4),TRNFEE
C
      DIMENSION IVPTR(4),DIST(8)
C
      DO 10 I=1,8
        DIST(I) = REGMIX(I)*100.
   10 CONTINUE
C
      IF(JIM.EQ.2 .AND. JATP.EQ.2) THEN
C
      WRITE(IREP,101) CSTIM, (DIST(KJ),KJ=1,8),
     *                ATPFEE,VGRORT
  101 FORMAT(
     * '0',11X,'Cost Assumptions',31X,'Fleet Assumptions',5X,
     *       'LDGV  LDT1  LDT2  HDGV  LDDV  LDDT  HDDV   MC  ',/,
     *    43('_'),12X,75('_'),/,
     * '   I/M inspection cost: (per insp) $',F6.2,15X,
     *       '  Vehicle percentages: ',8(F5.1,1X),/
     * '   ATP inspection cost: (per insp) $',F6.2,15X,
     *       '  Growth rate:  ',F4.1,' % per year'
     *  )
C
      ELSE IF(JIM.EQ.1 .AND. JATP.EQ.2) THEN
C
C     WRITE(IREP,104) ATPFEE,(VGRORT(KI),KI=1,8),
C    *                (DIST(KJ),KJ=1,8)
      WRITE(IREP,104) ATPFEE,(DIST(KJ),KJ=1,8),VGRORT
  104 FORMAT(
     * '0',11X,'Cost Assumptions',31X,'Fleet Assumptions',5X,
     *       'LDGV  LDT1  LDT2  HDGV  LDDV  LDDT  HDDV   MC',/,
     *     43('_'),12X,75('_'),/,
     * '   ATP inspection cost: (per insp) $',F6.2,15X,
     *       '  Vehicle percentages: ',8(F5.1,1X),/,
     * '                                    ',6X,15X,
     *       '  Growth rate:  ',F4.1,' % per year' )
C
      ELSE IF(JIM.EQ.2 .AND. JATP.EQ.1) THEN
C
      WRITE(IREP,105) CSTIM,(DIST(KJ),KJ=1,8),VGRORT
  105 FORMAT(
     * '0',11X,'Cost Assumptions',31X,'Fleet Assumptions',5X,
     *       'LDGV  LDT1  LDT2  HDGV  LDDV  LDDT  HDDV   MC  ',/,
     *     43('_'),12X,75('_'),/,
     * '   I/M inspection cost: (per insp) $',F6.2,15X,
     *       '  Vehicle percentages: ',8(F5.1,1X),/,
     * '                                    ',6X,15X,
     *       '  Growth rate:  ',F4.1,' % per year' )
C
      ENDIF
C
      IF(JPRGYR.NE.2020 .OR. JPRSYR.NE.2020)
     *  WRITE(IREP,110) PRGFEE,PRSFEE,TRNFEE
  110 FORMAT('   Purge inspect cost (per insp) : $',F6.2,/,
     *       '   Pressure insp cost (per insp) : $',F6.2,/,
     *       '   IM240 insp incremnt over Purge: $',F6.2)
C
      IF(IATPLP.EQ.1) WRITE(IREP,102) GASCST,TCOUNT,BYEAR
  102 FORMAT(  '   Avg. Gasoline Cost(per gallon): $',F6.2,15X,
     *   '  Fleet size is ',F9.0,' vehicles in base year ',I4)
C
C
      IF(IATPLP.EQ.2) WRITE(IREP,103) TCOUNT,BYEAR
  103 FORMAT(57X,
     *   '  Fleet size is ',F9.0,' vehicles in base year ',I4)
C
C
```

```
      IF ( JIM.EQ.2 .OR. JATP.EQ.2 .OR. JPRGYR.LT.2020 .OR.
     *  JPRSYR.LT.2020 ) WRITE(IREP,106)
  106 FORMAT(
     *       '0',5X,'  Repair Costs',12X,'Pre-81',4X,'81+',/,
     *           46('_')
     *       )
C
C
      IF (JIM.EQ.2) WRITE(IREP,107)(REPIM(KI),KI=1,4)
  107 FORMAT('  Avg. I/M repair cost      : $ ',F4.0,4X,F4.0,
     *        '  ( IM240 repair = $ ',F4.0,' NOx repair= $',F4.0,' )'
     *      )
C
C
      IF (JATP.EQ.2) WRITE(IREP,108)((ATCOST(KI,KJ),KI=1,2),KJ=1,6)
  108 FORMAT(
     *       '  Air Pump repair cost      : $ ',F4.0,4X,F4.0,/,
     *       '  Catalyst replacement cost: $ ',F4.0,4X,F4.0,/,
     *       '  Misfueled catalyst cost   : $ ',F4.0,4X,F4.0,/,
     *       '  Evap. system repair cost  : $ ',F4.0,4X,F4.0,/,
     *       '  PCV system repair cost    : $ ',F4.0,4X,F4.0,/,
     *       '  Gas cap repair cost       : $ ',F4.0,4X,F4.0
     *       )
C
      IF (JPRGYR.LT.2020 .OR. JPRSYR.LT.2020)
     *   WRITE(IREP,109)((ATCOST(KI,KJ),KI=1,2),KJ=7,8)
  109 FORMAT(
     *       '  Purge repair cost         : $ ',F4.0,4X,F4.0,/,
     *       '  Pressure repair cost      : $ ',F4.0,4X,F4.0
C    *         '   ( Purge+Press repair = Purge repair )'
     *       )
C
C
  999 RETURN
      END
```

```
      SUBROUTINE PRNBEN(IREP)
C
      INTEGER BYEAR,ATPFLG,PROMPT,ATPFQT,ATPPGM,DISTYP
      REAL EVDOL,NETCST,NETBEN
C
      CHARACTER*8 VNAME(4)
      CHARACTER*4 KTYPE(4,2),KCOV(2,2),KCOVST(8,2)
      CHARACTER*4 TTYPE(4,3),KFREQ(2,2)
C
      COMMON /COST02/ IFEVYR,ILEVYR
      COMMON /COST16/ DATPFE,DIMFEE,DIMREP,DATPRE,AATPFE,AIMFEE
      COMMON /COST18/ AIMREP,AATPRE,CFACTR,CATPFE(25,10,4)
C.. Add resting losses to output, 8/9/91
      COMMON /COST26/ FRSTLS(25,8,4,10),YRSTLS(10),BRSTLS
      COMMON /COST27/ IGRFLG,IATPLP,IDIFF,OUTPRF
      COMMON /COST28/ JATP,JIM,ISTRT,JCYDX,JPRGYR,JPRSYR
      COMMON /COST35/ TCST,TBEN(2),ADFBEN,ADIM(2),ADAT(2),ADET(2)
C   Add AEVAP 6/3/91
      COMMON /COST36/ YTONS(2,10),BTONS(2),BIDTON(2),AEVAP
      COMMON /COST37/ YRCOST(10),YRBEN(10,2),YCOUNT(39),ACOUNT
      COMMON /COST40/ YEVTON(10),BEVTON,YEREF(10),BEREF
      COMMON /COST41/ YERLOS(10),BERLOS
      COMMON /COST49/ PPFEB(25,10,4),APFBEN
C
      COMMON /COST51/ ARLOSS,AREVAP,ARSTLS
C
C  Write heading
C
      WRITE(IREP,101) IFEVYR,ILEVYR
  101 FORMAT(' ',/,
     * 8X,'Benefits (1000 tons/yr) and Costs (1000 $/yr) ',
     * 'are averaged over the calendar years ',I4,' thru ',I4,'.',/,
     *    130('_') )
C
C       IFICY = IFEVYR - 1974
C       ILICY = ILEVYR - 1974
        IFICY = IFEVYR - 1981
        ILICY = ILEVYR - 1981
C       IDIFF = ILEVYR - IFEVYR + 1
C
C...Separate out exhaust HC from total voc
C
      BEXTON = BTONS(1)-BEVTON-BEREF-BERLOS-BRSTLS
C
C  Write more headings
C
      WRITE(IREP,103)
  103 FORMAT(
     * 35X,'Cal.',4X,' Program Benefits and Costs ',
     * 4X,'  Fleet  ',9X,'Emissions Without Program Elements ',/,
     *   43X,28('_'),17X,50('_'),/,
     * 35X,'Year',4X,'  VOC        CO        Cost   ',4X,'  Size   ',
     * 4X,' ExhVOC      CO     Evap HC   Refuel  RnLoss  RstLos ',/,
     *   35X,4('_'),4X,2(7('_'),2X),10('_'),4X,9('_'),
     * 2X,6(2X,7('_')) )
C
C  Write benefits for each calendar year
C
      IYY = IFICY - 1
      DO 10 IY = 1,IDIFF
        IYY = IYY + 1
        ICY2 = IY + IFEVYR - 1
        YEXTON = YTONS(1,IY)-YEVTON(IY)-YEREF(IY)-YERLOS(IY)-YRSTLS(IY)
        WRITE(IREP,104) ICY2,
     *    (YRBEN(IY,IP),IP=1,2),YRCOST(IY),YCOUNT(IYY),
C    *    (YTONS(IP,IY),IP=1,2),YEVTON(IY),YEREF(IY),YERLOS(IY),YRSTLS(IY)
     *    YEXTON,YTONS(2,IY),YEVTON(IY),YEREF(IY),YERLOS(IY),YRSTLS(IY)
  104   FORMAT(35X,I4,4X,
     *         F7.3,1X,F8.3,2X,F10.0,4X,F9.0,2X,
     *         2X,F7.3,1X,F8.3,4(2X,F7.3),1X )
   10 CONTINUE
C
C  Note:  AEVAP also includes any other evap & runloss benefits
C  such as tampering checks besides purge/pressure testing.
C
C  Local variables for ATP benefit w/o AEVAP, & TCST + evap MPG
C  First assume is ATP, & Purge/Press coverage is no earlier than ATP
C
      ATPBEN = ADAT(1) - AEVAP
      NETBEN = TBEN(1)
```

```
      IF(JATP.EQ.1) THEN
        ATPBEN = ADAT(1)
        NETBEN = TBEN(1) + AEVAP
      ENDIF
      NETCST = TCST - APFBEN
      EXHBEN = TBEN(1) - AEVAP
C
C  Write total benefit breakdown and total benefits
C
      WRITE(IREP,102) ATPBEN,ADAT(2),AATPFE,
     *                AEVAP,APFBEN,
     *                ADIM(1),ADIM(2),AIMFEE,
     *                AATPRE,AIMREP,ADFBEN,
     *                ADET(1),ADET(2),
     *                NETBEN,TBEN(2),TCST,ACOUNT,
     *                BEXTON,BTONS(2),BEVTON,BEREF,BERLOS,BRSTLS
  102 FORMAT(
     *   43X,2(7('_'),2X),10('_'),/,
     * ' Average Annual ATP Benefit/Fee',12X,2(F7.3,2X),F10.0,/,
     * ' Evap/RunLoss HC & MPG Benefit ',12X,F7.3,10X,'(',F10.0,')',/
     * ' Average Annual I/M Benefit/Fee',12X,F7.3,1X,F8.3,2X,F10.0,/,
     * ' Avg Ann. ATP + P/P Repair Cost',12X,18X,F10.0,/,
     * ' Average Annual I/M Repair Cost',12X,18X,F10.0,/,
     * ' Average Annual Fuel Savings   ',12X,17X,'(',F10.0,')',/,
     * ' Tampering Deterrence          ',12X,2(F7.3,2X),/,
     *     43X,2(7('_'),2X),10('_'),4X,9('_'),2X,6(2X,7('_')),/,
     * ' Evap    RnLoss   ExhHC',5X,'Annual Average ',
     * F7.3,1X,F8.3,2X,F10.0,4X,F9.0,2X,2X,F7.3,1X,F8.3,4(2X,F7.3)
     * )
C
C  Calculate and write total benefits in kilograms per day.
C
      KBENHC = ((TBEN(1)/.365)*2000.)/2.2046
      KBENCO = ((TBEN(2)/.365)*2000.)/2.2046
C
      WRITE(IREP,105) AREVAP,ARLOSS,EXHBEN,KBENHC,KBENCO,BTONS(1)
  105 FORMAT(3(F7.3,1X),17X,'( ',I7,I9,'  kilograms per day )',6X,
     *  '( ',F7.3,' Total VOC ) ')
C
  999 RETURN
      END
```

```
      SUBROUTINE EBSIZE(ID,OTR)
C
C
C     Calls Function OTCALC
C
C     The Evap, Gas Cap and Crankcase tampering rates are stored
C     in BSIZE.
C
C        NHG=13  -  Evap Canister
C        NHG=14  -  Crankcase
C        NHG=15  -  Gas Cap
C
      COMMON /LOOKUP/ IVTAM,IQG,IPG,JPGD,IHG,IGCSF
      COMMON /MYCODE/ MY,IDX,JDX,LDXSY,LMYRVT,IAY,IMDXSY,IMKINK
      COMMON /TAMEQ4/ BTR(9,2)
      COMMON /COST32/ BSIZE(4,25,2,6,17,2),TRAT(9)
C
C  For MOBILE4, crankcase (IH = 3) processing does not change.
C     PCV Case
C
      IF(ID.EQ.7) THEN
        BSIZE(IVTAM,JDX,1,1,14,1) = OTR
C
C     EVAP Canister & GAS Cap Cases
C
C     NOTE: OTCALC(i,j,k,l)
C
C        i  -  8 = EVAP + GAS Cap tampering rate
C              6 = EVAP only tampering rate
C        j  -  1 = A Vehicle's tampering rate previous to ATP start
C              2 = Previous + Subsequent (Overall) tampering rate
C        k  -  3 = ATP effectiveness code for GAS Cap
C              1 = ATP effectiveness code for EVAP
C        l  -  1 = Previous tampering effectiveness code
C              2 = Subsequent tampering effectiveness code
C
      ELSE IF(ID.EQ.8)  THEN
C
C        No ATP Case
C
        IF(LMYRVT.EQ.1) THEN
          BSIZE(IVTAM,JDX,1,1,13,1) = BTR(6,1)
          BSIZE(IVTAM,JDX,1,1,15,1) = BTR(8,1) - BTR(6,1)
C
C        ATP Starts before the vehicle is built
C
        ELSE IF(LMYRVT.EQ.2 .AND. LDXSY.GT.JDX) THEN
          BSIZE(IVTAM,JDX,1,1,13,1) = OTCALC(6,2,1,2)
          BSIZE(IVTAM,JDX,1,1,15,1) = OTCALC(8,2,3,2)-OTCALC(6,2,3,2)
C
C        ATP Starts after the vehicle is built
C
        ELSE IF(LMYRVT.EQ.2 .AND. LDXSY.LE.JDX) THEN
          BSIZE(IVTAM,JDX,1,1,13,1) = OTCALC(6,1,1,1) +
     *          (OTCALC(6,2,1,2) - OTCALC(6,1,1,2))
          BSIZE(IVTAM,JDX,1,1,15,1) = OTCALC(8,1,3,1)-OTCALC(6,1,3,1)+
     *         OTCALC(8,2,3,2) - OTCALC(8,1,3,2)
     *       - (OTCALC(6,2,3,2) - OTCALC(6,1,3,2))
        ENDIF
      ENDIF
C
      RETURN
      END
```

```
      SUBROUTINE PRNLAP(IREP)
C
C  PRNLAP writes scenario parameters
C
C  Called by PRINT.
C
C    common blocks:
C    /ALUHIN/ AC,XLOAD,TRAILR,ABSHUM,DB,WB
C    /CITRV1/ RVPICY
C    /FLAGS2/ IMFLAG,ALHFLG
C    /FLAGS3/ ATPFLG
C    /FLAGS4/ PRTFLG,IDLFLG,NMHFLG,HCFLAG
C    /MAXIMA/ MAXVEH
C    /REGION/ IREJN,ALT
C    /RESUL1/ EFFTP,EFEXH,EFEVAP,EFLOSS,EFRUNL
C    /RESUL2/ EFIDLE
C    /RESUL3/ VFTP,VEXH,VEVAP,VLOSS,VRUNLS,VIDLE
C    /SCENE1/ SPD,PCCN,PCHC,PCCC
C    /STRING/ NOYES,COMMA,PERIOD
C    /TEMPS/  TEMEVP,TEMEXH
C    /USDATA/ USNAME,NUSD,IUSD
C    /VMXCOM/ VMTMIX
C
C  Local array subscripts:
C
C  NAMEVP(4)   -  NAMEVP ( IEVP )
C  NAMNMH(2)   -  NAMNMH ( NMHFLG )
C  NAMPOL(3)   -  NAMPOL ( IP )
C  NAMREG(3)   -  NAMREG ( IREJN )
C  NAMVEH(10)  -  NAMVEH ( IVF3 )
C
C  Local variable / array dictionary:
C
C   Name    Type              Description
C  ------   ----  ------------------------------------------------------
C  IP1       I    see parameter dictionary
C  IP2       I    see parameter dictionary
C  NAMNMH    C*8  prefix indicating type of HC (total vs non-methane)
C  NAMPOL    C*4  pollutant names
C  NAMREG    C*4  region names
C  NAMVEH    C*8  vehicle class names
C  NWITHC    I    number of substrings to be written with a comma appended
C  USC8      C*8  8 character underscore
C
      INTEGER ALHFLG
      INTEGER ATPFLG,TPDFLG,RLFLAG,TEMFLG,OUTFMT
      INTEGER PRTFLG,HCFLAG
      CHARACTER*8 USNAME
      CHARACTER*4 NOYES,COMMA,PERIOD
      CHARACTER*1 COLON
      CHARACTER*1 ASTMCL,ACLASS
      CHARACTER*4 SCNAME
C
      COMMON /ALUHIN/ AC,XLOAD(3),TRAILR(3),ABSHUM,DB,WB
      COMMON /CITPAR/ SCNAME(4)
      COMMON /CITRV1/ RVPBAS,RVPIUS,RVPICY,IUSESY,RVPUWX
      COMMON /FLAGS2/ MYMRFG,NEWFLG,IMFLAG,ALHFLG
      COMMON /FLAGS3/ ATPFLG,TPDFLG,RLFLAG,LOCFLG,TEMFLG,OUTFMT
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
      COMMON /REGION/ FEET(2),IREJN,ALT,INITPR
      COMMON /SCENE1/ SPD(8),PCCN,PCHC,PCCC
      COMMON /STRING/ NOYES(2),COMMA,PERIOD,COLON
      COMMON /TEMPS/  AMBT,TEMMIN,TEMMAX,TEMEXH(3),TEMEVP(6)
      COMMON /USDATA/ USNAME(4,4),NUSD,IUSD(4)
C
      CHARACTER*9 NAMVEH(8),NAMNMH(2),USC8,NAMEVP(4)
C
      CHARACTER*4 NAMREG(3),NAMPOL(3)
C
      DATA NAMVEH/
     *    '    LDGV',
     *    '   LDGT1',
     *    '   LDGT2',
     *    '    HDGV',
     *    '    LDDV',
     *    '    LDDT',
     *    '    HDDV',
     *    '     MC ' /
C
      DATA NAMREG/'Low ','High','Mid '/
C
```

```
      DATA USC8/'  _____'/
C
      DATA NAMPOL/' HC:',' CO:','NOX:'/
C
      DATA NAMNMH/'Total   ','Non-Meth'/
C
      DATA NAMEVP/'Hot Soak ','Diurnal  ','Multiple ','Crankcase'/
C
      WRITE(IREP,100)
  100 FORMAT(51X,'Local Parameters Selected: ',/,130('_') )
C
      IF(NUSD.EQ.0) GOTO 10
      IF(NUSD.EQ.1) WRITE(IREP,200)(USNAME(ICH,IUSD(1)),ICH=1,4),
     *                               PERIOD
      NWITHC=NUSD-1
      IF(NWITHC.GT.0) WRITE(IREP,200)
     *  ((USNAME(ICH,IUSD(ICT)),ICH=1,4),COMMA,ICT=1,NWITHC),
     *  (USNAME(ICH,IUSD(NUSD)),ICH=1,4),PERIOD
  200 FORMAT(' ','User supplied',4A8,T46,A1,4A8,T78,A1,4A8,T110,A1/
     *       ' ',T15,4A8,T46,A1,/)
C
   10 WRITE(IREP,215) SCNAME,TEMEXH,NAMREG(IREJN)
  215 FORMAT(
     *    T3,4A4,
     *    T38,'Ambient Temp:',F5.1,2(' /',F5.1),' (F)',
     *    T85,'Region: ',A4)
C
      WRITE(IREP,220) PCCN,PCHC,PCCC,ALT
  220 FORMAT(
     *    T36,'Operating Mode:',F5.1,2(' /',F5.1),
     *    T83,'Altitude:',F6.0,' Ft.')
C
      WRITE(IREP,300)
     *  RVPBAS,TEMMIN,RVPIUS,IUSESY,TEMMAX
  300 FORMAT('0',
     *           T5, '   Base RVP: ',F4.1,
     *           T79,'Minimum Temp: ',F4.0,' (F)',/,
     *           T5 ,' In-use RVP: ',F4.1,
     *           T35,'In-use Start Yr: ',I4,
     *           T79,'Maximum Temp: ',F4.0,' (F)')
C
      IF(ALHFLG.GT.1) WRITE(IREP,225)
     *   ABSHUM,
     *   AC,DB,WB
  225 FORMAT(
     *' ',T19,'Absolute Humidity:',F6.2,
     *    T48,'AC (DB / WB):',F5.1,' (',F5.1,' /',F5.1,')')
C
      WRITE(IREP,230)
     *   NAMVEH,(USC8,ITER=1,8),
     *   SPD
  230 FORMAT(
     *'0',' Vehicle Type:',7X,8(2X,A8),/,
     *    '              ',8X,8(2X,A8),/,
     *' ',' Veh. Speeds:',7X,8F10.1)
C
      IF(ALHFLG.GT.1) WRITE(IREP,235)
     *   XLOAD,
     *   TRAILR
  235 FORMAT(
     *' ',' Extra Load:',F11.3,2F10.3/
     *' ','Trlr in Tow:',F11.3,2F10.3)
C
      RETURN
      END
```

```
      SUBROUTINE GETCEI
C
C  GETCEI reads in the Cost Effective Inputs particular
C  to the Cost Effective model CEM4.1.
C
C  Called by MAIN.
C
C  Calls YRTEST.
C
C  Input on call:
C
C
C  Output on return:
C
C    common blocks:
C
C     /COST01/ ATPFEE
C     /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
C     /COST12/ IMFXFG,IAFXFG,IMCSFG,IAFEFG,IALDV
C     /COST22/ ATCOST(2,8)
C     /COST27/ IGRFLG,IATPLP,IDIFF,OUTPRF
C     /COST34/ TCOUNT,BYEAR,VGRORT,NCOUNT
C     /COST38/ STOCK(12,8),CLDIST(8)
C     /COST48/ PRGFEE,PRSFEE,CEVFEE(25,10,4),TRNFEE
C     /YEARS4/ IY1941,IY1960,IY2020
C
C  Notes:
C
C  GETCEI was added for CEM4.1 VERSION 2
C
C
      INTEGER BYEAR,OUTPRF
C
      COMMON /COST01/ ATPFEE
      COMMON /COST07/ CSTIM,GASCST,IMSTRT,ISCEN,MOVIM,MOVATP,REPIM(4)
      COMMON /COST12/ IMFXFG,IAFXFG,IMCSFG,IAFEFG,IALDV
      COMMON /COST22/ ATCOST(2,8)
      COMMON /COST27/ IGRFLG,IATPLP,IDIFF,OUTPRF
      COMMON /COST34/ TCOUNT,BYEAR,VGRORT
      COMMON /COST48/ PRGFEE,PRSFEE,CEVFEE(25,10,4),TRNFEE
      COMMON /YEARS4/ IY1941,IY1960,IY2020
C
C
      READ(7,*)
      READ(7,700) IMFXFG,MOVIM,IMSTRT,IMCSFG,IDIFF,OUTPRF
      IDIFF = 1
      IF(OUTPRF.LT.1.OR.OUTPRF.GT.5) OUTPRF = 3
      IF(IMCSFG.EQ.2) THEN
        READ(7,701) CSTIM,REPIM(1),REPIM(2),GASCST,REPIM(3),PRSFEE,
     *              PRGFEE,TRNFEE,REPIM(4)
      ENDIF
C
      READ(7,702) IAFXFG,MOVATP,IAFEFG
      IF(IAFEFG.EQ.2) THEN
        READ(7,703) ATPFEE,((ATCOST(I,J),I=1,2),J=1,8)
      ENDIF
C
      READ(7,704) IGRFLG
      IF(IGRFLG.EQ.2) THEN
        READ(7,705) VGRORT
        READ(7,707) TCOUNT,BYEAR
      ENDIF
C
  700 FORMAT(I1,2(1X,I2),3(1X,I1))
  701 FORMAT(F5.2,2(1X,F6.2),1X,F4.2,1X,F6.2,3(1X,F5.2),1X,F6.2)
  702 FORMAT(I1,1X,I2,1X,I1)
  703 FORMAT(F5.2,1X,16(F4.0,1X))
  704 FORMAT(I1)
  705 FORMAT(F4.1)
  706 FORMAT(8(F5.3,1X))
  707 FORMAT(F9.0,1X,I4)
C
C  Call YRTEST and change 2 digit years to 4 digit
C
      CALL YRTEST(IMSTRT,32,IY1960,IY2020,INERR)
C
      RETURN
C
      END
```

# APPENDIX B

## TECH4 MODEL VERSION 4.1 SOURCE CODE LISTING

# Appendix B : Tech 4.1 Model Source Code

```
CC
CC..MOBILE4.1 I/M Credit Model for 1981 and newer LDGV
CC          With Oxygenated Fuel Effects
CC                 (May 14, 1991)
CC               With Bag Fractions
CC                  (July 1991)
CC          With Calculated Repair Effects
CC                 (July 20, 1991)
CC
CC..Program Main
CC
CC..COMMON Blocks and DIMENSION Statements
CC
      COMMON /DAT01/ MYR,ISTD,ITECH,IBAG,IP,IAGE,ICUT,ITST
      COMMON /DAT02/ AMIL(25),ODOM(25),TMILE(25),WGT(25)
      COMMON /DAT03/ ENOX(4,2,2)
      COMMON /DAT04/ FAIL(25,4,2)
      COMMON /DAT05/ OXYE(2,3,4,3),OXYCON
      COMMON /DAT06/ FRAC(4,12)
      COMMON /DAT07/ ES0(2,4,4,2),EH0(2,4,4,2)
      COMMON /DAT08/ DN(3,4,4,2)
      COMMON /DAT09/ ZMIL(2,4,4,2),CWO(2,4,25,4,2),CIMW(2,4,25,4,2,3)
      COMMON /DAT10/ EWO(3,4,25,12),EIMW(2,4,25,12,3),EZM(2,4,12)
      COMMON /DAT11/ CREDIT(2,25,12,3,4)
      COMMON /DAT12/ ZML(3,4,12),ZML1(3,4,12),ZML2(3,4,12)
      COMMON /DAT13/ BFZML1(3,4,12),BFDET1(3,4,12)
      COMMON /DAT14/ DET(3,4,12),DET1(3,4,12),DET2(3,4,12)
      COMMON /DAT15/ CWOA(2,25,4,2),EWOA(3,25,12),EZMA(2,12)
      COMMON /DAT16/ XSIDR(2,4,2,3),XHIDR(2,4,2,3)
      COMMON /DAT17/ RSUP(2,4,2,3),RHIG(2,4,2,3)
      COMMON /DAT18/ SIZE(25,4,2,4)
      COMMON /DAT19/ GV(4,2),GH(4,2),GS(4,2),BH(4,2),BV(4,2)
      COMMON /DAT20/ EM0(2,4,4,2),EN0(3,4,4,2)
      COMMON /DAT21/ BFDET2(3,4,12),BFZML2(3,4,12)
      COMMON /DAT22/ RMAR(2,4,2,3),RNOR(2,4,2,3)
      COMMON /DAT24/ XMIDR(2,4,2,3),XNIDR(2,4,2,3)
      COMMON /DAT25/ EXPO(2,4,3,2),DOTS(4,2,4,2,2)
CC
C     OPEN(1,FILE='M5SIZE')
C     OPEN(2,FILE='M5TEST')
C     OPEN(3,FILE='M5MYR')
C     OPEN(4,FILE='M5REG')
      OPEN(13,FILE='T5V7OXY.CSV')
      OPEN(14,FILE='AAAAA')
CC
CC
CC..Calculate the mileage accumulated in each one year interval.
CC
      AMIL(1) = ODOM(1)
CC
      DO 10 IAGE=2,25
        AMIL(IAGE) = ODOM(IAGE) - ODOM(IAGE-1)
   10 CONTINUE
CC
CC..Model Year Grouping
CC..ISTD = 1 : 1981,1982 Model Years
CC..ISTD = 2 : 1983 and newer Model Years
CC
      DO 600 ISTD=1,2
CC
```

Appendix B : Tech 4.1 Model Source Code

```
CC..ITECH indicates the technology type used in the vehicles.
CC
CC..ITECH = 1 : Closed-Loop, Multi-Point Fuel Injected
CC..ITECH = 2 : Closed-Loop, Throttle-Body Fuel-Injected
CC..ITECH = 3 : Closed-Loop, Carbureted
CC..ITECH = 4 : Open-Loop, Any Carbureted or Fuel Injected
CC
      DO 600 ITECH=1,4
CC
CC..Vehicle age in years
CC
      DO 600 IAGE=1,25
CC
      CALL EGROUP
CC
CC..FTP Bag ( 1=FTP; 2=BAG1; 3=BAG2; 4=BAG3 )
CC
      DO 600 IBAG=1,4
CC
CC..Pollutant ( 1:HC, 2:CO )
CC
      DO 600 IP=1,2
CC
      CALL EMIT
      CALL IMEMIT
CC
  600 CONTINUE
CC
      CALL MYRSUB
      CALL REGR
      CALL JAN1
CC
      OPEN(7,FILE='T5V7EF.DAT')
      OPEN(8,FILE='T5V7ANN.IMC')
      OPEN(9,FILE='T5V7BI.IMC')
      OPEN(10,FILE='T5V7BF.DAT')
CC
      CALL OUTPUT
CC
C     CLOSE(1)
C     CLOSE(2)
C     CLOSE(3)
C     CLOSE(4)
      CLOSE(7)
      CLOSE(8)
      CLOSE(9)
C     CLOSE(10)
      CLOSE(13)
      CLOSE(14)
CC
      STOP
      END
```

Appendix B : Tech 4.1 Model Source Code

```
      SUBROUTINE EGROUP
CC
CC..This routine predicts the number of vehicles in each emission
CC..level category by technology and age.
CC
      COMMON /DAT01/ MYR,ISTD,ITECH,IBAG,IP,IAGE,ICUT,ITST
      COMMON /DAT02/ AMIL(25),ODOM(25),TMILE(25),WGT(25)
      COMMON /DAT04/ FAIL(25,4,2)
      COMMON /DAT18/ SIZE(25,4,2,4)
      COMMON /DAT19/ GV(4,2),GH(4,2),GS(4,2),BH(4,2),BV(4,2)
CC
CC..Calculate the number of "HIGH" emitting vehicles
CC
      SIZE(IAGE,ITECH,ISTD,2) = GH(ITECH,ISTD) * ODOM(IAGE)
CC
CC.."BH" is the change in the rate of occurrance of "HIGH"
CC..emitting vehicles assumed to occur at 50,000 miles.
CC
      IF(IAGE.GT.1 .AND. ODOM(IAGE-1).GT.5.0)
     * SIZE(IAGE,ITECH,ISTD,2) = SIZE(IAGE-1,ITECH,ISTD,2)
     *                  + BH(ITECH,ISTD)*GH(ITECH,ISTD)*AMIL(IAGE)
      IF(SIZE(IAGE,ITECH,ISTD,2).GT.1.00) SIZE(IAGE,ITECH,ISTD,2) = 1.00
      IF(SIZE(IAGE,ITECH,ISTD,2).LT.0.00) SIZE(IAGE,ITECH,ISTD,2) = 0.00
CC
CC..Calculate the number of "VERY HIGH" emitting vehicles
CC
      SIZE(IAGE,ITECH,ISTD,3) = GV(ITECH,ISTD) * ODOM(IAGE)
CC
CC.."BV" is the change in the rate of occurrance of "VERY HIGH"
CC..emitting vehicles assumed to occur at 50,000 miles.
CC
      IF(IAGE.GT.1 .AND. ODOM(IAGE-1).GT.5.0)
     * SIZE(IAGE,ITECH,ISTD,3) = SIZE(IAGE-1,ITECH,ISTD,3)
     *                  + BV(ITECH,ISTD)*GV(ITECH,ISTD)*AMIL(IAGE)
      IF(SIZE(IAGE,ITECH,ISTD,3).GT.1.00) SIZE(IAGE,ITECH,ISTD,3) = 1.00
      IF(SIZE(IAGE,ITECH,ISTD,3).LT.0.00) SIZE(IAGE,ITECH,ISTD,3) = 0.00
CC
CC..Calculates the number of "SUPER" emitting vehicles
CC
      SIZE(IAGE,ITECH,ISTD,4) = GS(ITECH,ISTD) * ODOM(IAGE)
      IF(SIZE(IAGE,ITECH,ISTD,4).GT.1.00) SIZE(IAGE,ITECH,ISTD,4) = 1.00
      IF(SIZE(IAGE,ITECH,ISTD,4).LT.0.00) SIZE(IAGE,ITECH,ISTD,4) = 0.00
CC
CC..Check for logical sizes
CC
      CHECK = SIZE(IAGE,ITECH,ISTD,3)
     *      + SIZE(IAGE,ITECH,ISTD,4)
      IF(CHECK.GT.1.0)
     *    SIZE(IAGE,ITECH,ISTD,3) = 1.0 - SIZE(IAGE,ITECH,ISTD,4)
CC
      CHECK = SIZE(IAGE,ITECH,ISTD,2)
     *      + SIZE(IAGE,ITECH,ISTD,3)
     *      + SIZE(IAGE,ITECH,ISTD,4)
      IF(CHECK.GT.1.0)
     *    SIZE(IAGE,ITECH,ISTD,2) = 1.0 - SIZE(IAGE,ITECH,ISTD,3)
     *                                  - SIZE(IAGE,ITECH,ISTD,4)
CC
CC..Calculate the number of "NORMAL" emitting vehicles
CC
      SIZE(IAGE,ITECH,ISTD,1) = 1.0
```

```
     *                          - SIZE(IAGE,ITECH,ISTD,2)
     *                          - SIZE(IAGE,ITECH,ISTD,3)
     *                          - SIZE(IAGE,ITECH,ISTD,4)
C      WRITE(1,701) IAGE,ITECH,ISTD,(SIZE(IAGE,ITECH,ISTD,J),J=1,4)
C 701 FORMAT(3I3,4F8.4)
CC
  999 RETURN
      END
```

Appendix B : Tech 4.1 Model Source Code

```
      SUBROUTINE EMIT
CC
CC..This routine combines the emission levels of each emission
CC..category based on the predicted category size.
CC
      COMMON /DAT01/ MYR,ISTD,ITECH,IBAG,IP,IAGE,ICUT,ITST
      COMMON /DAT02/ AMIL(25),ODOM(25),TMILE(25),WGT(25)
      COMMON /DAT07/ ES0(2,4,4,2),EH0(2,4,4,2)
      COMMON /DAT08/ DN(3,4,4,2)
      COMMON /DAT09/ ZMIL(2,4,4,2),CWO(2,4,25,4,2),CIMW(2,4,25,4,2,3)
      COMMON /DAT15/ CWOA(2,25,4,2),EWOA(3,25,12),EZMA(2,12)
      COMMON /DAT18/ SIZE(25,4,2,4)
      COMMON /DAT19/ GV(4,2),GH(4,2),GS(4,2),BH(4,2),BV(4,2)
      COMMON /DAT20/ EM0(2,4,4,2),EN0(3,4,4,2)
CC
      IF(IAGE.GT.1) GOTO 10
CC
CC..Emission levels at zero mileage point
CC
      ZMIL(IP,IBAG,ITECH,ISTD) = EN0(IP,IBAG,ITECH,ISTD)
CC
CC..Emission levels by age
CC
   10 ES = ES0(IP,IBAG,ITECH,ISTD)
      EH = EH0(IP,IBAG,ITECH,ISTD)
     *   + ( DN(IP,IBAG,ITECH,ISTD)*ODOM(IAGE) )
      EM = EM0(IP,IBAG,ITECH,ISTD)
     *   + ( DN(IP,IBAG,ITECH,ISTD)*ODOM(IAGE) )
      EN = EN0(IP,IBAG,ITECH,ISTD)
     *   + ( DN(IP,IBAG,ITECH,ISTD)*ODOM(IAGE) )
CC
CC  Adjust emissions for effects of Oxygenated Fuels
CC
      ENA=EN*OXY(IP,ITECH,EN)
      EMA=EM*OXY(IP,ITECH,EM)
      EHA=EH*OXY(IP,ITECH,EH)
      ESA=ES*OXY(IP,ITECH,ES)
CC
CC..Calculate the base (without I/M) composite emission levels by age
CC
      CWO(IP,IBAG,IAGE,ITECH,ISTD) =
     *   SIZE(IAGE,ITECH,ISTD,1) * EN
     * + SIZE(IAGE,ITECH,ISTD,2) * EM
     * + SIZE(IAGE,ITECH,ISTD,3) * EH
     * + SIZE(IAGE,ITECH,ISTD,4) * ES
      IF(IBAG.EQ.1)
     * CWOA(IP,IAGE,ITECH,ISTD) =
     *   SIZE(IAGE,ITECH,ISTD,1) * ENA
     * + SIZE(IAGE,ITECH,ISTD,2) * EMA
     * + SIZE(IAGE,ITECH,ISTD,3) * EHA
     * + SIZE(IAGE,ITECH,ISTD,4) * ESA
CC
C     IF(IP.EQ.1.AND.IBAG.EQ.1)
C    * WRITE(2,772) IAGE,ITECH,ISTD,EN,EM,EH,ES
C 772 FORMAT(3I4,4F7.3)
CC
  999 RETURN
      END
```

Appendix B : Tech 4.1 Model Source Code

```
      SUBROUTINE IMEMIT
CC
CC..This routine combines the emission levels of each emission
CC..category based on the predicted catagory size.
CC
      COMMON /DAT01/ MYR,ISTD,ITECH,IBAG,IP,IAGE,ICUT,ITST
      COMMON /DAT02/ AMIL(25),ODOM(25),TMILE(25),WGT(25)
      COMMON /DAT07/ ES0(2,4,4,2),EH0(2,4,4,2)
      COMMON /DAT08/ DN(3,4,4,2)
      COMMON /DAT09/ ZMIL(2,4,4,2),CWO(2,4,25,4,2),CIMW(2,4,25,4,2,3)
      COMMON /DAT16/ XSIDR(2,4,2,3),XHIDR(2,4,2,3)
      COMMON /DAT17/ RSUP(2,4,2,3),RHIG(2,4,2,3)
      COMMON /DAT18/ SIZE(25,4,2,4)
      COMMON /DAT20/ EM0(2,4,4,2),EN0(3,4,4,2)
      COMMON /DAT22/ RMAR(2,4,2,3),RNOR(2,4,2,3)
      COMMON /DAT24/ XMIDR(2,4,2,3),XNIDR(2,4,2,3)
      COMMON /DAT25/ EXPO(2,4,3,2),DOTS(4,2,4,2,2)
CC
      DIMENSION STD(2)
      DATA STD / .41, 3.4 /
CC
CC..Non-I/M emission levels
CC
      ES2 = ES0(IP,IBAG,ITECH,ISTD)
      EH2 = EH0(IP,IBAG,ITECH,ISTD)
     *    + ( DN(IP,IBAG,ITECH,ISTD)*ODOM(IAGE) )
      EM2 = EM0(IP,IBAG,ITECH,ISTD)
     *    + ( DN(IP,IBAG,ITECH,ISTD)*ODOM(IAGE) )
      EN2 = EN0(IP,IBAG,ITECH,ISTD)
     *    + ( DN(IP,IBAG,ITECH,ISTD)*ODOM(IAGE) )
CC
CC..For each test type   ITEST = 1 : Idle Test
CC..                     ITEST = 2 : IM240 with 1.6/30 HC/CO Cutpoints
CC..                     ITEST = 3 : IM240 with 0.8/15 HC/CO Cutpoints
CC
      DO 10 ITEST=1,3
CC
CC..The emissions of vehicles passing the short test are combined
CC..with the estimated emission levels of vehicles which are repaired.
CC
CC  DOTS(ITECH,A/B,IDOT,IP,ITST)
CC
      ITST=ITEST
      IF(ITEST.EQ.3) ITST=2
CC
C     IF(ES2.GT.0) REPS = EXPO(IP,ITECH,ITEST,1)
C    *     * EXP(-EXPO(IP,ITECH,ITEST,2)/ES2)
      CALL CONECT(ES2,REPS)
      IF(REPS.LT.STD(IP) .AND. ES2.GT.STD(IP)) REPS=STD(IP)
      IF(REPS.GT.ES2) REPS=ES2
      IF(ES2.LT.STD(IP)) REPS=ES2
      EIMS = (XSIDR(IP,ITECH,ISTD,ITEST)*REPS)  +
     *            ((1 - XSIDR(IP,ITECH,ISTD,ITEST))*ES2)
CC
C     REPH = EXPO(IP,ITECH,ITEST,1)
C    *     * EXP(-EXPO(IP,ITECH,ITEST,2)/EH2)
      CALL CONECT(EH2,REPH)
      IF(REPH.LT.STD(IP) .AND. EH2.GT.STD(IP)) REPH=STD(IP)
      IF(REPH.GT.EH2) REPH=EH2
      IF(EH2.LT.STD(IP)) REPH=EH2
```

```
      EIMH = (XHIDR(IP,ITECH,ISTD,ITEST)*REPH)  +
     *             ((1 - XHIDR(IP,ITECH,ISTD,ITEST))*EH2)
CC
C     REPM = EXPO(IP,ITECH,ITEST,1)
C    *     * EXP(-EXPO(IP,ITECH,ITEST,2)/EM2)
      CALL CONECT(EM2,REPM)
      IF(REPM.LT.STD(IP) .AND. EM2.GT.STD(IP)) REPM=STD(IP)
      IF(REPM.GT.EM2) REPM=EM2
      IF(EM2.LT.STD(IP)) REPM=EM2
      EIMM = (XMIDR(IP,ITECH,ISTD,ITEST)*REPM)  +
     *             ((1 - XMIDR(IP,ITECH,ISTD,ITEST))*EM2)
CC
C     REPN = EXPO(IP,ITECH,ITEST,1)
C    *     * EXP(-EXPO(IP,ITECH,ITEST,2)/EN2)
      CALL CONECT(EN2,REPN)
      IF(REPN.LT.STD(IP) .AND. EN2.GT.STD(IP)) REPN=STD(IP)
      IF(REPN.GT.EN2) REPN=EN2
      IF(EN2.LT.STD(IP)) REPN=EN2
      EIMN = (XNIDR(IP,ITECH,ISTD,ITEST)*REPN)  +
     *             ((1 - XNIDR(IP,ITECH,ISTD,ITEST))*EN2)
CC
      PS=XSIDR(IP,ITECH,ISTD,ITEST)
      PH=XHIDR(IP,ITECH,ISTD,ITEST)
      PM=XMIDR(IP,ITECH,ISTD,ITEST)
      PN=XNIDR(IP,ITECH,ISTD,ITEST)
      IF(IBAG.EQ.1 .AND. IAGE.EQ.1 .AND. IP.EQ.1)
     * WRITE(14,881) ISTD,ITECH,IP,ITEST,IAGE,REPS,REPH,REPM,REPN,
     * ES2,EH2,EM2,EN2,EIMS,EIMH,EIMM,EIMN,PS,PH,PM,PN
  881 FORMAT(5I3,12F7.2,4F7.3)
CC
CC..Emission levels by age and by test
CC..Calculate the base (with I/M) composite emission levels by age
CC
      CIMW(IP,IBAG,IAGE,ITECH,ISTD,ITEST) =
     *   SIZE(IAGE,ITECH,ISTD,1) * EIMN
     * + SIZE(IAGE,ITECH,ISTD,2) * EIMM
     * + SIZE(IAGE,ITECH,ISTD,3) * EIMH
     * + SIZE(IAGE,ITECH,ISTD,4) * EIMS
CC
C     IF(ITEST.EQ.3) THEN
C       CHK1=CIMW(IP,IBAG,IAGE,ITECH,ISTD,ITEST)
C       CHK2=CIMW(IP,IBAG,IAGE,ITECH,ISTD,ITEST-1)
C       IF(CHK1.GT.CHK2) THEN
C         CIMW(IP,IBAG,IAGE,ITECH,ISTD,ITEST)=CHK2
C     WRITE(14,882) ISTD,ITECH,IP,ITEST,IAGE,REPS,REPH,REPM,REPN,
C    *            ES2,EH2,EM2,EN2,EIMS,EIMH,EIMM,EIMN,PS,PH,PM,PN
C 882 FORMAT(5I3,12F7.3,4F7.3)
C       ENDIF
C     ENDIF
CC
CC
   10 CONTINUE
CC
  999 RETURN
      END
```

Appendix B : Tech 4.1 Model Source Code

```
      SUBROUTINE MYRSUB
CC
CC..This section combines the technologies into
CC..model year emission levels.
CC
      COMMON /DAT01/ MYR,ISTD,ITECH,IBAG,IP,IAGE,ICUT,ITST
      COMMON /DAT02/ AMIL(25),ODOM(25),TMILE(25),WGT(25)
      COMMON /DAT06/ FRAC(4,12)
      COMMON /DAT08/ DN(3,4,4,2)
      COMMON /DAT09/ ZMIL(2,4,4,2),CWO(2,4,25,4,2),CIMW(2,4,25,4,2,3)
      COMMON /DAT10/ EWO(3,4,25,12),EIMW(2,4,25,12,3),EZM(2,4,12)
      COMMON /DAT12/ ZML(3,4,12),ZML1(3,4,12),ZML2(3,4,12)
      COMMON /DAT15/ CWOA(2,25,4,2),EWOA(3,25,12),EZMA(2,12)
      COMMON /DAT14/ DET(3,4,12),DET1(3,4,12),DET2(3,4,12)
      COMMON /DAT20/ EM0(2,4,4,2),EN0(3,4,4,2)
CC
      DIMENSION EFFECT(12,25)
CC
      ZERO=0.0
CC
CC..Loop by MYR, CO standard, technology, age, bag, & pollutant
CC
CC..The ITEST loops only for the I/M composite emission arrays
CC
CC
      DO 300 MYR=1,12
       ISTD=1
       IF(MYR.GE.3) ISTD=2
      DO 300 IP=1,2
      DO 300 IBAG=1,4
      DO 300 ITECH=1,4
CC
CC..Zero mile emission levels by model year
CC
      EZM(IP,IBAG,MYR) = EZM(IP,IBAG,MYR)
     * + FRAC(ITECH,MYR) * ZMIL(IP,IBAG,ITECH,ISTD)
CC
CC  Oxygenated Fuel Effect
CC
      IF(IBAG.EQ.1) EZMA(IP,MYR)=EZMA(IP,MYR)
     * + FRAC(ITECH,MYR)*ZMIL(IP,IBAG,ITECH,ISTD)
     * * OXY(IP,ITECH,ZMIL(IP,IBAG,ITECH,ISTD))
CC
      DO 300 IAGE=1,25
CC
CC..Calculates the emission levels for
CC..January 1st dates from the emission levels by age.
CC..Since model year introduction is on October 1st, this
CC..requires a 75%/25% staggering.
CC
      EWO(IP,IBAG,IAGE,MYR) =
     *   EWO(IP,IBAG,IAGE,MYR)
     * + FRAC(ITECH,MYR) * CWO(IP,IBAG,IAGE,ITECH,ISTD)
CC
CC  Oxygenated Fuel Effect
CC
      IF(IBAG.EQ.1)
     * EWOA(IP,IAGE,MYR) = EWOA(IP,IAGE,MYR)
     * + FRAC(ITECH,MYR) * CWOA(IP,IAGE,ITECH,ISTD)
CC
```

```
      DO 200 ITEST=1,3
CC
      EIMW(IP,IBAG,IAGE,MYR,ITEST) =
     *    EIMW(IP,IBAG,IAGE,MYR,ITEST)
     *  + FRAC(ITECH,MYR) * CIMW(IP,IBAG,IAGE,ITECH,ISTD,ITEST)
CC
CC
  200 CONTINUE
  300 CONTINUE
CC
CC  Write out the Oxygenated Fuels Effect
CC
      DO 774 MYR=1,12
       ISTD=1
       IF(MYR.GE.3) ISTD=2
       IAGE=0
CC
C      WRITE(13,773) MYR,IAGE,ZERO,
C    *  EZM(1,1,MYR),EZMA(1,MYR),
C    *  EZM(2,1,MYR),EZMA(2,MYR)
CCCCCC     *  EZM(3,1,MYR),EZMA(3,MYR)
CC
      DO 774 IAGE=1,25
      DO 772 ITECH=1,4
       EMIT=EN0(3,1,ITECH,ISTD)+DN(3,1,ITECH,ISTD)*ODOM(IAGE)
       EWO(3,1,IAGE,MYR)=EWO(3,1,IAGE,MYR)
     *  + EMIT*FRAC(ITECH,MYR)
       EWOA(3,IAGE,MYR)=EWOA(3,IAGE,MYR)
     *  + EMIT*FRAC(ITECH,MYR)*OXY(3,ITECH,EMIT)
  772 CONTINUE
CC
       EFFECT(MYR,IAGE) =
     * (EWO(2,1,IAGE,MYR)-EWOA(2,IAGE,MYR))
     * / EWO(2,1,IAGE,MYR)
CC
C      WRITE(13,773) MYR,IAGE,ODOM(IAGE),
C    *  EWO(1,1,IAGE,MYR),EWOA(1,IAGE,MYR),
C    *  EWO(2,1,IAGE,MYR),EWOA(2,IAGE,MYR),
C    *  EWO(3,1,IAGE,MYR),EWOA(3,IAGE,MYR)
C 773 FORMAT(2(I4,','),F9.4,',',6(F8.3,','))
CC
  774 CONTINUE
CC
      DO 10 MYR=1,12
       WRITE(13,775) (EWO(2,1,IAGE,MYR),IAGE=1,25)
   10 CONTINUE
      DO 20 MYR=1,12
       WRITE(13,776) (EFFECT(MYR,IAGE),IAGE=1,25)
   20 CONTINUE
  775 FORMAT(5X,'*',25(F7.2,','))
  776 FORMAT(5X,'*',25(F4.3,','))
CC
  999 RETURN
      END
```

Appendix B : Tech 4.1 Model Source Code

```
      SUBROUTINE REGR
CC
CC..This subroutine uses a weighted regression equation to
CC..linearize the emission level results for each model year.
CC
      COMMON /DAT01/ MYR,ISTD,ITECH,IBAG,IP,IAGE,ICUT,ITST
      COMMON /DAT02/ AMIL(25),ODOM(25),TMILE(25),WGT(25)
      COMMON /DAT03/ ENOX(4,2,2)
      COMMON /DAT06/ FRAC(4,12)
      COMMON /DAT07/ ES0(2,4,4,2),EH0(2,4,4,2)
      COMMON /DAT08/ DN(3,4,4,2)
      COMMON /DAT10/ EWO(3,4,25,12),EIMW(2,4,25,12,3),EZM(2,4,12)
      COMMON /DAT12/ ZML(3,4,12),ZML1(3,4,12),ZML2(3,4,12)
      COMMON /DAT14/ DET(3,4,12),DET1(3,4,12),DET2(3,4,12)
      COMMON /DAT20/ EM0(2,4,4,2),EN0(3,4,4,2)
CC
      DO 40 MYR=1,12
      DO 40 IBAG=1,4
      DO 40 IP=1,2
CC
      SUMX  = 0.0
      SUMY  = 0.0
      SUMXY = 0.0
      SUMXX = 0.0
CC
      N = 5
CC
      DO 10 IAGE=1,N
CC
       IF(IAGE.EQ.1) EM = EZM(IP,IBAG,MYR)
       IF(IAGE.GT.1) EM = EWO(IP,IBAG,IAGE-1,MYR)
CC
       IF(IAGE.EQ.1) XM = 0.0
       IF(IAGE.GT.1) XM = ODOM(IAGE-1)
CC
       SUMX  = SUMX  +  XM
       SUMY  = SUMY  +  EM
       SUMXY = SUMXY +  (XM*EM)
       SUMXX = SUMXX +  (XM**2)
CC
C     IF(IP.EQ.1.AND.IBAG.EQ.1)
C    * WRITE(4,774) IAGE,MYR,EM,XM,SUMX,SUMY,SUMXY,SUMXX
C 774 FORMAT(2I4,6F8.4)
CC
   10 CONTINUE
CC
      SUM1 = N * SUMXY - SUMX * SUMY
      SUM2 = N * SUMXX - SUMX**2
      D1 =  SUM1 / SUM2
      Z1 =  (SUMY/N) - D1 * (SUMX/N)
CC
CC..Store the regression results
CC
      ZML1(IP,IBAG,MYR) = Z1
      DET1(IP,IBAG,MYR) = D1
      ZML2(IP,IBAG,MYR) = ZML1(IP,IBAG,MYR) + DET1(IP,IBAG,MYR)*5.0
CC
      IF(ZML1(IP,IBAG,MYR).GE.0.0) GO TO 30
CC
CC..If the emission level at zero miles is less than zero,
```

```
CC..then the regression is altered to intercept at zero.
CC
      ZML1(IP,IBAG,MYR) = 0.0
      DET1(IP,IBAG,MYR) = SUMXY / SUMXX
      ZML2(IP,IBAG,MYR) = ZML1(IP,IBAG,MYR) + DET1(IP,IBAG,MYR)*5.0
CC
   30 SUMX  = 0.0
      SUMY  = 0.0
      SUMXY = 0.0
      SUMXX = 0.0
CC
      M1 = 25 - N
      M2 = N + 1
CC
      DO 20 IAGE=M2,25
CC
       IF(IAGE.EQ.1) EM = EZM(IP,IBAG,MYR)
       IF(IAGE.GT.1) EM = EWO(IP,IBAG,IAGE-1,MYR)
CC
       IF(IAGE.EQ.1) XM = 0.0
       IF(IAGE.GT.1) XM = ODOM(IAGE-1)
CC
       SUMX  = SUMX  +  XM
       SUMY  = SUMY  +  EM
       SUMXY = SUMXY +  (XM*EM)
       SUMXX = SUMXX +  (XM**2)
CC
  20   CONTINUE
CC
      SUM1 = M1 * SUMXY - SUMX * SUMY
      SUM2 = M1 * SUMXX - SUMX**2
      D1 =  SUM1 / SUM2
      Z1 =  (SUMY/M1) - D1 * (SUMX/M1)
CC
CC..Store the regression results
CC
      DET2(IP,IBAG,MYR) = D1
CC
CC..Single Linear Regression
CC
      SUMX  = 0.0
      SUMY  = 0.0
      SUMXY = 0.0
      SUMXX = 0.0
C     SUMW  = 0.0
CC
      DO 60 IAGE=1,25
CC
       IF(IAGE.EQ.1) EM = EZM(IP,IBAG,MYR)
       IF(IAGE.GT.1) EM = EWO(IP,IBAG,IAGE-1,MYR)
CC
       IF(IAGE.EQ.1) XM = 0.0
       IF(IAGE.GT.1) XM = ODOM(IAGE-1)
CC
       SUMX  = SUMX  + ( WGT(IAGE) * XM )
       SUMY  = SUMY  + ( WGT(IAGE) * EM )
       SUMXY = SUMXY + ( WGT(IAGE) * (XM*EM))
       SUMXX = SUMXX + ( WGT(IAGE) * (XM**2))
CC
  60   CONTINUE
```

```
CC
      SUM1 = SUMXY - SUMX * SUMY
      SUM2 = SUMXX - SUMX**2
      D1 =  SUM1 / SUM2
      Z1 =  SUMY - D1 * SUMX
CC
CC..Store the regression results
CC
      ZML(IP,IBAG,MYR) = Z1
      DET(IP,IBAG,MYR) = D1
CC
      IF(ZML(IP,IBAG,MYR).GE.0.0) GO TO 40
CC
CC..If the emission level at zero miles is less than zero,
CC..then the regression is altered to intercept at zero.
CC
      ZML(IP,IBAG,MYR) = 0.0
      DET(IP,IBAG,MYR) = SUMXY / SUMXX
CC
   40 CONTINUE
CC
CC..Since the NOx emissions are not combined from emission level
CC..groups, the NOx emission factors can be calculated directly
CC..from the regressions.
CC
      IP=3
CC
      DO 50 MYR=1,12
       ISTD=1
       IF(MYR.GE.3) ISTD=2
      DO 50 IBAG=1,4
      DO 50 ITECH=1,4
CC
      ZML(IP,IBAG,MYR) = ZML(IP,IBAG,MYR) +
     *  EN0(IP,IBAG,ITECH,ISTD)*FRAC(ITECH,MYR)
CC
      DET(IP,IBAG,MYR) = DET(IP,IBAG,MYR) +
     *  DN(IP,IBAG,ITECH,ISTD)*FRAC(ITECH,MYR)
CC
      ZML1(IP,IBAG,MYR)=ZML(IP,IBAG,MYR)
      DET1(IP,IBAG,MYR)=DET(IP,IBAG,MYR)
      DET2(IP,IBAG,MYR)=DET(IP,IBAG,MYR)
CC
   50 CONTINUE
CC
CC  Split 1983-85 from 1986+ rates
CC
      DO 56 MYR=3,12
        ZML(IP,1,MYR) = 0.0
        DET(IP,1,MYR) = 0.0
        DO 55 ITECH=1,4
          MYG=1
          IF(MYR.GE.6) MYG=2
          ZML(IP,1,MYR) = ZML(IP,1,MYR)
     *                  + ENOX(ITECH,MYG,1) * FRAC(ITECH,MYR)
          DET(IP,1,MYR) = DET(IP,1,MYR)
     *                  + ENOX(ITECH,MYG,2) * FRAC(ITECH,MYR)
   55   CONTINUE
        ZML1(IP,1,MYR)=ZML(IP,1,MYR)
        DET1(IP,1,MYR)=DET(IP,1,MYR)
```

```
        DET2(IP,1,MYR)=DET1(IP,1,MYR)
   56 CONTINUE
CC
CC
      CALL BAGF
CC
  999 RETURN
      END
```

```
      SUBROUTINE BAGF
CC
CC..This routine calculates the bag fractions for hot/cold starts
CC
CC..Last Updated : November 15, 1988
CC
      COMMON /DAT01/ MYR,ISTD,ITECH,IBAG,IP,IAGE,ICUT,ITST
      COMMON /DAT12/ ZML(3,4,12),ZML1(3,4,12),ZML2(3,4,12)
      COMMON /DAT13/ BFZML1(3,4,12),BFDET1(3,4,12)
      COMMON /DAT14/ DET(3,4,12),DET1(3,4,12),DET2(3,4,12)
      COMMON /DAT21/ BFDET2(3,4,12),BFZML2(3,4,12)
CC
      DIMENSION BFRAC(4)
CC
      DATA BFRAC  / 1.000, 0.206, 0.521, 0.273 /
CC
      DO 20 IP=1,3
      DO 20 MYR=1,12
CC
       Z2 = 0.0
       Z3 = 0.0
       D2 = 0.0
       D3 = 0.0
CC
CC..Sum up the bag regression coeffs weighted by the FTP bag fractions
CC
      DO 10 IBAG=2,4
CC
       Z2 = Z2 + ZML1(IP,IBAG,MYR)  * BFRAC(IBAG)
       Z3 = Z3 + ZML2(IP,IBAG,MYR) * BFRAC(IBAG)
       D2 = D2 + DET1(IP,IBAG,MYR)  * BFRAC(IBAG)
       D3 = D3 + DET2(IP,IBAG,MYR) * BFRAC(IBAG)
CC
   10 CONTINUE
CC
CC..Set the combined FTP bag fraction to 1.00
CC
      BFZML1(IP,1,MYR)  = Z2 / Z2
      BFZML2(IP,1,MYR) = Z3 / Z2
      BFDET1(IP,1,MYR)  = D2 / Z2
      BFDET2(IP,1,MYR) = D3 / Z2
CC
CC..Divide each bag regression coeff by the weighted sum
CC
      DO 20 IBAG=2,4
CC
       BFZML1(IP,IBAG,MYR) = ZML1(IP,IBAG,MYR) / Z2
       BFZML2(IP,IBAG,MYR) = ZML2(IP,IBAG,MYR) / Z2
       BFDET1(IP,IBAG,MYR) = DET1(IP,IBAG,MYR) / Z2
       BFDET2(IP,IBAG,MYR) = DET2(IP,IBAG,MYR) / Z2
CC
   20 CONTINUE
CC
      RETURN
      END
```

Appendix B : Tech 4.1 Model Source Code

```
      SUBROUTINE JAN1
CC
CC..This subroutine calculates the average emissions of each
CC..model year on January first.  It creates the I/M credits
CC..and passes them to OUTPUT.
CC
      COMMON /DAT02/ AMIL(25),ODOM(25),TMILE(25),WGT(25)
      COMMON /DAT10/ EWO(3,4,25,12),EIMW(2,4,25,12,3),EZM(2,4,12)
      COMMON /DAT11/ CREDIT(2,25,12,3,4)
      COMMON /DAT12/ ZML(3,4,12),ZML1(3,4,12),ZML2(3,4,12)
      COMMON /DAT14/ DET(3,4,12),DET1(3,4,12),DET2(3,4,12)
CC
      DIMENSION ANSWNO(2,25,12),ANSWIM(2,25,12,3,3)
      DIMENSION EPRED(2,4,25,12,3),PRED(2,4,25,12,3)
      DIMENSION SLOPE(2,12,26),ZERO(2,12,26)
CC
CC
      IBAG = 1
      DO 100 MYR  = 1,12
      DO 100 IP   = 1,2
CC
CC..The deteriorations before and after the "KINK" are transferred
CC..to the array SLOPE for each vehicle age.
CC
      DO 95 I = 1,25
CC
       IF(I.LE.4)  SLOPE(IP,MYR,I) = DET1(IP,IBAG,MYR)
       IF(I.GE.5)  SLOPE(IP,MYR,I) = DET2(IP,IBAG,MYR)
CC
       IF(I.LE.4)  ZERO(IP,MYR,I) = ZML1(IP,IBAG,MYR)
       IF(I.GE.5)  ZERO(IP,MYR,I) = ZML2(IP,IBAG,MYR) -
     *                              DET2(IP,IBAG,MYR)*5.0
CC
   95 CONTINUE
CC
CC..Computes the NON-I/M emission level by age, by pollutant,
CC..by bag, and by myr.
CC
      DO 100 IAGE = 1,24
CC
      IF(IAGE .GT. 1) GOTO 33
CC
CC..Vehicle age is one.
CC
      ANSWNO(IP,IAGE,MYR) =
     *.75*(ZERO(IP,MYR,IAGE) + SLOPE(IP,MYR,IAGE)*.625*ODOM(IAGE) ) +
     *.25*(ZERO(IP,MYR,IAGE+1) + SLOPE(IP,MYR,IAGE+1)*
     *         (.125*(ODOM(IAGE+1)-ODOM(IAGE))+ODOM(IAGE)) )
      GOTO 34
CC
CC..Vehicle age is greater than one.
CC
   33 ANSWNO(IP,IAGE,MYR) =
     *.75*(ZERO(IP,MYR,IAGE) + SLOPE(IP,MYR,IAGE) *
     *         (.625*(ODOM(IAGE)-ODOM(IAGE-1))+ODOM(IAGE-1)) )  +
     *.25*(ZERO(IP,MYR,IAGE+1) + SLOPE(IP,MYR,IAGE+1) *
     *         (.125*(ODOM(IAGE+1)-ODOM(IAGE))+ODOM(IAGE)) )
CC
CC..Compute the I/M emission level by age, by pollutant,
CC..by bag, by myr and by test for IAGE = 1.  The predicted emission
```

```
CC..level is from the regression equation and the actual model
CC..emission level points.
CC
   34 DO 100 ITEST=1,3
CC
      EPRED(IP,IBAG,IAGE,MYR,ITEST) =
     * 1 -  ((EWO(IP,IBAG,IAGE,MYR) - EIMW(IP,IBAG,IAGE,MYR,ITEST)) /
     *                    EWO(IP,IBAG,IAGE,MYR))
CC
      PRED(IP,IBAG,IAGE,MYR,ITEST) =
     *    (ZERO(IP,MYR,IAGE) + SLOPE(IP,MYR,IAGE)*ODOM(IAGE)) *
     *     EPRED(IP,IBAG,IAGE,MYR,ITEST)
CC
CC..Determine I/M credits for each inspection frequency.
CC
CC      ITYP = 1 : Annual
CC             2 : Biennial 1 - 3 - 5 - etc
CC             3 : Biennial 2 - 4 - 6 - etc
CC
      DO 110 ITYP = 1,3
CC
       IF(ITYP.GE.2) GOTO 60
CC
CC..Annual I/M Credits
CC
      IF(IAGE .GT. 1) GOTO 50
CC
      ANSWIM(IP,IAGE,MYR,ITEST,ITYP) =
     *  (.75*(.625*SLOPE(IP,MYR,IAGE)*ODOM(IAGE) + ZERO(IP,MYR,IAGE)))
     * + .25*(PRED(IP,IBAG,IAGE,MYR,ITEST) + SLOPE(IP,MYR,IAGE+1)*
     *        (.125*(ODOM(IAGE+1)-ODOM(IAGE))) )
      GOTO 60
CC
   50 ANSWIM(IP,IAGE,MYR,ITEST,ITYP) =
     *.75*(PRED(IP,IBAG,IAGE-1,MYR,ITEST) +
     *  SLOPE(IP,MYR,IAGE) * (.625*(ODOM(IAGE)-ODOM(IAGE-1))) ) +
     *.25*(PRED(IP,IBAG,IAGE,MYR,ITEST) +
     *  SLOPE(IP,MYR,IAGE+1) * (.125*(ODOM(IAGE+1)-ODOM(IAGE))) )
CC
      GOTO 90
CC
CC..Biennial I/M Credits
CC
CC    IMODE =  1 :  Odd year
CC             2 :  Even year
CC
   60 IMODE = MOD(IAGE,2)
CC
CC..Biennial 1 - 3 - 5 - etc   1st Year Exception
CC..          same as no I/M first year
CC
      IF(ITYP .EQ. 2 .AND. IAGE .EQ. 1)
     *   ANSWIM(IP,IAGE,MYR,ITEST,ITYP) =
     *  (.75*(.625*SLOPE(IP,MYR,IAGE)*ODOM(IAGE) + ZERO(IP,MYR,IAGE)))
     * + .25*(PRED(IP,IBAG,IAGE,MYR,ITEST) + SLOPE(IP,MYR,IAGE+1)*
     *        (.125*(ODOM(IAGE+1)-ODOM(IAGE))) )
CC
CC..Biennial 2 - 4 - 6 - etc   1st Year Exception
CC..          same as no I/M first year
CC
```

```
      IF(ITYP .EQ. 3 .AND. IAGE .EQ. 1)
     *  ANSWIM(IP,IAGE,MYR,ITEST,ITYP) =
     *   .75*(ZERO(IP,MYR,IAGE) + SLOPE(IP,MYR,IAGE)*.625*ODOM(IAGE))+
     *   .25*(ZERO(IP,MYR,IAGE) + SLOPE(IP,MYR,IAGE+1)*
     *  (.125*(ODOM(IAGE+1)-ODOM(IAGE))+ODOM(IAGE)) )
CC
CC..Biennial 2 - 4 - 6 - etc   2nd Year Exception
CC
      IF(ITYP .EQ. 3 .AND. IAGE .EQ. 2)
     *          ANSWIM(IP,IAGE,MYR,ITEST,ITYP) =
     *    .75*(ZERO(IP,MYR,IAGE) +
     *          SLOPE(IP,MYR,IAGE)*(ODOM(IAGE-1)) +
     *          SLOPE(IP,MYR,IAGE)*(.625*(ODOM(IAGE)-ODOM(IAGE-1)))) +
     *    .25*(PRED(IP,IBAG,IAGE,MYR,ITEST) +
     *          SLOPE(IP,MYR,IAGE+1)*.125*(ODOM(IAGE+1)-ODOM(IAGE)))
CC
      IF(IAGE.EQ.1 .OR. (ITYP.EQ.3 .AND. IAGE.EQ.2))  GOTO 90
CC
CC..The Principle Biennial Cases 1-3-5-etc and 2-4-6-etc
CC
CC..An Even Year for the 1-3-5 or An Odd Year for the 2-4-6
CC          There is no I/M inspection that year
CC
      IF((IMODE.EQ.1 .AND. ITYP.EQ.3) .OR. (IMODE.EQ.0.AND.ITYP.EQ.2))
     *         ANSWIM(IP,IAGE,MYR,ITEST,ITYP) =
     *    .75*(PRED(IP,IBAG,IAGE-1,MYR,ITEST) +
     *          SLOPE(IP,MYR,IAGE)*(.625*(ODOM(IAGE)-ODOM(IAGE-1)))) +
     *    .25*(PRED(IP,IBAG,IAGE-1,MYR,ITEST) +
     *          SLOPE(IP,MYR,IAGE)*(ODOM(IAGE)-ODOM(IAGE-1)) +
     *          SLOPE(IP,MYR,IAGE+1)*.125*(ODOM(IAGE+1)-ODOM(IAGE)))
CC
CC..An Odd Year for the 1-3-5 or An Even Year for the 2-4-6
CC..          There is an I/M inspection that year
CC
      IF((IMODE.EQ.0 .AND. ITYP.EQ.3) .OR. (IMODE.EQ.1.AND.ITYP.EQ.2))
     *         ANSWIM(IP,IAGE,MYR,ITEST,ITYP) =
     *     .75*(PRED(IP,IBAG,IAGE-2,MYR,ITEST) +
     *          SLOPE(IP,MYR,IAGE-1)*(ODOM(IAGE-1)-ODOM(IAGE-2)) +
     *          SLOPE(IP,MYR,IAGE)*(.625*(ODOM(IAGE)-ODOM(IAGE-1)))) +
     *     .25*(PRED(IP,IBAG,IAGE,MYR,ITEST)  +
     *          SLOPE(IP,MYR,IAGE+1)*(.125*(ODOM(IAGE+1)-ODOM(IAGE))))
CC
CC..Combined 1-3-5 and 2-4-6 biennial cases
CC
   90 CREDIT(IP,IAGE,MYR,ITEST,ITYP) =
     * (ANSWNO(IP,IAGE,MYR)-ANSWIM(IP,IAGE,MYR,ITEST,ITYP))
     *          / (ANSWNO(IP,IAGE,MYR))
CC
  110 CONTINUE
CC
CC..Store resulting I/M credits
CC
        CREDIT(IP,IAGE,MYR,ITEST,4) =
     *  (CREDIT(IP,IAGE,MYR,ITEST,2) + CREDIT(IP,IAGE,MYR,ITEST,3))/2
CC
  100 CONTINUE
CC
      RETURN
      END
```

```
      SUBROUTINE OUTPUT
CC
CC..Outputs results for emission factors, bag fractions and
CC..I/M credits.
CC
      COMMON /DAT05/ OXYE(2,3,4,3),OXYCON
      COMMON /DAT11/ CREDIT(2,25,12,3,4)
      COMMON /DAT12/ ZML(3,4,12),ZML1(3,4,12),ZML2(3,4,12)
      COMMON /DAT13/ BFZML1(3,4,12),BFDET1(3,4,12)
      COMMON /DAT14/ DET(3,4,12),DET1(3,4,12),DET2(3,4,12)
      COMMON /DAT21/ BFDET2(3,4,12),BFZML2(3,4,12)
CC
      INTEGER IP,IBAG
      CHARACTER*4 LAB1(3)/'  HC',' CO',' NOX'/
      CHARACTER*4 LAB2(5)/'FTP ',
     *                    'BAG1',
     *                    'BAG2',
     *                    'BAG3',
     *                    'BAGI'/
CC
      NP = 3
      N1 = 1
      N3 = 3
CC
CC..Write out Emission Factors on Device #7
CC
      WRITE(7,100) N1
      WRITE(7,600)
      DO 20 IP=1,NP
      WRITE(7,500)
      DO 20 MYR=1,12
      NYR=1980+MYR
      IBAG=1
      T50 = ZML1(IP,IBAG,MYR) + 5.0*DET1(IP,IBAG,MYR)
      T100 = T50 + 5.0*DET2(IP,IBAG,MYR)
      WRITE(7,300) NYR,LAB2(IBAG),LAB1(IP),
     *  ZML1(IP,IBAG,MYR),DET1(IP,IBAG,MYR),DET2(IP,IBAG,MYR),
     *  T50,T100,ZML(IP,IBAG,MYR),DET(IP,IBAG,MYR)
   20 CONTINUE
CC
CC..Write out Annual I/M credits on Device #8
CC
      WRITE(8,102) N3
      DO 10 ITEST=1,3
      DO 10 MYR=1,12
        NYR=1980+MYR
      DO 10 IP=1,2
        WRITE(8,200) (CREDIT(IP,IAGE,MYR,ITEST,1),IAGE=1,24),
     *     NYR,LAB1(IP)
   10 CONTINUE
CC
CC..Write out Biennial I/M Credits on Device #9
CC
      WRITE(9,103) N3
      DO 130 ITEST=1,3
      DO 130 MYR=1,12
        NYR=1980+MYR
      DO 130 IP=1,2
        WRITE(9,200) (CREDIT(IP,IAGE,MYR,ITEST,4),IAGE=1,24),
     *     NYR,LAB1(IP)
```

```
  130 CONTINUE
CC
CC..Write out Bag Fractions on Device #10
CC
      WRITE(10,101) N1
      DO 30 IP=1,3
      WRITE(10,500)
      DO 30 MYR=1,12
      NYR=1980+MYR
      WRITE(10,400) NYR,LAB1(IP),
     *(BFZML1(IP,IBAG,MYR),BFDET1(IP,IBAG,MYR),BFZML2(IP,IBAG,MYR),
     *                     BFDET2(IP,IBAG,MYR),IBAG=2,4),
     * BFZML1(IP,1,MYR),BFDET1(IP,1,MYR),BFZML2(IP,1,MYR),
     *                   BFDET2(IP,1,MYR)
   30 CONTINUE
CC
  100 FORMAT(I1,/,' **',/,
     *' ** MOBILE4.1 LDGV Emission Factors',/,' **')
  101 FORMAT(I1,/,/,
     *' ** MOBILE4.1 LDGV Bag Fractions **',/,/,
     *23X,'Bag 1',20X,'Bag 2',25X,'Bag 3',25X,'FTP',/,
     *9X,4('   ------------------------'),/,
     *9X,4('   ZML1   DET1   ZML2   DET2'),/,
     *9X,4('   ----   ----   ----   ----'))
  102 FORMAT(I1,/,' **',/,
     *' ** MOBILE4.1 Annual I/M Credits',
     */,' **')
  103 FORMAT(I1,/,' **',/,
     *' ** MOBILE4.1 Biennial I/M Credits',
     */,' **')
  200 FORMAT(24F4.3,5X,I4,A4)
  600 FORMAT(18X,'  ZML ',3X,' DET1 ',3X,' DET2 ',3X,
     * '     @ 50k','     @100k',3X,'  ZML ',3X,'  DET ')
  300 FORMAT(
     * 1X,I4,' : ',2A4,'=',
     * F6.3,' + ',F6.3,3X,
     * F6.3,3X,2F10.3,2(3X,F6.3))
  400 FORMAT(1X,I4,A4,16F7.4)
  500 FORMAT('-')
CC
      RETURN
      END
```

```
      FUNCTION OXY(IP,ITECH,EMIT)
C
      COMMON /DAT05/ OXYE(2,3,4,3),OXYCON
C
      OXY=1.0
C
      IEG=0
      IF(EMIT.LT.OXYE(1,1,ITECH,IP)) THEN
        OXY=1.0-OXYCON*OXYE(2,1,ITECH,IP)/100.
        GOTO 99
      ENDIF
      IF(EMIT.GE.OXYE(1,3,ITECH,IP)) THEN
        OXY=1.0-OXYCON*OXYE(2,3,ITECH,IP)/100.
        GOTO 99
      ENDIF
      IF(EMIT.LT.OXYE(1,2,ITECH,IP) .AND.
     *   EMIT.GE.OXYE(1,1,ITECH,IP)) IEG=2
      IF(EMIT.LT.OXYE(1,3,ITECH,IP) .AND.
     *   EMIT.GE.OXYE(1,2,ITECH,IP)) IEG=3
C
      X1=OXYE(1,IEG-1,ITECH,IP)
      X2=OXYE(1,IEG,ITECH,IP)
      Y1=OXYE(2,IEG-1,ITECH,IP)
      Y2=OXYE(2,IEG,ITECH,IP)
C
      ODET=(Y2-Y1)/(X2-X1)
      OZML=Y1-X1*ODET
C
      OXY=1-(OZML+ODET*EMIT)*OXYCON/100.
C
   99 RETURN
      END
```

```
      SUBROUTINE CONECT(EIN,OUT)
CC
CC   DOTS(ITECH,A/B,IDOT,IP,ITEST)
CC
      COMMON /DAT01/ MYR,ISTD,ITECH,IBAG,IP,IAGE,ICUT,ITST
      COMMON /DAT25/ EXPO(2,4,3,2),DOTS(4,2,4,2,2)
CC
      OUT=EIN
CC
      IF(EIN.LE.DOTS(ITECH,1,1,IP,ITST)) THEN
        SLP = DOTS(ITECH,2,1,IP,ITST)
     *      / DOTS(ITECH,1,1,IP,ITST)
        OUT = SLP * EIN
      ENDIF
CC
      IF(EIN.GT.DOTS(ITECH,1,1,IP,ITST) .AND.
     *   EIN.LE.DOTS(ITECH,1,2,IP,ITST)) THEN
        SLP = ( DOTS(ITECH,2,2,IP,ITST) -
     *          DOTS(ITECH,2,1,IP,ITST) )
     *      / ( DOTS(ITECH,1,2,IP,ITST) -
     *          DOTS(ITECH,1,1,IP,ITST) )
        CPT = DOTS(ITECH,2,1,IP,ITST) -
     *        DOTS(ITECH,1,1,IP,ITST)*SLP
        OUT = CPT + SLP*EIN
      ENDIF
CC
      IF(EIN.GT.DOTS(ITECH,1,2,IP,ITST) .AND.
     *   EIN.LE.DOTS(ITECH,1,3,IP,ITST)) THEN
        SLP = ( DOTS(ITECH,2,3,IP,ITST) -
     *          DOTS(ITECH,2,2,IP,ITST) )
     *      / ( DOTS(ITECH,1,3,IP,ITST) -
     *          DOTS(ITECH,1,2,IP,ITST) )
        CPT = DOTS(ITECH,2,2,IP,ITST) -
     *        DOTS(ITECH,1,2,IP,ITST)*SLP
        OUT = CPT + SLP*EIN
      ENDIF
CC
      IF(EIN.GT.DOTS(ITECH,1,3,IP,ITST) .AND.
     *   EIN.LE.DOTS(ITECH,1,4,IP,ITST)) THEN
        SLP = ( DOTS(ITECH,2,4,IP,ITST) -
     *          DOTS(ITECH,2,3,IP,ITST) )
     *      / ( DOTS(ITECH,1,4,IP,ITST) -
     *          DOTS(ITECH,1,3,IP,ITST) )
        CPT = DOTS(ITECH,2,3,IP,ITST) -
     *        DOTS(ITECH,1,3,IP,ITST)*SLP
        OUT = CPT + SLP*EIN
      ENDIF
CC
      IF(EIN.GT.DOTS(ITECH,1,4,IP,ITST)) THEN
        OUT = DOTS(ITECH,2,4,IP,ITST)
      ENDIF
CC
      RETURN
      END
```

```
      BLOCK DATA BD01
CC
CC..This block data is used to initialize data arrays
CC
      COMMON /DAT10/ EWO(3,4,25,12),EIMW(2,4,25,12,3),EZM(2,4,12)
      COMMON /DAT12/ ZML(3,4,12),ZML1(3,4,12),ZML2(3,4,12)
      COMMON /DAT14/ DET(3,4,12),DET1(3,4,12),DET2(3,4,12)
      COMMON /DAT15/ CWOA(2,25,4,2),EWOA(3,25,12),EZMA(2,12)
CC
      DATA EWO  / 3600*0.0 /
      DATA EIMW / 7200*0.0 /
      DATA EZM  /   96*0.0 /
CC
      DATA ZML  / 144*0.0 /
      DATA ZML1 / 144*0.0 /
      DATA ZML2 / 144*0.0 /
CC
      DATA DET  / 144*0.0 /
      DATA DET1 / 144*0.0 /
      DATA DET2 / 144*0.0 /
CC
      DATA CWOA / 400*0.0 /
      DATA EWOA / 900*0.0 /
      DATA EZMA /  24*0.0 /
CC
      END
```

```
      BLOCK DATA BD02
CC
CC..Emission Level Data Block
CC
      COMMON /DAT07/ ES0(2,4,4,2),EH0(2,4,4,2)
      COMMON /DAT19/ GV(4,2),GH(4,2),GS(4,2),BH(4,2),BV(4,2)
CC
CC
CC..Change in the rate of increase in the number of HIGH emitters
CC..                    BH(ITECH,ISTD)
CC                   MPFI    TBI     Carb    Oplp
      DATA BH /13.8353,13.8353,0.9643,1.0000,
     *          4.4709,15.2076,2.3200,1.0000 /
CC
CC..Change in the rate of increase in the number of VERY HIGH emitters
CC..                    BV(ITECH,ISTD)
CC                   MPFI    TBI     Carb    Oplp
      DATA BV / 1.0000,1.0000,1.0000,1.0000,
     *          1.0000,1.0000,1.0000,1.0000 /
CC
CC..Growth in the number of HIGHS per 10,000 miles
CC..                    GH(ITECH,ISTD)
CC                  MPFI      TBI       Carb       Oplp
      DATA GH /  .0065,    .0065,    .0270,     .02704,
     *           .0090,    .0040,    .0140,     .01298  /
CC
CC..Growth in the number of VERY HIGHS per 10,000 miles
CC..                    GV(ITECH,ISTD)
CC                  MPFI      TBI       Carb       Oplp
      DATA GV /  .01933,   .01198,   .03762,    .03530,
     *           .00840,   .02012,   .01487,    .00433  /
CC
CC..Growth in the number of SUPERS per 10,000 miles
CC..                    GS(ITECH,ISTD)
CC                  MPFI     TBI      Carb     Oplp
      DATA GS  / .00257, .00257, .00257, .00000,
     *           .00194, .00194, .00194, .00000 /
CC
CC..Average emissions of SUPERS (from 37 EF & IM vehicles)
CC..              ES0(IP,IBAG,ITECH,ISTD)
CC
      DATA ES0 /
CC..1981,1982 model year vehicles
     1  15.259,173.84, 18.376,154.87,16.344,193.62,10.813,150.52,
     2  15.259,173.84, 18.376,154.87,16.344,193.62,10.813,150.52,
     3  15.259,173.84, 18.376,154.87,16.344,193.62,10.813,150.52,
     4   0.000,  0.00,  0.000,  0.00, 0.000,  0.00, 0.000,  0.00,
CC..1983 and newer model year vehicles
     1  11.123,189.00, 7.6414,163.53,12.874,204.06,10.460,179.79,
     2  18.083,183.59, 13.582,177.29,23.081,208.03,12.076,142.32,
     3  12.870,246.85, 13.435,266.05,13.935,265.45,10.435,197.65,
     4   0.000,  0.00,  0.000,  0.00, 0.000,  0.00, 0.000,  0.00 /
CC
CC..Emission Levels of VERY HIGH Emitters at zero miles
CC..        EH0(IP,IBAG,ITECH,ISTD)
CC
      DATA EH0/
CC..1981,1982 model year vehicles
     * 0.606,  18.049, 1.489,  25.589, 0.392,  15.029, 0.349,  18.063,
     * 1.163,  22.059, 2.896,  64.029, 0.583,   7.181, 0.954,  18.611,
```

```
     * 1.950,  33.396, 3.604,  47.486, 1.632,  32.110, 1.301,  25.174,
     * 1.589,  27.650, 2.583,  45.178, 1.225,  21.845, 1.524,  25.403,
CC..1983 and newer vehicles
     * 2.019,  22.301, 5.041,  37.189, 1.742,  22.043, 1.369,  16.248,
     * 2.242,  44.416, 2.900,  56.086, 2.267,  46.292, 1.705,  32.087,
     * 2.002,  36.130, 4.320,  55.834, 1.464,  30.566, 1.272,  31.744,
     * 1.352,  34.021, 1.441,  40.120, 1.386,  34.668, 1.217,  28.081 /
CC
      END
```

```
      BLOCK DATA BD03
CC
CC..Emission Level Data Block
CC
      COMMON /DAT03/ ENOX(4,2,2)
      COMMON /DAT08/ DN(3,4,4,2)
      COMMON /DAT20/ EM0(2,4,4,2),EN0(3,4,4,2)
CC
CC
CC..Emission level of HIGHs at zero mileage
CC..          EM0(IP,IBAG,ITECH,ISTD)
CC
      DATA EM0/
CC..1981,1982 model year vehicles
     * 0.374,  3.879,  0.954,   5.778, 0.272,  4.591,  0.128,  0.992,
     * 0.758,  6.843,  1.540,  17.730, 0.566,  5.088,  0.530,  2.013,
     * 0.781,  8.496,  2.027,  22.919, 0.404,  4.073,  0.551,  5.963,
     * 0.757,  8.142,  1.494,  17.342, 0.474,  4.430,  0.735,  8.196,
CC..1983 and newer model year vehicles
     * 0.997,  7.602,  1.933,  12.231, 0.712,  6.344,  0.834,  6.538,
     * 0.762,  8.820,  1.288,  18.793, 0.611,  5.238,  0.651,  8.072,
     * 0.703,  8.577,  1.740,  17.608, 0.376,  4.252,  0.543,  9.925,
     * 0.840,  8.386,  1.461,  17.215, 0.536,  3.871,  0.951, 10.367 /
CC
CC
CC..Emission level of NORMAL emitting vehicles at zero mileage
CC..          EN0(IP,IBAG,ITECH,ISTD)
CC
       DATA EN0 /
CC..1981,1982 model year vehicles
     *.188, 1.548, .380,.722,5.515,.821,.034,.466,.218,.071,.578,.348,
     *.279, 3.422, .545,.789,9.081,.902,.138,2.155,.451,.160,1.578,.460,
     *.288, 3.067, .678,.752,9.350,1.203,.127,.911,.491,.241,2.394,.635,
     *.306, 3.368, .649,.632,8.501,.983,.185,1.275,.512,.287,3.447,.655,
CC..1983 and newer model year vehicles
     *.269, 2.598, .617,.831,7.073,.966,.080,1.052,.451,.202,2.163,.667,
     *.242, 2.953, .529,.619,7.074,.902,.118,1.337,.395,.193,2.912,.504,
     *.222, 2.209, .635,.586,7.006,1.021,.108,.468,.446,.164,1.890,.699,
     *.334, 4.093,.524,.594,10.555,.640,.207,1.262,.478,.377,4.589,.521/
CC
CC..Emission deterioration of NORMAL vehicles per 10,000 miles
CC..              DN(IP,IBAG,ITECH,ISTD)
CC
       DATA DN /
CC..1981,1982 model year vehicles
     *.0450,.5807,.1280,
     *.0556,.9654,.1345,.0395,.4866,.1112,.0487,.4784,.1557,
     *.0161,.2520,.1414,
     *.0156,.4582,.1497,.0119,.0323,.1264,.0245,.5045,.1626,
     *.0253,.3281,.0696,
     *.0535,.8313,.0561,.0181,.1893,.0657,.0183,.2174,.0876,
     *.0230,.2877,.0440,
     *.0654,1.0489,.0281,.0106,.0813,.0444,.0151,.1088,.0556,
CC..1983 and newer model year vehicles
     *.0115,.1554,.0163,
     *.0137,.1382,.0248,.0122,.1838,.0106,.0080,.1105,.0218,
     *.0134,.1572,.0419,
     *.0188,.1931,.0469,.0125,.1606,.0328,.0109,.1213,.0549,
     *.0199,.2282,.0593,
     *.0429,.7472,.0555,.0107,.0732,.0587,.0194,.1298,.0631,
```

```
     *.0248,.2093,.0540,
     *.0623,.4080,.0731,.0164,.1454,.0441,.0128,.1799,.0585/
CC
CC
CC..1983-85/1986+ split for NOx emissions
CC         ENOX(ITECH,MYR SPLIT,ZML/DR)
CC
      DATA ENOX/
CC..Zero Mile Levels
CC       MPFI     TBI    Carb    OPLP
     * 0.689, 0.585, 0.692, 0.524,
     * 0.539, 0.316, 0.478, 0.524,
CC..Deterioration Rates
CC        MPFI      TBI     Carb     OPLP
     * 0.0185, 0.0470, 0.0558, 0.0540,
     * 0.0185, 0.0470, 0.0558, 0.0540 /
CC
      END
```

```
      BLOCK DATA BD04
CC
CC..I/M Identification Rate (IDR) effects block data
CC
      COMMON /DAT16/ XSIDR(2,4,2,3),XHIDR(2,4,2,3)
      COMMON /DAT24/ XMIDR(2,4,2,3),XNIDR(2,4,2,3)
CC
CC
CC..The fraction of excess emissions identified by the short
CC..test for each emission level group.
CC..Modified Idle, 2spd, & Loaded (1.2/220) for total emissions
CC..rather than Excess emissions for Mobile 4.1, 7/19/91.
CC..Format:    MPFI          TBI          CARB       OpLoop
CC..          HC   CO      HC    CO     HC   CO     HC  CO
CC.. 81-81
CC..  83+
CC
CC..                XSIDR(IP,ITECH,ISTD,ITEST)
CC
       DATA XSIDR/
CC..Idle test identification rate for SUPERS
     1       .6048,.6968,.6048,.6968,.6048,.6968,.0,    .0,
     2       .8978,.9656,.8978,.9656,.8978,.9656,.0,    .0,
CC..2500/Idle test identification rate for SUPERS
     1       .6523,.8577,.6523,.8577,.6523,.8577,.0,    .0,
     2       .8978,.9656,.8978,.9656,.8978,.9656,.0,    .0,
CC..Loaded/Idle test identification rate for SUPERS
     1       .6523,.8577,.6523,.8577,.6523,.8577,.0,    .0,
     2       .8978,.9656,.8978,.9656,.8978,.9656,.0,    .0 /
CC
CC..                XHIDR(IP,ITECH,ISTD,ITEST)
CC
       DATA XHIDR/
CC..Idle test identification rate for VERY HIGHs
     1       .2736,.3231,.2736,.3231,.3858,.4108,.4568,.5194,
     2       .5676,.6129,.2651,.2695,.3640,.3180,.3640,.3180,
CC..2500/Idle test identification rate for VERY HIGHs
     1       .2736,.3231,.2736,.3231,.4789,.5331,.6197,.6162,
     2       .6187,.7465,.3616,.4206,.5684,.6832,.5684,.6832,
CC..Loaded/Idle test identification rate for VERY HIGHs
     1       .2736,.3231,.2736,.3231,.5476,.6037,.6197,.6162,
     2       .6187,.7465,.3904,.4337,.5684,.6832,.5684,.6832 /
CC
CC..                XMIDR(IP,ITECH,ISTD,ITEST)
CC
       DATA XMIDR/
CC..Idle test identification rate for HIGHs
     1       .0506,.1135,.0506,.1135,.0563,.0492,.2274,.1522,
     2       .2507,.2208,.0336,.0613,.0694,.0415,.0694,.0415,
CC..2500/Idle test identification rate for HIGHs
     1       .0506,.1135,.0506,.1135,.0898,.0834,.2274,.1522,
     2       .3436,.3501,.1924,.1532,.0694,.0415,.0694,.0415,
CC..Loaded/Idle test identification rate for HIGHs
     1       .0506,.1135,.0506,.1135,.0910,.0896,.2274,.1522,
     2       .3866,.3937,.1924,.1532,.0694,.0415,.0694,.0415 /
CC
CC
CC..                XNIDR(IP,ITECH,ISTD,ITEST)
CC
       DATA XNIDR/
```

```
CC..Idle test identification rate for NORMALs
     1        .0556,.0774,.0139,.0139,.0188,.0204,.0093,.0131,
     2        .0360,.0414,.0425,.0436,.0023,.0078,.0023,.0078,
CC..2500/Idle test identification rate for NORMALs
     1        .0556,.0774,.0139,.0139,.0371,.0427,.0201,.0317,
     2        .0575,.0694,.0476,.0514,.0140,.0156,.0065,.0208,
CC..Loaded/Idle test identification rate for NORMALs
     1        .0556,.0774,.0139,.0139,.0371,.0427,.0201,.0317,
     2        .0907,.1023,.0712,.0739,.0140,.0156,.0231,.0403 /
CC
      END
```

```
      BLOCK DATA BD05
CC
CC..I/M Repair Effects block data
CC
      COMMON /DAT17/ RSUP(2,4,2,3),RHIG(2,4,2,3)
      COMMON /DAT22/ RMAR(2,4,2,3),RNOR(2,4,2,3)
      COMMON /DAT25/ EXPO(2,4,3,2),DOTS(4,2,4,2,2)
CC
CC  DOTS(ITECH,A/B,IDOT,IP,ITST)
CC
      DATA DOTS /
CC
     *0.7400,0.7400,.96765,.96765, .41083,.41083,.62235,.62235,
     *1.9223,1.9223,2.0226,2.0226, .60615,.60615,1.1894,1.1894,
     *3.9023,3.9023,3.1063,3.1063, 1.0769,1.0769,1.3254,1.3254,
     *14.282,14.282,8.5543,8.5543, 1.3808,1.3808,1.5286,1.5286,
CC
     *9.2708,9.2708,10.487,10.487, 4.9900,4.9900,9.8624,9.8624,
     *28.031,28.031,29.550,29.550, 9.4669,9.4669,12.969,12.969,
     *90.038,90.038,53.520,53.520, 12.148,12.148,17.434,17.434,
     *190.66,190.66,134.75,134.75, 20.620,20.620,18.281,18.281,
CC
     *.82667,.82667,.93026,.93026, .40750,.40750,.57641,.57641,
     *1.9846,1.9846,1.9431,1.9431, .59231,.59231,1.0349,1.0349,
     *3.9314,3.9314,2.9862,2.9862, 1.0271,1.0271,1.1413,1.1413,
     *14.282,14.282,8.2523,8.2523, 1.3808,1.3808,1.4141,1.4141,
CC
     *10.334,10.334,10.622,10.622, 4.8950,4.8950,9.2808,9.2808,
     *35.518,35.518,29.053,29.053, 9.8631,9.8631,12.489,12.489,
     *104.50,104.50,54.282,54.282, 11.925,11.925,13.190,13.190,
     *190.66,190.66,136.97,136.97, 20.620,20.620,13.596,13.596 /
CC
CC  EXPO(IP,ITECH,ITEST,A/B)   Aexp(-B/x)=y
CC
      DATA EXPO /
     * 0.6682, 6.1319, 0.7476, 8.4157, 1.3629, 13.4934,1.1487, 9.9503,
     * 0.6736, 6.8360, 0.6839, 7.9328, 1.1585, 10.7263,1.2079, 9.1495,
     * 0.6736, 6.8360, 0.6839, 7.9328, 1.1585, 10.7263,1.2079, 9.1495,
     * 0.2676, 3.4348, 0.3419, 3.0945, 0.7034, 5.4373, 0.5682, 2.1526,
     * 0.2911, 6.3200, 0.3262, 2.8702, 0.6309, 4.1224, 0.4449, 1.7352,
     * 0.2911, 6.3200, 0.3262, 2.8702, 0.6309, 4.1224, 0.4449, 1.7352 /
CC
CC..Emission level after repairs expressed as a fraction of
CC..the emission level before repairs.
CC
CC..       RSUP(IP,ITECH,ISTD,ITEST) 4/11/91
CC
       DATA RSUP/
CC..2500/Idle Test emission effect from repairs for SUPERS
     1       .958, .975, .968, .952, .864, .930, .000, .000,
     2       .958, .975, .968, .952, .864, .930, .000, .000,
CC..2500/Idle Test emission effect from repairs for SUPERS
     1       .958, .975, .968, .952, .864, .930, .000, .000,
     2       .958, .975, .968, .952, .864, .930, .000, .000,
CC..2500/Idle Test emission effect from repairs for SUPERS
     1       .958, .975, .968, .952, .864, .930, .000, .000,
     2       .958, .975, .968, .952, .864, .930, .000, .000 /
CC
CC..                RHIG(IP,ITECH,ISTD,ITEST)
CC
```

```
      DATA RHIG/
CC..2500/Idle Test emission effect of repairs for VERY HIGHS
     1       .609, .772, .879, .909, .668, .760, .627, .741,
     2       .609, .772, .879, .909, .668, .760, .627, .741,
CC..2500/Idle Test emission effect of repairs for VERY HIGHS
     1       .609, .772, .879, .909, .668, .760, .627, .741,
     2       .609, .772, .879, .909, .668, .760, .627, .741,
CC..2500/Idle Test emission effect of repairs for VERY HIGHS
     1       .609, .772, .879, .909, .668, .760, .627, .741,
     2       .609, .772, .879, .909, .668, .760, .627, .741 /
CC
CC..                RMAR(IP,ITECH,ISTD,ITEST)
CC                  (Same as for Very Highs)
      DATA RMAR/
CC..2500/Idle Test emission effect of repairs for HIGHS
     1       .609, .772, .879, .909, .668, .760, .627, .741,
     2       .609, .772, .879, .909, .668, .760, .627, .741,
CC..2500/Idle Test emission effect of repairs for HIGHS
     1       .609, .772, .879, .909, .668, .760, .627, .741,
     2       .609, .772, .879, .909, .668, .760, .627, .741,
CC..2500/Idle Test emission effect of repairs for HIGHS
     1       .609, .772, .879, .909, .668, .760, .627, .741,
     2       .609, .772, .879, .909, .668, .760, .627, .741 /
CC
CC..                RNOR(IP,ITECH,ISTD,ITEST)
CC
      DATA RNOR/
CC..2500/Idle Test emission effect of repairs for NORMALs
     1       .375, .508, .352, .390, .263, .280, .420, .603,
     2       .375, .508, .352, .390, .263, .280, .420, .603,
CC..2500/Idle Test emission effect of repairs for NORMALs
     1       .375, .508, .352, .390, .263, .280, .420, .603,
     2       .375, .508, .352, .390, .263, .280, .420, .603,
CC..2500/Idle Test emission effect of repairs for NORMALs
     1       .375, .508, .352, .390, .263, .280, .420, .603,
     2       .375, .508, .352, .390, .263, .280, .420, .603 /
C
      END
```

```
      BLOCK DATA BD06
CC
CC..Fleet Description Block
CC
      COMMON /DAT02/ AMIL(25),ODOM(25),TMILE(25),WGT(25)
      COMMON /DAT06/ FRAC(4,12)
CC
CC..Technology Sales Fractions Projections
CC..        FRAC(ITECH,MYR)
CC
      DATA FRAC /
CC     MPFI  TBI   Carb  Oplp
CC..1981 Model Year
     * .061, .029, .629, .281,
CC..1982 Model Year
     * .062, .106, .506, .325,
CC..1983 Model Year
     * .088, .183, .486, .244,
CC..1984 Model Year
     * .110, .282, .551, .058,
CC..1985 Model Year
     * .307, .208, .408, .077,
CC..1986 Model Year
     * .400, .270, .325, .005,
CC..1987 Model Year
     * .374, .365, .250, .010,
CC..1988 Model Year
     * .492 ,.407, .101, .000,
CC..1989 Model Year
     * .597, .275, .125, .003,
CC..1990 Model Year
     * .761, .219, .018, .001,
CC..1991 Model Year
     * .795, .202, .003, .000,
CC..1992 and Newer Model Years
     * .815, .185, .000, .000 /
CC
CC..Fleet January 1st VMT weighting factors
CC
      DATA WGT / 0.030, 0.120, 0.111, 0.099, 0.088,
     *           0.078, 0.068, 0.060, 0.054, 0.048,
     *           0.043, 0.038, 0.033, 0.028, 0.024,
     *           0.020, 0.017, 0.013, 0.010, 0.007,
     *           0.004, 0.002, 0.002, 0.001, 0.003 /
CC
CC..Cumulative January 1st mileage accumulation by age
CC
      DATA ODOM/ 1.3118, 2.6058, 3.8298, 4.9876, 6.0829,
     *           7.1190, 8.0991, 9.0262, 9.9031,10.7326,
     *          11.5172,12.2594,12.9615,13.6257,14.2540,
     *          14.8483,15.4104,15.9421,16.4451,16.9209,
     *          17.3712,17.7969,18.1997,18.5806,18.9410 /
CC
      END
      BLOCK DATA BD07
C
C  Oxygenated Fuels Effects Block
C
      COMMON /DAT05/ OXYE(2,3,4,3),OXYCON
C
```

```
      DATA OXYCON / 1.0 /
C
C  OXYE(XY,IEMIT,ITECH,IP)
C
      DATA OXYE /
C HC
     * 24*0.00,
C CO
     * 3.50,3.46, 15.26,9.87, 95.79,11.44,
     * 3.72,4.93, 15.26,9.87, 95.79,11.44,
     * 4.18,6.77, 15.26,9.87, 95.79,11.44,
     * 3.50,9.97, 15.26,9.97, 95.79, 9.97,
C NOx
     * 24*0.00 /
C
      END
```

# APPENDIX C

## EVAPORATIVE EMISSIONS AND RUNNING LOSS

## EMISSION FACTOR DERIVATION

# EVAPORATIVE HC EMISSIONS

## 1.0 Introduction

There have been more vehicles tested by EPA's Emission Factors Program (EFP) since the issuance of MOBILE4. From the EFP test facility located at Motor Vehicle Emissions Laboratory (MVEL) in Ann Arbor, Michigan (EFP-MVEL), EPA continues recruiting in-use vehicles and testing them with the certification test procedure -- a diurnal test, followed by exhaust emissions test on a Federal Testing Procedure (FTP) cycle, and then a hot soak test. A certification test fuel with fuel volatility level of 9.0 psi Reid Vapor Pressure (RVP) is used. Two additional fuels with 10.4 and 11.7 psi RVPs were also used during FY84 through FY89 to characterize the evaporative emissions effect due to different fuel volatility levels that were commercially available for in-use vehicles. Since FY90, the 9.0 psi RVP fuel has been the only gasoline fuel used in the EFP-MVEL testing.

EPA added "Hammond Program" (EFP-Hammond) to the so-called MVEL "traditional" EFP during FY90. A brief description of this new program is given in section 1.1. Due to the addition of this new test program, a different modeling approach is used for MOBILE4.1's evaporative diurnal and hot soak emissions.

For example, in the MOBILE4 evaporative diurnal and hot soak emissions model, there were seven elements of evaporative emissions: standard level, emissions due to insufficient canister purge, emissions due to excess fuel volatility, problem-free emission levels, emissions due to malmaintenance and/or defect, non-tampered emission levels, and emissions from tampering. The problem-free emission rates were the sum of the first three elements. The non-tampered emissions were the emissions from problem-free vehicles plus the emissions from malmaintenance and/or defect. Finally, the in-use evaporative diurnal and hot soak emissions were estimated by accounting for emissions from both the non-tampered and tampered fractions of the vehicle fleet.

However, in the MOBILE4.1 evaporative emissions model, there are three different types of evaporative HC emissions: emissions from pass vehicles, emissions from vehicles that failed pressure test, and emissions from vehicles that failed purge test. These three types of emissions are defined for both diurnal and hot soak emissions in MOBILE4.1.

## 1.1 Hammond Program

EPA's Hammond program was initiated in FY90. This program utilizes the testing facilities for the State of Indiana's Inspection and Maintenance (I/M) programs located at Hammond, Indiana. While waiting for the required I/M tests, in-use vehicle owners were asked to participate additional tests defined by EPA's new EFP. One of the tests those I/M vehicles were asked to participate was a transient cycle called "IM240," which is a shortened version of the certification FTP cycle. All participating vehicles were also tested for their evaporative emissions control system to see if there exists either pressure and/or purge failure.

The pressure test is performed by using a gauge to measure the pressure between a vehicle's fuel tank rollover valve and evaporative canister, by introducing nitrogen at 14" of water pressure. Two minutes after the initiation of this test, if the evaporative system holds less than 8" pressure, the vehicle is considered to have pressure problem in its evaporative emissions control system, thus failing the pressure test.

The purge test is performed by using a flow meter measuring the purge air between a vehicle's canister and engine. The cumulative purge air over the entire IM240 cycle is measured. If the flow rates are less than 1.0 cubic liter, the vehicle's evaporative emissions control system is considered to have insufficient purge, thus failing the purge test.

As of January 30, 1991, 2,497 I/M vehicles were tested for potential pressure and purge failures under the Hammond program. The model years of these in-use vehicles ranged from 1976 to 1991. Overall failure rates were: 12.7 percent for the pressure test, 11.5 percent for the purge test, and 21.1 percent for either. These failure rates were analyzed and then characterized in terms of vehicle's age, and are summarized in Table 1.

Some of the failed vehicles were also tested for their diurnal and hot soak emission levels. The results seem to suggest that emissions from vehicles that failed pressure test are similar to the emissions from vehicles with no evaporative emissions control system, and are somewhat higher than the emissions from vehicles that failed purge test.

## 1.2 Modeling Approach

As mentioned in section 1.0, the MOBILE4.1 evaporative emissions model include: emissions from pass vehicles, emissions from vehicles that failed pressure test, and emissions from vehicles that failed purge test.

Test results obtained from EFP-MVEL were used to:

a) characterize the fuel volatility effect on emissions,
b) derive emission levels for pass vehicles, and,
c) describe the emissions effects due to other parameters, such as fuel delivery system, vehicle type, etc.

Results obtained from EFP-Hammond program were used to:

a) define pass versus pressure and/or purge failure vehicles,
b) estimate the emission levels due to pressure and/or purge failures, and,
c) see if the pressure/purge test results are applicable to and/or are consistent with mechanics' visual diagnosis check in EPA's EFP at MVEL.

In addition to test data, a theoretical vapor generating model (based on Wade equation) was also used for the diurnal emissions model to:

a) determine the emissions effect from a combination of fuel volatility, temperature rise, fuel tank capacity, and tank fill level,

b) describe the emissions from vehicles that failed either pressure or purge test, and,

c) define the emission levels from vehicles that have two or more consecutive no-driving days.

The "pass" vehicles are defined as vehicles that are not tampered, nor failing pressure/purge tests. Therefore, in terms of the MOBILE4 evaporative emissions categories, the pass vehicles include vehicles that have no visible nor measurable problems in their evaporative emissions control system components, or problems that do not appear to directly relate to pressure leaks or purge deficiency.

Table 2 provides a list of the criteria used in defining pressure/purge failures as well as tampered vehicles from the EFP-MVEL data base. As can be seen, "tampered" in the MOBILE4.1 model is now a subsample of the failure vehicles by definition. In general, pressure failures indicate the potential existence of a leakage on vehicle's evaporative emissions control system components, which include: gas cap, filler neck, sending unit, rollover valve, and vent hoses. Purge failures are usually caused by an in-operative canister purge solenoid or valve, or disconnected, missing, or damaged purge hoses.

## 2.0 Diurnal Emissions

As in MOBILE4, the diurnal emissions (in unit of grams per one hour test) are described as a function of Uncontrolled Diurnal Index (UDI). This UDI is the uncontrolled diurnal emissions (in grams), calculated from a combination of weathered fuel volatility level (in psi RVP), fuel tank temperature rise (in °F), fuel tank capacity (assumed a sales-weighted 16.2 gallon tank for LDGVs), and percent tank fill (set as 54.57%), normalized at FTP conditions (which include using 9.0 psi RVP fuel, 60 to 84°F temperature rise, and 40% tank fill). The calculations of uncontrolled diurnal emissions are based upon a theoretical vapor generating model (Wade equation). For example, with 9.0 psi RVP fuel, 72 to 96°F temperature rise and 40% tank fill, the UDI is calculated to be 1.7448. The followings are some examples of the calculated UDI values, all at 60 to 84°F temperature rise and 40% tank fill, with different fuel volatility levels:

| | Fuel Volatilities in psi RVP | | | |
|---|---|---|---|---|
| | 9.0 | 10.5 | 11.5 | 11.7 |
| UDI | 1.0 | 1.4567 | 1.9581 | 2.0677 |

The UDIs are used to describe diurnal emissions for pass vehicles as well as for vehicles that failed pressure/purge tests.

### 2.1 1981+ Light-Duty Gasoline-Powered Vehicles and Trucks

The MOBILE4.1 diurnal emissions for model years 1981 and later light-duty gasoline-powered vehicles and trucks (LDGVs and LDGTs) are based upon EPA's EFP test results. Table 3 summarizes the emissions data obtained from EFP-MVEL in terms of sample sizes and average emissions for various categories (such as pass/fail vehicles, different fuel delivery systems and vehicle types).

Note that due to a lack of class 2 truck data in the EFP-MVEL sample, the two classes of light-duty trucks (classes 1 and 2) are combined as one LDGT group. Also, because of insufficient data, two types of fuel injection fuel delivery systems (ported fuel-injection [PFI] and throttle body fuel-injection [TBI]) are also being combined as one fuel-injected (FINJ) group for the LDGTs.

#### 2.1.1 Pass Vehicles

Diurnal emissions for pass vehicles were derived from EPA's EFP-MVEL data. The derived equational form for model years 1981+ pass light-duty vehicles and trucks is:

$$DI_{Pass} = a + b * UDI + c * UDI^2 \quad (2.1)$$

where:

| Vehicle Type /Fuel System | Regression Coefficient a | b | c |
|---|---|---|---|
| LDGV/CARB | -4.3304 | 5.9904 | 0.0 |
| LDGV/PFI | -0.0879 | 0.0 | 1.4179 |
| LDGV/TBI | -0.8233 | 0.0 | 2.0433 |
| LDGT/CARB | -7.6803 | 9.7703 | 0.0 |
| LDGT/FINJ | -3.8537 | 4.9437 | 0.0 |

The coefficients from equation (2.1) were derived from EFP-MVEL data, where the three UDI values corresponding to 9.0, 10.4, and 11.7 psi RVP fuel volatility levels were 1.0, 1.4567, and 2.0677, respectively. The constant terms of equation (2.1) (denoted as "a" above) were adjusted so that when UDI is 1.0 the predicted diurnal emissions are equal to the average diurnal emissions at 9.0 psi RVP from the EFP-MVEL sample.

For carbureted vehicles, the equation (2.1) is to be extrapolated when the UDI values are greater than 2.0677. However, when the UDI values are less than 1.0, new sets of coefficients listed below are used. These coefficients were derived from a two-step analysis: first, all carbureted vehicle data were used to fit an exponential function, then, the predicted emissions for UDIs at 1.0 and lower were used to fit a linear regression line. Again, the constant terms were adjusted so that when UDI is 1.0 the predicted diurnal emissions are equal to the average diurnal emissions at 9.0 psi RVP from the EFP-MVEL sample. In addition, a lower bound of the diurnal emissions is set to equal to the resting loss emissions.

| Vehicle Type /Fuel System | Regression Coefficient a | b | c |
|---|---|---|---|
| LDGV/CARB | -0.2888 | 1.9488 | 0.0 |
| LDGT/CARB | 0.1412 | 1.9488 | 0.0 |

For fuel-injected vehicles, equation (2.1) is to be extrapolated when the UDI values are beyond the existing data (i.e., UDI values are either less than 1.0 or greater than 2.0677). At low UDI values the calculated diurnal emissions may become negative. A lower bound of the diurnal emissions is set to equal to the resting loss emissions.

Graphic presentations of 1981+ LDGV/LDGT diurnal emissions as a function of UDI for pass vehicles are shown in Figures 1 and 2.

### 2.1.2 Failed Vehicles

To estimate the diurnal emission levels for vehicles that failed either pressure or purge test, two steps of analyses were used: 1) the theoretical vapor generating model, and, 2) data from EFP-Hammond.

The theoretical vapor generating model was used to describe the relationships between UDI and the emission levels from failed vehicles (see Attachment). It is assumed that fuel delivery system is not a significant parameter on failed diurnal emission levels, although the emissions simulation was based on a late model-year fuel-injection system. Uncontrolled diurnal emissions (in grams) were calculated at various fuel volatility levels (from 7.5 to 11.0 psi RVP) for the temperature rise of 72 to 96°F. These calculated uncontrolled diurnal emissions were used for the pressure failure levels. The purge failure levels were the calculated uncontrolled emissions subtracted by a backpurge effect. The g/test diurnal emissions for failed LDGVs are expressed as linear functions of UDI:

$$DI_{Failed\ Pressure} = 2.2002 + 7.5626 * UDI$$

$$DI_{Failed\ Purge} = -4.2897 + 7.4563 * UDI$$

At UDI = 1.7448 (72 to 96°F temperature rise, 9.0 psi RVP fuel, and 40% tank fill), the diurnal emissions estimated from the above two equations are 15.40 and 8.72 grams for vehicles that failed pressure and purge test, respectively.

From EFP-Hammond data base, 30 LDGVs (as listed in Table 4) were also tested for diurnal emissions under the conditions of 72 to 96°F temperature rise, 9 psi RVP fuel, and 40% tank fill (i.e., also with UDI = 1.7448). These vehicles were found to have failed either pressure or purge test at the Hammond I/M Lane. Their average diurnal emissions were:

| Category | N | G/Test Diurnal |
|---|---|---|
| Failed Pressure | 12 | 27.73 |
| Failed Purge | 18 | 15.58 |

The average diurnal emission levels from EFP-Hammond were compared with the estimated emissions from the theoretical vapor generating model. The data versus model ratios of 1.801185 ( = 27.73/15.40 for the pressure failure) and 1.786687 ( = 15.58/8.72 for the purge failure) were the multiplicative factors used to derive new diurnal emission equations for LDGVs that failed either pressure or purge test:

$$DI_{Failed\ Pressure} = 1.801185 * (2.2002 + 7.5626 * UDI)$$
$$= 3.9630 + 13.6216 * UDI \quad (2.2)$$

$$DI_{Failed\ Purge} = 1.786687 * (-4.2897 + 7.4563 * UDI)$$
$$= -7.6643 + 13.3221 * UDI \quad (2.3)$$

Note that equations (2.2) and (2.3) were derived based on a sales-weighted LDGV fuel tank capacity of 16.2 gallons. The fuel tank capacities of LDGTs are, in general, larger than the LDGVs. Many of the LDGTs are also equipped with an auxiliary fuel tank of a similiar capacity as the primary tank. Based on EPA's Certification data base, the sales-weighted primary fuel tank capacity for model year 1988 LDGTls was 19.0 gallons. When including the auxiliary fuel tank, the sales-weighted capacity for LDGTls became 20.8 gallons. Therefore, an average fuel tank capacity ratio of 1.17 (19.0 gallon/16.2 gallon) is used to estimate the diurnal emissions of failed LDGTs:

$$DI_{Failed\ LDGTs} = 1.17 * DI_{Failed\ LDGVs} \quad (2.4)$$

This approach implies that the diurnal emissions from failed LDGTs are 117 percent higher than those from failed LDGVs. This assumption is well-supported from EFP-MVEL test data. As can be seen from Table 3, the average diurnal emissions from failed LDGTs are 125 percent higher at 11.7 psi RVP fuel, and 138 percent higher at 9.0 psi RVP fuel, than the average emissions from failed LDGVs.

Under FTP conditions, the diurnal emissions for vehicles that failed either pressure or purge test are calculated to be:

| Vehicle Type | Diurnal (G/Test) Failed Pressure | Failed Purge |
|---|---|---|
| LDGVs | 17.58 | 5.66 |
| LDGTs | 20.57 | 6.62 |

In general, diurnal emission levels for vehicles that failed either pressure or purge test at any other UDI values for 1981+ LDGVs and LDGTs can be calculated from equations (2.2) through (2.4). Note that the pressure failure equation can be extrapolated down to UDI = 0.0 without getting negative emission values. When UDI is at 0.58 or lower, however, the purge failure equation is predicting zero or negative diurnal emissions. A lower bound of the failed purge diurnal emissions is also set to equal to the resting loss emissions.

Graphic presentations of 1981+ LDGV/LDGT diurnal emissions as a function of UDI for vehicles failed either pressure or purge test are shown in Figures 3 and 4.

### 2.1.3 Pre-1981 LDGV Diurnal Emission Rates

Pre-1981 model year LDGVs are predominately carbureted vehicles. In this section, the diurnal emissions from pass vehicles and from vehicles that failed either pressure or purge test for pre-1981 LDGVs are determined. The following is a list of methodologies used for deriving these emissions:

1) For pre-1971 no evaporative emission standard vehicles, all three emissions are set to be the same as the MOBILE4 uncontrolled emission rates. However, if the MOBILE4 uncontrolled emission rates are lower than the estimated emission levels from vehicles that failed pressure test, the new failed pressure emission levels are used.

2) Emissions are calculated from equations derived for 1981+ LDGV group (e.g., for diurnal emissions, use equations (2.1) through (2.4) defined in sections 2.1.1 and 2.1.2).

3) As the MOBILE4 emission rates came from the average values of test data, it is assumed that data from various model years were results from vehicles tested at about the same age by EPA's EFP. The average mileages of the current 1981+ sample were:

| VTYP | CARB | PFI | TBI | FINJ |
|---|---|---|---|---|
| LDGV | 55,057 | 42,115 | 48,890 | |
| LDGT | 52,794 | | | 44,759 |

These average mileages fell into 4-5 year old category. The fractions of the 4 year old LDGV fleet that failed either pressure or purge test are (from Table 1) 0.053 and 0.060, respectively. With the emission levels from vehicles that failed either pressure or purge test being already defined, the following relationships are established:

$$E = 0.887 * E_{Pass} + [0.053 * E_{Failed\ Pressure}] + [0.06 * E_{Failed\ Purge}]$$

Therefore, the emission levels for pass vehicles can be back calculated from the above equation.

4) Assume the same MOBILE4 uncontrolled emission rates.

5) Use the emission ratio from:

$$(MOBILE4_{MYR1} / MOBILE4_{MYR2}) = (MOBILE4.1_{MYR1} / MOBILE4.1_{MYR2})$$

6) Use the emission ratio from:

$$(Failed\ Pressure_{MYR1} / Failed\ Pressure_{MYR2}) = (Failed\ Purge_{MYR1} / Failed\ Purge_{MYR2})$$

The MOBILE4 FTP diurnal emissions in g/test for pre-1981 LDGVs at two different RVP fuels were:

| MYR Group | M4 Diurnal (G/Test) 9.0 RVP | 11.5 RVP |
|---|---|---|
| Pre-1971 | 26.08 | 47.99 |
| 1971 | 16.28 | 38.58 |
| 1972-77 | 8.98 | 23.53 |
| 1978-80 | 5.16 | 14.47 |

The derived MOBILE4.1 LDGV FTP diurnal emissions for the two RVP fuels are:

| | FTP Diurnal Emissions (G/Test) at 9.0 RVP | | | at 11.5 RVP | | |
|---|---|---|---|---|---|---|
| MYR Group | Pass | Failed Purge | Failed Pressure | Pass | Failed Purge | Failed Pressure |
| Pre-1971 | 26.08[1] | 26.08[1] | 26.08[1] | 47.99[1] | 47.99[1] | 47.99[1] |
| 1971 | 15.03[3] | 26.08[1] | 26.08[1] | 37.38[3] | 47.99[1] | 47.99[1] |
| 1972-77 | 8.27[5] | 9.33[3] | 20.39[5] | 22.80[5] | 23.83[3] | 35.45[4] |
| 1978-80 | 4.39[3] | 5.66[2] | 17.58[2] | 13.24[3] | 18.42[2] | 30.64[2] |
| 1981+ Carb | 1.66[2] | 5.66[2] | 17.58[2] | 7.40[2] | 18.42[2] | 30.64[2] |

Note that the 1981+ carbureted diurnal emissions were calculated from equations (2.1) through (2.3). They were listed above for comparison purposes only, since all pre-1981 LDGVs are of carbureted fuel delivery system. As in MOBILE4, the pre-1981 FTP LDGV diurnal emissions in g/test for any other RVP fuels are calculated by interpolating between these two given emission levels.

Using the assumption that in-use vehicles were tested at the age of four, the MOBILE4.1 FTP diurnal emissions in g/test for LDGVs at two different RVP fuels are:

| MYR Group | M4.1 Diurnal (G/Test) 9.0 RVP | 11.5 RVP |
|---|---|---|
| Pre-1971 | 26.08 | 47.99 |
| 1971 | 16.28 | 38.58 |
| 1972-77 | 8.98 | 23.53 |
| 1978-80 | 5.16 | 14.47 |
| 1981+ Carb | 2.74 | 9.29 |

### 2.1.4 Pre-1981 LDGT1 Diurnal Emission Rates

In MOBILE4, as well as its earlier versions, pre-1981 LDGV emission rates were used directly for pre-1981 LDGT1s, since there were insufficient test data from LDGT1s to derive their own emission rates and LDGT1s have the same evaporative emission standards as the LDGVs. The MOBILE4 FTP diurnal emissions in g/test for pre-1981 LDGT1s at two different RVP fuels were:

| | M4 Diurnal (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1971 | 26.08 | 47.99 |
| 1971 | 16.28 | 38.58 |
| 1972-77 | 8.98 | 23.53 |
| 1978-80 | 5.16 | 14.47 |

However, as discussed in section 2.1.2, LDGT1s in general are equipped with larger capacity of fuel tank than the LDGVs. From model years 1981+ EF data, where the majority of truck data were available, the average LDGT1 diurnal emissions are found to be significantly higher than their LDGV counterpart (see Table 3). Thus, it is reasonable for LDGT1's to have higher diurnal emissions than the LDGVs, whether for pass vehicles, or for vehicles that failed either pressure or purge test.

The MOBILE4.1 LDGT1 diurnal emission rates were estimated by multiplying a factor of 1.17 (the ratio of the average LDGT1 and LDGV fuel tank capacities, as discussed in section 2.1.2).

| | FTP Diurnal Emissions (G/Test) | | | | | |
|---|---|---|---|---|---|---|
| | at 9.0 RVP | | | at 11.5 RVP | | |
| MYR Group | Pass | Failed Purge | Failed Pressure | Pass | Failed Purge | Failed Pressure |
| Pre-1971 | 30.51 | 30.51 | 30.51 | 56.15 | 56.15 | 56.15 |
| 1971 | 17.59 | 30.51 | 30.51 | 43.73 | 56.15 | 56.15 |
| 1972-77 | 9.68 | 10.92 | 23.86 | 26.68 | 27.88 | 41.48 |
| 1978-80 | 5.14 | 6.62 | 20.57 | 15.49 | 21.55 | 35.85 |
| 1981+ Carb | 2.09[2] | 6.62 | 20.57 | 11.45[2] | 21.55 | 35.85 |

Note that the 1981+ carbureted diurnal emissions were calculated from equations (2.1) through (2.4). They were listed above for comparison purpose only, since all pre-1981 LDGT1s are of carbureted fuel delivery system. As in MOBILE4, the pre-1981 FTP LDGT1 diurnal emissions in g/test for any other RVP fuels are calculated by interpolating between these two given emission levels.

Using the assumption that in-use vehicles were tested at the age of four, the MOBILE4.1 FTP diurnal emissions in g/test for LDGT1s at two different RVP fuels are:

| | M4.1 Diurnal (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1971 | 30.51 | 56.15 |
| 1971 | 19.05 | 45.13 |
| 1972-77 | 10.51 | 27.54 |
| 1978-80 | 6.05 | 16.93 |
| 1981+ Carb | 3.34 | 13.35 |

As can be seen, the new LDGT1 diurnal emissions for MOBILE4.1 are slightly higher than the diurnal rates assumed for MOBILE4.

### 2.1.5 Pre-1981 LDGT2 Diurnal Emission Rates

In MOBILE4, the same post-1979 LDGT1 diurnal emissions were assumed for LDGT2s, based on their similar evaporative emissions standards and their similar fuel tank capacities. The diurnal emissions for pre-1979 LDGT2s were assumed to be the same as the pre-controlled HDGV diurnal emission levels, as there were no separate vehicle category of LDGT2 before the model year of 1979. The MOBILE4 FTP diurnal emissions in g/test for LDGT2s at two different RVP fuels were:

| | M4 Diurnal (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1979 | 42.33 | 77.89 |
| 1979-80 | 5.16 | 14.47 |

Using the same methodology as in LDGT1s (section 2.1.4), the MOBILE4.1 FTP g/test diurnal emissions for LDGT2s at two different RVP fuels are:

| | FTP Diurnal Emissions (g/test) | | | | | |
|---|---|---|---|---|---|---|
| | at 9.0 RVP | | | at 11.5 RVP | | |
| MYR Group | Pass | Failed Purge | Failed Pressure | Pass | Failed Purge | Failed Pressure |
| Pre-1979 | 42.33 | 42.33 | 42.33 | 77.89 | 77.89 | 77.89 |
| 1979-80 | 5.14 | 6.62 | 20.57 | 15.49 | 21.55 | 35.85 |
| 1981+ Carb | 2.09[2] | 6.62 | 20.57 | 11.45[2] | 21.55 | 35.85 |

Note that the 1981+ carbureted diurnal emissions were calculated from equations (2.1) through (2.4). They were listed above for comparison purpose only, since all 1979-80 LDGT2s are of carbureted fuel delivery system. As in MOBILE4, the pre-1981 FTP LDGT2 diurnal emissions in g/test for any other RVP fuels are calculated by interpolating between these two given emission levels.

Using the assumption that in-use vehicles were tested at the age of four, the MOBILE4.1 FTP diurnal emissions in g/test for LDGT2s at two different RVP fuels are:

| | M4.1 Diurnal (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1979 | 42.33 | 77.89 |
| 1979-80 | 6.05 | 16.93 |
| 1981+ Carb | 3.34 | 13.35 |

### 2.1.6 HDGV Diurnal Emission Rates

The MOBILE4 FTP diurnal emissions in g/test for HDGVs at two different RVP fuels were:

| | M4 Diurnal (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1985 | 42.33 | 77.89 |
| 1985+ | 4.68 | 17.94 |

The same algorithm as MOBILE4 HDGV evaporative emissions were used to estimate model year 1985+ HDGV diurnal emission levels for pass vehicles, as well as HDGVs that failed either pressure or purge test. The bases used in the calculations were the 1981+ LDGT1 diurnal emission rates (i.e., 2.09/11.45 g/test for pass vehicles, 20.57/35.85 g/test for vehicles that failed pressure test, and 6.62/21.55 g/test for vehicles that failed purge test, at 9.0 and 11.5 psi RVP fuels, respectively). In general, the following equation is used to estimate HDGV diurnal emission rates:

$$DI_{HDGV} = [DI_{LDGT1} * 1.5 * 0.875] + [DI_{LDGT1} * 2.0 * 0.125]$$

where, the constant values of 1.5 and 2.0 were the ratios of the evaporative emission standards between HDGVs and LDGT1s. The constant values of 0.875 and 0.125 were the estimated market shares of HDGVs under each evaporative emissions standards.

The MOBILE4.1 FTP g/test diurnal emissions for HDGVs at two different RVP fuels were:

| | FTP Diurnal Emissions (g/test) | | | | | |
|---|---|---|---|---|---|---|
| | at 9.0 RVP | | | at 11.5 RVP | | |
| MYR Group | Pass | Failed Purge | Failed Pressure | Pass | Failed Purge | Failed Pressure |
| Pre-1985 | 42.33 | 42.33 | 42.33 | 77.89 | 77.89 | 77.89 |
| 1985+ | 3.27 | 10.34 | 32.14 | 17.89 | 33.67 | 56.02 |

As in MOBILE4, the FTP HDGV diurnal emissions in g/test for any other RVP fuels are calculated by interpolating between these two given emission levels. Assuming that in-use vehicles were tested at the age of four, the MOBILE4.1 FTP diurnal emissions in g/test for HDGVs at two different RVP fuels are:

| | M4.1 Diurnal (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1985 | 42.33 | 77.89 |
| 1985+ | 5.22 | 20.86 |

### 2.1.7 Motorcycle Diurnal Emission Rates

There were no new data available for the motorcylce diurnal emissions since the release of MOBILE4 model. Therefore, the MOBILE4.1 diurnal emissions for motorcycles are the same as those used for MOBILE4.

## 2.2 Other Types of Diurnal Emissions

Three other types of diurnal emissions used in the MOBILE4/MOBILE4.1 models are: in-use full diurnal emissions (FDI), partial diurnal emissions (PDI), and multiple diurnal emissions (MDI). The g/test diurnal emissions discussed in the previous sections (2.1, 2.1.1 through 2.1.7) were all derived from one hour heat build test results.

Under in-use conditions, however, vehicles may experience diurnal emissions from a much slower temperature rise for a much longer time frame, for example, for the entire period of six hours when the ambient temperatures are increasing from the minimum to the maximum. Sometimes one full diurnal may be interrupted (or cut short) by the start of a trip during the ambient temperature rising period so that vehicles may only experience a partial diurnal. Vehicles may have multiple diurnal emissions when they have not being driven for two or more consecutive days. Some vehicles may have short but frequent trips or one long trip that they have no diurnal emissions at all during one particular day. The fractions of occurrences of these various types of diurnal emissions are discussed in section 5.0. The levels of these various types of diurnal emissions are discussed in the following sections.

### 2.2.1 In-Use G/Day Full Diurnal (FDI) Emissions

In MOBILE4, the in-use (6-hour) g/day full diurnal emissions are the FTP one-hour emission rates (g/test) adjusted for 121 and 124 percent at 9.0 and 11.5 psi RVP fuels, respectively.

There has been very limited data available in this area since the release of MOBILE4 model. The adjustment factors of 1.21 and 1.24 were derived from testing of one late model year carbureted vehicle with its canister disconnected. It is unclear whether the differences in emissions between a slower (six hours) temperature rise and faster (one hour) heat build should be classified as diurnal or resting loss emissions, as the levels seem to be more similar to the latter. For these reasons, it is assumed that the 21 (or 24) percent emission increases due to the slower temperature rise are the resting loss emissions and the in-use six-hour full diurnal emission rates are the same as the one-hour FTP diurnal emissions. Consequently, the MOBILE4 adjustment factors of 1.21 and 1.24 used for in-use full diurnal emission calculations are no longer applicable in MOBILE4.1.

## 2.2.2 Partial Diurnal (PDI) Emissions

Many of the MOBILE4 assumptions used for partial diurnals remained unchanged for the MOBILE4.1 model, with one exception.

By definition, partial diurnals occur only when the vehicle's engine has been turned-off for at least three hours, but less than six hours, between the daily minimum and maximum temperatures when the ambient temperatures are increasing (i.e., between 7 AM and 3 PM). The two temperatures used to calculate the partial diurnal emissions are:

1) the ambient temperature at two hours (rather than the one hour assumed in MOBILE4) after the end of a trip, and,

2) the ambient temperature at the time when a new trip starts.

The three types of partial diurnals and their characteristics are described below:

| Description | Temperature | | Percent of Occurrence |
|---|---|---|---|
| | Minimum | Maximum | |
| 8 AM - 11 AM | $T_{10AM}$ | $T_{11AM}$ | 32.36 |
| 10 AM - 3 PM | $T_{12PM}$ | $T_{3PM}$ | 7.09 |
| 8 AM - 2 PM | $T_{10AM}$ | $T_{2PM}$ | 3.69 |

The temperatures at 10AM, 11AM, and 2PM are calculated by the following equations:

$$T_{10\ AM} = Tmin + 0.53 * (Tmax - Tmin) \quad (2.5)$$

$$T_{11\ AM} = Tmin + 0.71 * (Tmax - Tmin) \quad (2.6)$$

$$T_{2\ PM} = Tmin + 0.94 * (Tmax - Tmin) \quad (2.7)$$

where:

Tmin = the minimum temperature of the day, in °F
Tmax = the maximum temperature of the day, in °F.

The ambient temperature at 3PM is just the maximum ambient temperature of the day.

### 2.2.3 Multiple Diurnal (MDI) Emissions

In MOBILE4, due to a lack of data, the adjusted in-use diurnal emissions from tampered vehicles were used for multiple diurnal emission rates. It has been suggested that this assumption may not be technically correct. With vehicles parked for two or more consecutive days, their diurnal emission levels are dependent upon many factors: ambient temperature rise, backpurge during the cooling of the ambient temperature, canister capacity and efficiency, fuel weathering, and tank fill level. When all these parameters are being considered, the multiple diurnal emissions may be lower (on a grams-per-day basis) than the diurnal emissions under uncontrolled or tampered conditions.

Similar to the FTP one-hour (or in-use full) diurnal emissions, the MOBILE4.1 multiple diurnal emissions model also includes three elements: emissions from pass vehicles, emissions from vehicles that failed pressure test, and emissions from vehicles that failed purge test. Multiple diurnal emissions for vehicles that failed either pressure or purge test are assumed to be the same as their FTP one-hour diurnal counterparts. These emissions were based on both the theoretical vapor generating model and test data from EFP-Hammond (see discussions in section 2.1.2).

Multiple diurnal emission rates for pass vehicles were based on the theoretical vapor generating model. Overall grams per day emissions modeled from late model year fuel-injected technology vehicles were simulated at various fuel volatility levels for one to seven consecutive no-driving days. The temperature rise of 72 to 96°F and 40% tank fill level were assumed. Also, it is assumed that backpurge occures in 50% of the vehicles experiencing multiple diurnals.

To summarize results, Table 2 from Attachment has been copied and presented at the top portion of Table 5. Ratios of emissions from any day (day 2 through day 7) to emissions at day 1 for each fuel volatility level were calculated and listed at the lower portion of Table 5. These ratios, then, were weighted according to the re-normalized fractions of occurrence for days 2 through 7. Finally, a nonlinear regression line was fitted through the weighted ratios. The equational form for the ratio as a function of fuel volatility is:

$$CF_{MDI,Pass} = EXP\ (4.8491 - 0.33424 * RVP) \qquad (2.8)$$

Both the weighted and predicted ratios at each fuel volatility level are given in Table 5. The multiple diurnal emissions for pass vehicles are calculated by:

$$MDI_{Pass} = DI_{Pass} * CF_{MDI,Pass} \qquad (2.9)$$

Using equations (2.8) and (2.9), the multiple diurnal emissions for pass vehicles are sometimes calculated to be higher than the emissions from vehicles that failed purge, especially for pre-2.0 SHED evaporative emissions standard vehicles (e.g., pre-1981 LDGVs). One of the reasons is that the emissions calculated to derive equation (2.8) were based on late model year fuel-injected vehicle performance, while all pre-2.0 SHED evaporative emissions standard vehicles are of carbureted technology. Also, for the pre-2.0 SHED evaporative emissions standard era, the emission levels for pass vehicles were similar to the emission levels for vehicles that failed purge. Therefore, it is reasonable to set the maximum levels of multiple diurnal emissions for pass vehicles equal to the emissions from vehicles that failed purge, i.e.,

$$MDI_{Pass} = MDI_{Failed\ Purge} \qquad (2.10)$$

To summarize, multiple diurnal emissions for pass vehicles are calculated by the following two methods:

1) use equations (2.8) and (2.9), or,

2) use equation (2.10), if the calculated emission levels from equations (2.8) and (2.9) are greater than the multiple diurnal emissions from vehicles that failed purge.

These two methods are used for all LDGVs and LDGTs, pre-1981 model years as well as 1981+ model years. As there is no multiple diurnals assumed for HDGVs and MCs, these two methods are not applicable to these two vehicle types.

## 3.0 Hot Soak Emissions

As in MOBILE4, the hot soak emissions (in unit of grams per one hour test) are described as two step functions of fuel volatility in psi RVP and ambient temperature in °F. The hot soak emissions are measured at FTP test conditions, i.e., with 9.0 psi RVP fuel, 40% tank fill, and at the ambient temperature of 82°F. In the model, hot soak emissions are first adjusted for fuel volatility effect, then corrected for the temperature effect at ambient temperatures 41°F and higher.

### 3.1 1981+ LDGVS and LDGTS

As in the MOBILE4.1 diurnal emissions model, the g/test hot soak emissions are derived for pass vehicles, for vehicles that failed pressure test, and for vehicles that failed purge test. Table 3 also summarizes the average hot soak emissions from the current EFP-MVEL data base.

#### 3.1.1 Pass Vehicles

Hot soak emissions for pass vehicles were derived from EPA's EFP-MVEL data. For model years 1981+ pass light-duty vehicles and trucks, the derived equational forms for g/test hot soak emissions are:

$$HS_{Pass} = a + b * RVP \qquad (3.1)$$

or,

$$HS_{Pass} = c + d * RVP + e * RVP^2 \qquad (3.2)$$

where:

| Vehicle Type /Fuel System | Regression Coefficient a | b | c | d | e |
|---|---|---|---|---|---|
| LDGV/CARB | 0.14593 | 0.13823 | -1.436657 | 0.0 | 0.034897 |
| LDGV/PFI | -0.46673 | 0.10297 | 18.437 | -4.2538 | 0.25072 |
| LDGV/TBI | 0.198327 | 0.041297 | -4.669710 | 0.58219 | 0.0 |
| LDGT/CARB | -0.16407 | 0.13823 | -5.196600 | 0.69740 | 0.0 |
| LDGT/FINJ | 0.078327 | 0.041297 | -4.789710 | 0.58219 | 0.0 |

Equation (3.1) is used when fuel volatility is less than 9.0 psi RVP, while equation (3.2) is used when fuel volatility is equal to or high than 9.0 psi RVP. The coefficients from equation (3.1) were regression results from data where the fuel RVP is 9.0 psi and from limited emissions data at lower fuel volatility levels of 6.5 and 8.0 psi RVP. The coefficients from equation (3.2) were derived from EFP-MVEL data, where the three fuel volatility levels were 9.0, 10.5, and 11.7 psi RVP.

The constant terms of equations (3.1) and (3.2) (denoted as "a" and "c" above) were adjusted so that at 9.0 psi RVP the predicted hot soak emissions are equal to the average values at 9.0 psi RVP of the EFP-MVEL sample. Note that the lower bound of fuel volatility for equation (3.1) is 5.0 psi RVP, and the lower bound of hot soak emissions is set to equal to the resting loss emissions.

Graphic presentations of 1981+ LDGV/LDGT hot soak emissions for pass vehicles as a function of fuel volatility are shown in Figures 5 and 6. There has been no new data available to develop new hot soak temperature correction factors. Therefore, the equations used to correct for temperature effect from MOBILE4 will be used again in MOBILE4.1 for pass vehicles.

### 3.1.2 Failed Vehicles

During FY91, five vehicles were tested for hot soak emissions with canister connected and disconnected at two levels of fuel volatilities (9.0 and 10.5 psi RVP) and at three levels of ambient temperatures (70, 82, and 95°F). These five vehicles were:

| Model Year | Make | Fuel System |
|---|---|---|
| 1979 | Cutlass | Carbureted |
| 1983 | Cutlass | Carbureted |
| 1983 | Skylark | TBI |
| 1990 | Taurus | PFI |
| 1990 | Lumina | PFI |

Overall average hot soak emissions with canister disconnected (or uncontrolled hot soak emissions) at various ambient temperatures and fuel volatilities are summarized below:

| Temperature in °F | Hot Soak (G/Test) | |
|---|---|---|
| | 9.0 RVP | 10.5 RVP |
| 70.0 | 5.62 | 10.71 |
| 82.0 | 7.93 | 16.11 |
| 95.0 | 20.08 | 39.27 |

Regression equation has been derived to describe the relationships of the uncontrolled hot soak emissions, versus the fuel volatility, and ambient temperature:

$$HS_{uncontrolled} = EXP\ [2.2307 + 0.4443 * (RVP - 9.0) + 0.05114 * (TEMP - 82.0)]$$

where:

HS = uncontrolled hot soak emissions in g/test,
EXP = exponential function,
RVP = fuel volatility in psi, and
TEMP = ambient temperatures in °F.

Due to limited available data, it is assumed that the estimated uncontrolled hot soak emissions are the emission levels for vehicles that failed pressure test.

From EFP-Hammond data base, 18 of the 30 LDGVs (as listed in Table 4) were also tested for hot soak emissions at 92°F ambient temperature, and with 9.0 psi RVP fuel. These vehicles were found to have failed purge test at the Hammond I/M Lane. The average hot soak emissions were 10.56 g/test. Therefore, for vehicles that failed purge test, the hot soak emissions can be estimated from the above failed pressure hot soak emission equation but normalized at the average emissions from Hammond data.

The hot soak emissions equations for failed vehicles are:

$$HS_{Failed\ Pressure} = EXP\ [2.2307 + 0.4443 * (RVP-9.0) + 0.05114 * (TEMP-82.0)] \quad (3.3)$$

$$HS_{Failed\ Purge} = EXP\ [1.84567 + 0.4443 * (RVP-9.0) + 0.05114 * (TEMP-82.0)] \quad (3.4)$$

Using these two equations (3.3 and 3.4), the predicted hot soak emissions for LDGVs that failed either pressure or purge test at various ambient temperatures and fuel volatilities are shown in the table below:

| | Predicted Hot Soak (G/Test) | | | | | |
|---|---|---|---|---|---|---|
| | 9.0 RVP | | 10.5 RVP | | 11.7 RVP | |
| Temperature in °F | Failed Pres | Failed Purge | Failed Pres | Failed Purge | Failed Pres | Failed Purge |
| 70.0 | 5.04 | 3.43 | 9.81 | 6.68 | 16.72 | 11.38 |
| 82.0 | 9.31 | 6.33 | 18.12 | 12.33 | 30.89 | 21.02 |
| 92.0 | 15.52 | 10.56 | 30.22 | 20.56 | 40.00 | 35.05 |
| 95.0 | 18.09 | 12.31 | 35.23 | 23.97 | 40.00 | 40.00 |

Note that these equations can be extrapolated beyond the ambient temperature ranges of 70.0 and 95.0°F and fuel volatility levels of 9.0 and 10.5 psi RVP. To be consistent with the hot soak emissions calculations for pass vehicles, lower limits are also set at 5.0 psi RVP fuel volatility and 41°F ambient temperature. There are also a lower bound of hot soak emissions being equal to the resting loss emissions and an upper bound of 40.00 g/test of hot soak emissions for LDGVs.

Equations (3.3) and (3.4) are also used to calculate hot soak emissions for all other vehicle types (such as LDGT1s, LDGT2s, and HDGVs) that failed pressure or purge test.

Graphic presentations of 1981+ LDGV/LDGT hot soak emissions as a function of fuel volatility at 82°F for vehicles that failed either pressure or purge test are shown in Figure 7.

### 3.1.3 Pre-1981 LDGV Hot Soak Emission Rates

The same list of methodologies used to derive diurnal emissions, as described in section 2.1.3, is also used for hot soak emissions calculations. The MOBILE4 FTP hot soak emissions in g/test for pre-1981 LDGVs at two different RVP fuels were:

| | M4 Hot Soak (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1971 | 14.67 | 22.45 |
| 1971 | 10.91 | 16.15 |
| 1972-77 | 8.27 | 12.32 |
| 1978-80 | 2.46 | 4.30 |

The derived MOBILE4.1 LDGV FTP hot soak emissions for the two RVP fuels are:

| | FTP Hot Soak Emissions (g/test) | | | | | |
|---|---|---|---|---|---|---|
| | at 9.0 RVP | | | at 11.5 RVP | | |
| MYR Group | Pass | Failed Purge | Failed Pressure | Pass | Failed Purge | Failed Pressure |
| Pre-1971 | 14.67[1] | 14.67[1] | 14.67[1] | 28.26[1] | 28.26[1] | 28.26[1] |
| 1971 | 10.43[3] | 14.67[1] | 14.67[1] | 14.61[3] | 28.26[1] | 28.26[1] |
| 1972-77 | 7.77[3] | 9.98[6] | 14.67[4] | 11.10[5] | 19.23[2] | 28.26[1] |
| 1978-80 | 1.79[3] | 6.33[2] | 9.31[2] | 3.89[5] | 19.23[2] | 28.26[2] |
| 1981+ Carb | 1.39[2] | 6.33[2] | 9.31[2] | 3.18[2] | 19.23[2] | 28.26[2] |

Note that the 1981+ carbureted hot soak rates were calculated from equations (3.2) through (3.4). They were listed above for comparison purpose only, as all pre-1981 LDGVs are of carbureted fuel delivery system. As in MOBILE4, the pre-1981 FTP LDGV hot soak emissions in g/test for any other RVP fuels are calculated by interpolating between these two given emission levels.

Using the assumption that in-use vehicles were tested at the age of four, the MOBILE4.1 FTP hot soak emissions in g/test for LDGVs at two different RVP fuels are:

| | M4.1 Hot Soak (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1971 | 14.67 | 28.26 |
| 1971 | 10.91 | 16.15 |
| 1972-77 | 8.27 | 12.50 |
| 1978-80 | 2.46 | 6.10 |
| 1981+ Carb | 1.91 | 5.47 |

### 3.1.4 Pre-1981 LDGT1 Hot Soak Emission Rates

As in MOBILE4, the pre-1981 LDGV hot soak emission rates are used also for pre-1981 LDGT1s because of their similar evaporative emission standards. The MOBILE4 FTP hot soak emissions in g/test for pre-1981 LDGT1s at two different RVP fuels were:

| | M4 Hot Soak (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1971 | 14.67 | 22.45 |
| 1971 | 10.91 | 16.15 |
| 1972-77 | 8.27 | 12.32 |
| 1978-80 | 2.46 | 4.30 |

The derived MOBILE4.1 LDGT1 FTP hot soak emissions for the two RVP fuels are:

| | FTP Hot Soak Emissions (g/test) | | | | | |
|---|---|---|---|---|---|---|
| | at 9.0 RVP | | | at 11.5 RVP | | |
| MYR Group | Pass | Failed Purge | Failed Pressure | Pass | Failed Purge | Failed Pressure |
| Pre-1971 | 14.67 | 14.67 | 14.67 | 28.26 | 28.26 | 28.26 |
| 1971 | 10.43 | 14.67 | 14.67 | 14.61 | 28.26 | 28.26 |
| 1972-77 | 7.77 | 9.98 | 14.67 | 11.10 | 19.23 | 28.26 |
| 1978-80 | 1.79 | 6.33 | 9.31 | 3.89 | 19.23 | 28.26 |
| 1981+ Carb | 1.08 | 6.33 | 9.31 | 2.82 | 19.23 | 28.26 |

Note that the 1981+ carbureted hot soak rates were calculated from equations (3.2) through (3.4). They were listed above for comparison purpose only, as all pre-1981 LDGT1s are of carbureted fuel delivery system. As in MOBILE4, the pre-1981 FTP LDGT1 hot soak emissions in g/test for any other RVP fuels are calculated by interpolating between these two given emission levels.

Assuming that in-use vehicles were tested at the age of four, the MOBILE4.1 FTP hot soak emissions in g/test for LDGT1s at two different RVP fuels are:

| | M4.1 Hot Soak (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1971 | 14.67 | 28.26 |
| 1971 | 10.91 | 16.15 |
| 1972-77 | 8.27 | 12.50 |
| 1978-80 | 2.46 | 6.10 |
| 1981+ Carb | 1.83 | 5.15 |

### 3.1.5 Pre-1981 LDGT2 Hot Soak Emission Rates

As in MOBILE4, the same post-1979 LDGT1 hot soak emission rates are assumed for LDGT2s, based on their similar evaporative emission standards. The pre-1979 LDGT2 hot soak emission rates were the same as the pre-controlled HDGV hot soak rates, as there were no separate vehicle category of LDGT2s before the model year of 1979. The MOBILE4 FTP hot soak emissions in g/test for pre-1981 LDGT2s at two different RVP fuels were:

| | M4 Hot Soak (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1979 | 18.08 | 27.66 |
| 1979-80 | 2.46 | 4.30 |

The derived MOBILE4.1 LDGT2 FTP hot soak emissions for the two RVP fuels are:

| | FTP Hot Soak Emissions (g/test) | | | | | |
|---|---|---|---|---|---|---|
| | at 9.0 RVP | | | at 11.5 RVP | | |
| MYR Group | Pass | Failed Purge | Failed Pressure | Pass | Failed Purge | Failed Pressure |
| Pre-1979 | 18.08 | 18.08 | 18.08 | 44.16 | 44.16 | 44.16 |
| 1979-80 | 1.79 | 6.33 | 9.31 | 3.89 | 19.23 | 28.26 |
| 1981+ Carb | 1.08 | 6.33 | 9.31 | 2.82 | 19.23 | 28.26 |

As in MOBILE4, the pre-1981 FTP LDGT2 hot soak emissions in g/test for any other RVP fuels are calculated by interpolating between these two given emission levels.

Assuming that in-use vehicles were tested at the age of four, the MOBILE4.1 FTP hot soak emissions in g/test for LDGT2s at two different RVP fuels are:

| | M4.1 Hot Soak (g/test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1979 | 18.08 | 44.16 |
| 1979-80 | 2.46 | 6.10 |
| 1981+ Carb | 1.83 | 5.15 |

### 3.1.6 HDGV Hot Soak Emission Rates

The MOBILE4 FTP hot soak emissions in g/test for HDGVs at two different RVP fuels were:

| | M4 Hot Soak (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1985 | 18.08 | 27.66 |
| 1985+ | 2.12 | 4.77 |

As in the diurnal emissions calculations, the same algorithm from MOBILE4 HDGV evaporative emissions are used to estimate 1985+ hot soak emission rates for pass vehicles, as well as HDGVs that failed either pressure or purge test. The bases used in the calculations were the 1981+ LDGT1 hot soak emission rates (1.08/2.82 g/test for pass vehicles, 9.31/28.26 g/test for vehicles that failed pressure test, and 6.33/19.23 g/test for vehicles that failed purge test, at 9.0 and 11.5 psi RVP fuels, respectively).

The new MOBILE4.1 FTP g/test hot soak emissions for HDGVs at two different RVP fuels are:

| | FTP Hot Soak Emissions (g/test) | | | | | |
|---|---|---|---|---|---|---|
| | at 9.0 RVP | | | at 11.5 RVP | | |
| MYR Group | Pass | Failed Purge | Failed Pressure | Pass | Failed Purge | Failed Pressure |
| Pre-1985 | 18.08 | 18.08 | 18.08 | 44.16 | 44.16 | 44.16 |
| 1985+ | 1.69 | 9.89 | 14.55 | 4.41 | 30.05 | 44.16 |

As in MOBILE4, the FTP HDGV hot soak emissions in g/test for any other RVP fuels are calculated by interpolating between these two given emission levels.

Assuming that in-use vehicles were tested at the age of four, the MOBILE4.1 FTP hot soak emissions in g/test for HDGVs at two different RVP fuels are:

| | Hot Soak (G/Test) | |
|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP |
| Pre-1985 | 18.08 | 44.16 |
| 1985+ | 2.86 | 8.06 |

### 3.1.7 Motorcycle Hot Soak Emission Rates

There were no new data available for motorcylces hot soak emission rates since the release of MOBILE4 model. Therefore, the MOBILE4.1 hot soak emissions for motorcycles are the same as those used for MOBILE4.

## 4.0 High Altitude

In MOBILE4 model, a set of altitude adjustment factors was used to calculate the evaporative diurnal and hot soak emissions for vehicles operating in high altitude region. These altitude adjustment factors were based on either actual test data or from their emissions standard ratio. For example, the MOBILE4 FTP diurnal and hot soak emissions in g/test for high altitude LDGVs at two different RVP fuels were:

| | Diurnal (G/Test) | | Hot Soak (G/Test) | |
|---|---|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP | 9.0 RVP | 11.5 RVP |
| Pre-1971 | 33.90 | 62.39 | 19.07 | 29.18 |
| 1971 | 21.16 | 50.15 | 14.18 | 20.99 |
| 1972-76 | 17.15 | 44.93 | 17.15 | 20.96 |
| 1977 | 8.98 | 23.53 | 8.27 | 12.32 |
| 1978-80 | 13.36 | 36.85 | 6.37 | 11.15 |

Note that the emission rates for model years 1972-76 were actual test results from EPA's EFP test facility in Denver, Colorado. The emissions for model year 1977 were the same as the low altitude rates (because of their same evaporative emissions standard). The emission rates for model years 1978-80 were estimated by multiplying a factor of 2.59 to the low altitude rates. Finally, the emission rates for all other model year groups were calculated by multiplying an adjustment factor of 1.30.

The same set of altitude adjustment factors is used again in MOBILE4.1 and are summarized in Table 6. The only exception is that, for model years 1978-80, the MOBILE4 adjustment factor of 2.59 has been changed to 1.30. These high altitude adjustment factors are used for both diurnal and hot soak emissions of pass vehicles, as well as vehicles that failed either pressure or purge test. For example, the derived MOBILE4.1 high altitude LDGV diurnal emissions at two RVP fuel levels are:

| | LDGV Diurnal Emissions (G/Test) | | | | | |
|---|---|---|---|---|---|---|
| | at 9.0 RVP | | | at 11.5 RVP | | |
| MYR Group | Pass | Failed Purge | Failed Pressure | Pass | Failed Purge | Failed Pressure |
| Pre-1971 | 33.90 | 33.90 | 33.90 | 62.39 | 62.39 | 62.39 |
| 1971 | 19.54 | 33.90 | 33.90 | 48.59 | 62.39 | 62.39 |
| 1972-76 | 10.16 | 13.82 | 27.46 | 33.13 | 45.06 | 56.15 |
| 1977 | 8.27 | 9.33 | 20.39 | 22.80 | 23.83 | 35.45 |
| 1978-80 | 5.71 | 7.36 | 22.85 | 17.21 | 23.95 | 39.83 |
| 1981-83 Carb | 2.16 | 7.36 | 22.85 | 9.62 | 23.95 | 39.83 |
| 1984+ Carb | 1.66 | 5.66 | 17.58 | 7.40 | 18.42 | 30.64 |

Similarly, the derived MOBILE4.1 high altitude LDGV hot soak emissions at two RVP fuel levels are:

| | LDGV Hot Soak Emissions (G/Test) | | | | | |
|---|---|---|---|---|---|---|
| | at 9.0 RVP | | | at 11.5 RVP | | |
| MYR Group | Pass | Failed Purge | Failed Pressure | Pass | Failed Purge | Failed Pressure |
| Pre-1971 | 19.07 | 19.07 | 19.07 | 36.74 | 36.74 | 36.74 |
| 1971 | 13.56 | 19.07 | 19.07 | 18.99 | 36.74 | 36.74 |
| 1972-76 | 10.03 | 14.52 | 19.07 | 18.87 | 27.30 | 36.74 |
| 1977 | 7.77 | 9.98 | 14.67 | 11.10 | 19.23 | 28.26 |
| 1978-80 | 2.33 | 8.23 | 12.10 | 5.06 | 25.00 | 36.74 |
| 1981-83 Carb | 1.81 | 8.23 | 12.10 | 4.13 | 25.00 | 36.74 |
| 1984+ Carb | 1.39 | 6.33 | 9.31 | 3.18 | 19.23 | 28.26 |

Assuming that in-use vehicles were tested at the age of four, the MOBILE4.1 FTP diurnal and hot soak emissions in g/test for high altitude LDGVs at two different RVP fuels are:

| | Diurnal (G/Test) | | Hot Soak (G/Test) | |
|---|---|---|---|---|
| MYR Group | 9.0 RVP | 11.5 RVP | 9.0 RVP | 11.5 RVP |
| Pre-1971 | 33.90 | 62.39 | 19.07 | 36.74 |
| 1971 | 21.16 | 50.15 | 14.18 | 20.99 |
| 1972-76 | 11.30 | 35.07 | 10.91 | 20.32 |
| 1977 | 8.98 | 23.53 | 8.27 | 12.50 |
| 1978-80 | 6.72 | 18.81 | 3.20 | 7.94 |
| 1981-83 Carb | 3.57 | 12.08 | 2.74 | 7.11 |
| 1984+ Carb | 2.74 | 9.29 | 2.11 | 5.47 |

## 5.0 Trip Related Estimates

Most of the MOBILE4 trip-related estimates, such as trips per day (TPD), miles per day (MPD), fractions of occurrences for FDI, MDI, and PDI are also used in MOBILE4.1, with some modifications. There is no new data available to derive new estimates. Therefore, the data base where these estimates were derived from is the same 1979 GM-NPD survey data used in MOBILE4.

### 5.1 Trips Per Day and Miles Per Day

The trips per day and miles per day equations used for LDGVs and LDGTs have the following forms:

$$TPD = 4.7187 - 0.058508 * AGE \quad (5.1)$$

$$MPD = JAMAR / 365.0 \quad (5.2)$$

where: TPD = estimated number of trips per day,
AGE = vehicle age in years,
MPD = estimated miles driven per day,
JAMAR = January 1 annual mileage accumulation rate, which is also a function of vehicle age.

These equations were used in MOBILE4 to calculate the estimated trips per day and miles per day for vehicles at ages 1 through 20. In MOBILE4.1, equations (5.1) and (5.2) are used to obtain TPD and MPD estimates for LDGVs and LDGTs for ages 1 through 25.

The TPD and MPD estimates for HDGVs and MCs remain unchanged in MOBILE4.1:

| | HDGVs | MCs |
|---|---|---|
| TPD | 6.88 | 1.35 |
| MPD | 33.97 | 10.02 |

## 5.2 Other Trip-Related Estimates -- LDGVS and LDGTS

Percents of other trip-related estimates for LDGVs and LDGTs used in MOBILE4 were:

| Description | | Percent | Total Percent |
|---|---|---|---|
| Driving Days | | 76.15 | 76.15 |
| Single Full Diurnal Days | | 22.37 | |
| Partial Diurnal Days | | 43.14 | |
| i) 8 AM to 11 AM | 32.36% | | |
| ii) 10 AM to 3 PM | 7.09% | | |
| iii) 8 AM to 2 PM | 3.69% | | |
| 3+ multiple Diurnal Days | | 3.89 | |
| No Diurnal Days | | 6.75 | |
| No Driving Days | | 23.85 | 23.85 |
| Single Full Diurnal Days | | 11.59 | |
| 2+ Multiple Diurnal Days | | 12.26 | |

In MOBILE4.1, all the above estimates are expressed in terms of vehicle's age. For example, the proportions of vehicles having at least one trip on any given day for age 1 vehicles are higher than those for age 2 vehicles, etc. The equational forms for various types of driving days (in percent) are:

Driving Days = 87.07 - 1.72 * AGE (5.3)
Single Full Diurnal = 25.58 - 0.5 * AGE (5.4)

Partial Diurnal Days:

8AM-11AM Partial Diurnal = 37.0 - 0.73 * AGE (5.5)
10AM-3PM Partial Diurnal = 8.11 - 0.16 * AGE (5.6)
8AM-2PM Partial Diurnal = 4.22 - 0.08 * AGE (5.7)

3+ Multiple Diurnal = 4.45 - 0.09 * AGE (5.8)
No Diurnal Days = 7.72 - 0.15 * AGE

The equational forms for various types of driving days (in percent) are:

No Driving Days = 12.93 + 1.72 * AGE
Single Full Diurnal Days = 6.31 + 0.84 * AGE (5.9)
2+ Multiple Diurnal Days = 6.62 + 0.88 * AGE (5.10)

Table 7 summarizes the results.

## 5.5 Other Trip-Related Estimates for HDGVs

Percents of all trip-related estimates for HDGVs used in MOBILE4 were:

| Description | Percent | Total Percent |
|---|---|---|
| Driving Days | 27.10 | 27.10 |
| No Driving Days | 72.90 | 72.90 |
| Single Full Diurnal Days | 49.80 | |
| 2 Multiple Diurnal Days | 13.70 | |
| 3+ Multiple Diurnal Days | 9.40 | |

Due to a lack of data, no equations as functions of vehicle's age were derived. These estimates are used in MOBILE4.1 again.

Table 1

Pressure/Purge Failure Rates
by Vehicle Age
Source: EPA's EFP-Hammond Data

| Age of Vehicle | LDGV Failure Rates | | |
|---|---|---|---|
| | Purge | Pressure | Either |
| 01 | 0.043 | 0.043 | 0.080 |
| 02 | 0.043 | 0.043 | 0.080 |
| 03 | 0.043 | 0.043 | 0.080 |
| 04 | 0.060 | 0.053 | 0.096 |
| 05 | 0.060 | 0.053 | 0.103 |
| 06 | 0.069 | 0.053 | 0.120 |
| 07 | 0.094 | 0.053 | 0.150 |
| 08 | 0.094 | 0.106 | 0.188 |
| 09 | 0.142 | 0.152 | 0.258 |
| 10 | 0.214 | 0.171 | 0.323 |
| 11 | 0.224 | 0.236 | 0.389 |
| 12 | 0.229 | 0.336 | 0.442 |
| 13+ | 0.229 | 0.336 | 0.451 |

Table 2

Criteria Used to Define Pressure and Purge Failures
Emission Factors Programs

| Evaporative System Component | Diagnosis |
|---|---|
| **Purge Failures** | |
| Canister Purge Solenoid/Valve | Missing<br>Disconnected or Bypassed<br>Leaks Vacuum<br>Sticking<br>Inoperative |
| Vacuum or Vent Lines | Disconnected or Missing<br>Plugged or Damaged<br>Misrouted |
| Purge Hose | disconnected or Missing<br>Split or Not sealed |
| Canister Purge TVS<br>ECM signal to purge solenoid | Stuck<br>None detected |
| **Pressure Failures** | |
| Gas Cap | Non OEM or Missing<br>Leaking |
| Sending Unit Gasket<br>Fuel Tank Rollover | Leaking<br>Valve leaking or Stuck |
| Fuel Tank Filler Neck | Leaking |
| **Both Pressure and Purge Failures** | |
| Canister<br>Carburetor Bowl Vent Line<br>Fuel Line to Canister<br>EFE Control Switch<br>Bowl Vent Solenoid | Missing<br>Disconnected or Leaks<br>Disconnected<br>Missing<br>Disconnected |

Table 3

Date: April 26, 1991

Statistics on Evaporative Emissions
(Average G/Test Hot Soak and Diurnal)
Source: EPA's EFP-MVEL

| Fuel Delivery System | 9.0 RVP | | | 10.4 RVP | | | 11.7 RVP | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | HS | DI | N | HS | DI | N | HS | DI |
| **Light-Duty Gasoline-Powered Vehicles** | | | | | | | | | |
| All | | | | | | | | | |
| Carbureted | 386 | 1.99 | 2.65 | 158 | 3.43 | 5.52 | 380 | 4.17 | 9.59 |
| PFI | 347 | 0.70 | 1.90 | 69 | 2.09 | 4.80 | 254 | 3.84 | 6.85 |
| TBI | 315 | 0.82 | 1.75 | 95 | 1.42 | 3.90 | 274 | 2.99 | 8.91 |
| Failed Purge | | | | | | | | | |
| Carbureted | 31 | 5.32 | 5.11 | 17 | 7.14 | 8.76 | 30 | 10.25 | 15.19 |
| PFI | 13 | 4.27 | 6.93 | 2 | 16.21 | 7.70 | 9 | 21.07 | 12.63 |
| TBI | 13 | 3.26 | 7.19 | 2 | 3.27 | 13.52 | 10 | 13.69 | 21.71 |
| Failed Pressure | | | | | | | | | |
| Carbureted | 37 | 3.15 | 7.44 | 17 | 6.14 | 9.76 | 37 | 5.10 | 15.93 |
| PFI | 12 | 3.22 | 10.84 | 3 | 9.16 | 9.36 | 7 | 10.96 | 25.27 |
| TBI | 9 | 2.77 | 9.21 | 2 | 1.25 | 11.77 | 7 | 13.92 | 24.42 |
| (FPurge,FPressure) | | | | | | | | | |
| All | 115 | 3.85 | 7.22 | 43 | 6.86 | 9.51 | 100 | 9.97 | 17.24 |
| Tampered | | | | | | | | | |
| Carbureted | 7 | 7.77 | 10.28 | 2 | 16.00 | 22.70 | 7 | 9.05 | 19.36 |
| PFI | 1 | 0.29 | 13.79 | 0 | - | - | 1 | 0.20 | 21.44 |
| TBI | 2 | 11.49 | 10.52 | 0 | - | - | 1 | 36.43 | 28.28 |
| Pass | | | | | | | | | |
| Carbureted | 258 | 1.21 | 1.38 | 95 | 1.89 | 3.74 | 253 | 3.25 | 7.25 |
| PFI | 299 | 0.41 | 1.03 | 61 | 1.36 | 3.66 | 219 | 2.97 | 5.64 |
| TBI | 233 | 0.47 | 0.93 | 79 | 0.85 | 3.32 | 206 | 1.77 | 7.68 |
| Others* | | | | | | | | | |
| Carbureted | 53 | 2.27 | 3.02 | 27 | 3.88 | 5.80 | 53 | 3.79 | 11.85 |
| PFI | 22 | 1.19 | 5.42 | 3 | 0.51 | 21.57 | 18 | 3.25 | 10.78 |
| TBI | 58 | 1.01 | 2.38 | 12 | 4.91 | 4.77 | 50 | 3.71 | 8.86 |
| (Pass,Others) | | | | | | | | | |
| Carbureted | 311 | 1.39 | 1.66 | 122 | 2.33 | 4.20 | 306 | 3.34 | 8.05 |
| PFI | 321 | 0.46 | 1.33 | 64 | 1.32 | 4.50 | 237 | 2.99 | 6.03 |
| TBI | 291 | 0.57 | 1.22 | 91 | 1.39 | 3.51 | 256 | 2.15 | 7.91 |

*All vehicles that had some non-zero ECOMP codes but were not defined as either purge, failure, pressure failure, or tampered.

Table 3 (Continued)

Date: April 26, 1991

Statistics on Evaporative Emissions
(Average G/Test Hot Soak and Diurnal)
Source: EPA's EFP-MVEL

| Fuel Delivery System | 9.0 RVP | | | 10.4 RVP | | | 11.7 RVP | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | HS | DI | N | HS | DI | N | HS | DI |
| **Light-Duty Gasoline-Powered Trucks** | | | | | | | | | |
| All | | | | | | | | | |
| Carbureted | 170 | 1.53 | 2.93 | 6 | 5.35 | 10.01 | 199 | 4.13 | 14.02 |
| Fuel-Injected | 80 | 0.58 | 1.90 | 0 | - | - | 42 | 1.32 | 8.64 |
| Failed Purge | | | | | | | | | |
| Carbureted | 7 | 5.06 | 9.44 | 1 | 21.68 | 25.47 | 12 | 10.20 | 17.36 |
| Fuel-Injected | 1 | 0.19 | 0.62 | 0 | - | - | 0 | - | - |
| Failed Pressure | | | | | | | | | |
| Carbureted | 10 | 2.89 | 8.71 | 0 | - | - | 11 | 7.23 | 23.65 |
| Fuel-Injected | 2 | 0.40 | 22.42 | 0 | - | - | 1 | 6.81 | 54.35 |
| (FPurge,FPres) | | | | | | | | | |
| All | 20 | 3.27 | 9.93 | 1 | 21.68 | 25.47 | 24 | 8.70 | 21.79 |
| Tampered | | | | | | | | | |
| Carbureted | 4 | 8.94 | 8.41 | 0 | - | - | 6 | 19.47 | 32.06 |
| Fuel-Injected | 1 | 11.10 | 23.32 | 0 | - | - | 1 | 26.94 | 53.62 |
| Pass | | | | | | | | | |
| Carbureted | 129 | 1.00 | 1.69 | 4 | 2.31 | 3.63 | 128 | 2.19 | 10.54 |
| Fuel-Injected | 69 | 0.43 | 0.95 | 0 | - | - | 37 | 0.36 | 6.75 |
| Others* | | | | | | | | | |
| Carbureted | 20 | 1.59 | 4.68 | 1 | 1.17 | 20.07 | 42 | 5.31 | 18.58 |
| Fuel-Injected | 7 | 0.62 | 2.50 | 0 | - | - | 3 | 2.83 | 1.70 |
| (Pass,Others) | | | | | | | | | |
| Carbureted | 149 | 1.08 | 2.09 | 5 | 2.08 | 6.92 | 170 | 2.96 | 12.52 |
| Fuel-Injected | 76 | 0.45 | 1.09 | 0 | - | - | 40 | 0.55 | 6.37 |

*All vehicles that had some non-zero ECOMP codes but were not defined as either purge, failure, pressure failure, or tampered.

Table 4

Failed Pressure/Purge Test Results
92°F Hot Soak, 9 psi RVP Fuel
72-96°F Diurnal Heat Build, 40% Tank Fill
Source: EPA's EFP-Hammond

| Vehicle # | Model Year | Fuel System | Failed Purge | | Failed Pressure |
|---|---|---|---|---|---|
| | | | Hot Soak | Diurnal | Diurnal |
| 576 | 1981 | Carb | 1.95 | 13.32 | |
| 640 | 1981 | PFI | | | 76.22 |
| 660 | 1981 | Carb | 15.96 | 11.93 | |
| 665 | 1981 | Carb | | | 77.92 |
| 724 | 1982 | Carb | | | 24.76 |
| 443 | 1983 | TBI | 6.17 | 2.68 | |
| 736 | 1983 | Carb | | | 17.55 |
| 1541 | 1983 | TBI | | | 10.85 |
| 1635 | 1984 | PFI | 12.05 | 13.36 | |
| 1640 | 1984 | PFI | 1.62 | 20.08 | |
| 1530 | 1984 | TBI | | | 17.01 |
| 1552 | 1984 | TBI | 3.70 | 21.92 | |
| 722 | 1985 | PFI | | | 16.38 |
| 1542 | 1985 | PFI | | | 11.38 |
| 740 | 1985 | Carb | | | 14.47 |
| 1524 | 1985 | Carb | 26.08 | 25.55 | |
| 673 | 1985 | TBI | 1.73 | 19.30 | |
| 1526 | 1985 | TBI | 9.26 | 22.85 | |
| 1612 | 1985 | TBI | 5.54 | 13.01 | |
| 1532 | 1986 | PFI | 33.30 | 22.22 | |
| 743 | 1986 | TBI | | | 5.41 |
| 1537 | 1986 | TBI | | | 33.45 |
| 1544 | 1986 | TBI | 25.37 | 14.40 | |
| 1529 | 1987 | PFI | 0.96 | 2.80 | |
| 659 | 1988 | PFI | 2.77 | 21.34 | |
| 1533 | 1988 | PFI | 0.52 | 0.65 | |
| 1548 | 1988 | PFI | 20.97 | 34.61 | |
| 1555 | 1988 | TBI | 7.36 | 15.44 | |
| 730 | 1989 | PFI | | | 27.37 |
| 1525 | 1989 | PFI | 14.71 | 4.90 | |
| | | N: | 18 | 18 | 12 |
| | | Average: | 10.557 | 15.576 | 27.727 |

Table 5

Multiple Diurnal Emissions
Pass Vehicles
Source: Table 2 of Attachment

| Day | Fractions of Occurrence | 7.5 RVP | 8.0 RVP | 8.5 RVP | 8.7 RVP | 9.0 RVP | 10.0 RVP | 11.0 RVP |
|---|---|---|---|---|---|---|---|---|
| | | Calculated Emissions (in Grams) | | | | | | |
| 1 | 0.341 | 0.2 | 0.4 | 0.7 | 0.8 | 1.1 | 2.5 | 5.3 |
| 2 | 0.078 | 1.6 | 2.4 | 3.4 | 3.8 | 4.7 | 8.7 | 15.5 |
| 3 | 0.037 | 2.6 | 3.6 | 5.0 | 5.7 | 6.8 | 11.9 | 20.0 |
| 4 | 0.021 | 3.3 | 4.5 | 6.2 | 6.9 | 8.2 | 13.8 | 22.3 |
| 5 | 0.014 | 3.8 | 5.3 | 7.0 | 7.9 | 9.2 | 15.0 | 23.6 |
| 6 | 0.008 | 4.3 | 5.8 | 7.7 | 8.6 | 10.0 | 15.8 | 24.3 |
| 7 | 0.003 | 4.7 | 6.3 | 8.2 | 9.0 | 10.5 | 16.4 | 24.7 |
| | | Calculated Emission Ratios (Relative to Day 1 Emissions) | | | | | | |
| 2 | 0.484 | 8.0 | 6.0 | 4.9 | 4.8 | 4.3 | 3.5 | 2.9 |
| 3 | 0.230 | 13.0 | 9.0 | 7.1 | 7.1 | 6.2 | 4.8 | 3.8 |
| 4 | 0.130 | 16.5 | 11.3 | 8.9 | 8.6 | 7.5 | 5.5 | 4.2 |
| 5 | 0.087 | 19.0 | 13.3 | 10.0 | 9.9 | 8.4 | 6.0 | 4.5 |
| 6 | 0.050 | 21.5 | 14.5 | 11.0 | 10.8 | 9.1 | 6.3 | 4.6 |
| 7 | 0.019 | 23.5 | 15.8 | 11.7 | 11.3 | 9.5 | 6.6 | 4.7 |
| | | Occurrence Weighted Ratio | | | | | | |
| | | 12.2 | 8.6 | 6.8 | 6.7 | 5.8 | 4.5 | 3.5 |
| | | Predicted Ratio* | | | | | | |
| | | 10.4 | 8.8 | 7.4 | 7.0 | 6.3 | 4.5 | 3.2 |

*Predicted ratios are calculated from equation:
Ratio = EXP (4.8491 - 0.33424 * RVP)

Table 6

High Altitude Adjustment Factors
Evaporative Emissions

| Vehicle Type | Model Year Group | Adjustment Factor |
|---|---|---|
| LDGVs | Pre-1972 | 1.30 |
| | 1972-76 | * |
| | 1977 | 1.00 |
| | 1978-81 | 1.30 |
| | 1982-83 | 1.30 |
| | 1984+ | 1.00 |
| LDGT1s | Pre-1972 | 1.30 |
| | 1972-76 | * |
| | 1977 | 1.00 |
| | 1978-81 | 1.30 |
| | 1982+ | 1.30 |
| LDGT2s | All | 1.30 |
| HDGVs | All | 1.30 |
| MCs | All | 1.30 |

* Based on actual test data.

TABLE 7

Trip-Related Estimates (in Percent)
LDGVs and LDGTs
Source: 1979 GM-NPD Survey Data

| | Trip Days | | | | | | | No Trip Days | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Single Full | Partial Diurnal Days | | | 3+ | No | No | Single Full | 2+ |
| Veh Age | Trip Days | DI Days | 8AM-11AM | 10AM-3PM | 8AM-2PM | MDI Days | DI Days | Trip Days | DI Days | MDI Days |
| 01 | 85.35 | 25.08 | 36.27 | 7.95 | 4.14 | 4.36 | 7.57 | 14.65 | 7.15 | 7.50 |
| 02 | 83.63 | 24.58 | 35.54 | 7.79 | 4.06 | 4.27 | 7.42 | 16.37 | 7.99 | 8.38 |
| 03 | 81.91 | 24.08 | 34.81 | 7.63 | 3.98 | 4.18 | 7.27 | 18.09 | 8.83 | 9.26 |
| 04 | 80.19 | 23.58 | 34.08 | 7.47 | 3.90 | 4.09 | 7.12 | 19.81 | 9.67 | 10.14 |
| 05 | 78.47 | 23.08 | 33.35 | 7.31 | 3.82 | 4.00 | 6.97 | 21.53 | 10.51 | 11.02 |
| 06 | 76.75 | 22.58 | 32.62 | 7.15 | 3.74 | 3.91 | 6.82 | 23.25 | 11.35 | 11.90 |
| 07 | 75.03 | 22.08 | 31.89 | 6.99 | 3.66 | 3.82 | 6.67 | 24.97 | 12.19 | 12.78 |
| 08 | 73.31 | 21.58 | 31.16 | 6.83 | 3.58 | 3.73 | 6.52 | 26.69 | 13.03 | 13.66 |
| 09 | 71.59 | 21.08 | 30.43 | 6.67 | 3.50 | 3.64 | 6.37 | 28.41 | 13.87 | 14.54 |
| 10 | 69.87 | 20.58 | 29.70 | 6.51 | 3.42 | 3.55 | 6.22 | 30.13 | 14.71 | 15.42 |
| 11 | 69.87 | 20.08 | 28.97 | 6.35 | 3.34 | 3.46 | 6.07 | 31.85 | 15.55 | 16.30 |
| 12 | 68.15 | 19.58 | 28.24 | 6.19 | 3.26 | 3.37 | 5.92 | 33.57 | 16.39 | 17.18 |
| 13 | 66.43 | 19.08 | 27.51 | 6.03 | 3.18 | 3.28 | 5.77 | 35.29 | 17.23 | 18.06 |
| 14 | 64.71 | 18.58 | 26.78 | 5.87 | 3.10 | 3.19 | 5.62 | 37.01 | 18.07 | 18.94 |
| 15 | 62.99 | 18.08 | 26.05 | 5.71 | 3.02 | 3.10 | 5.47 | 38.73 | 18.91 | 19.82 |
| 16 | 61.27 | 17.58 | 25.32 | 5.55 | 2.94 | 3.01 | 5.32 | 40.45 | 19.75 | 20.70 |
| 17 | 59.55 | 17.08 | 24.59 | 5.39 | 2.86 | 2.92 | 5.17 | 42.17 | 20.59 | 21.58 |
| 18 | 57.83 | 16.58 | 23.86 | 5.23 | 2.78 | 2.83 | 5.02 | 43.89 | 21.43 | 22.46 |
| 19 | 56.11 | 16.08 | 23.13 | 5.07 | 2.70 | 2.74 | 4.87 | 45.61 | 22.27 | 23.34 |
| 20 | 54.39 | 15.58 | 22.40 | 4.91 | 2.62 | 2.65 | 4.72 | 47.33 | 23.11 | 24.22 |
| 21 | 50.95 | 15.08 | 21.67 | 4.75 | 2.54 | 3.46 | 6.07 | 31.85 | 15.55 | 16.30 |
| 22 | 49.23 | 14.58 | 20.94 | 4.59 | 2.46 | 3.37 | 5.92 | 33.57 | 16.39 | 17.18 |
| 23 | 47.51 | 14.08 | 20.21 | 4.43 | 2.38 | 3.28 | 5.77 | 35.29 | 17.23 | 18.06 |
| 24 | 45.79 | 13.58 | 19.48 | 4.27 | 2.30 | 3.19 | 5.62 | 37.01 | 18.07 | 18.94 |
| 25+ | 44.07 | 13.08 | 18.75 | 4.11 | 2.22 | 3.10 | 5.47 | 38.73 | 18.91 | 19.82 |

ATTACHMENT

*Figure 1*
**1981+ Passing Vehicles LDGV Diurnal Emissions (g/test)**

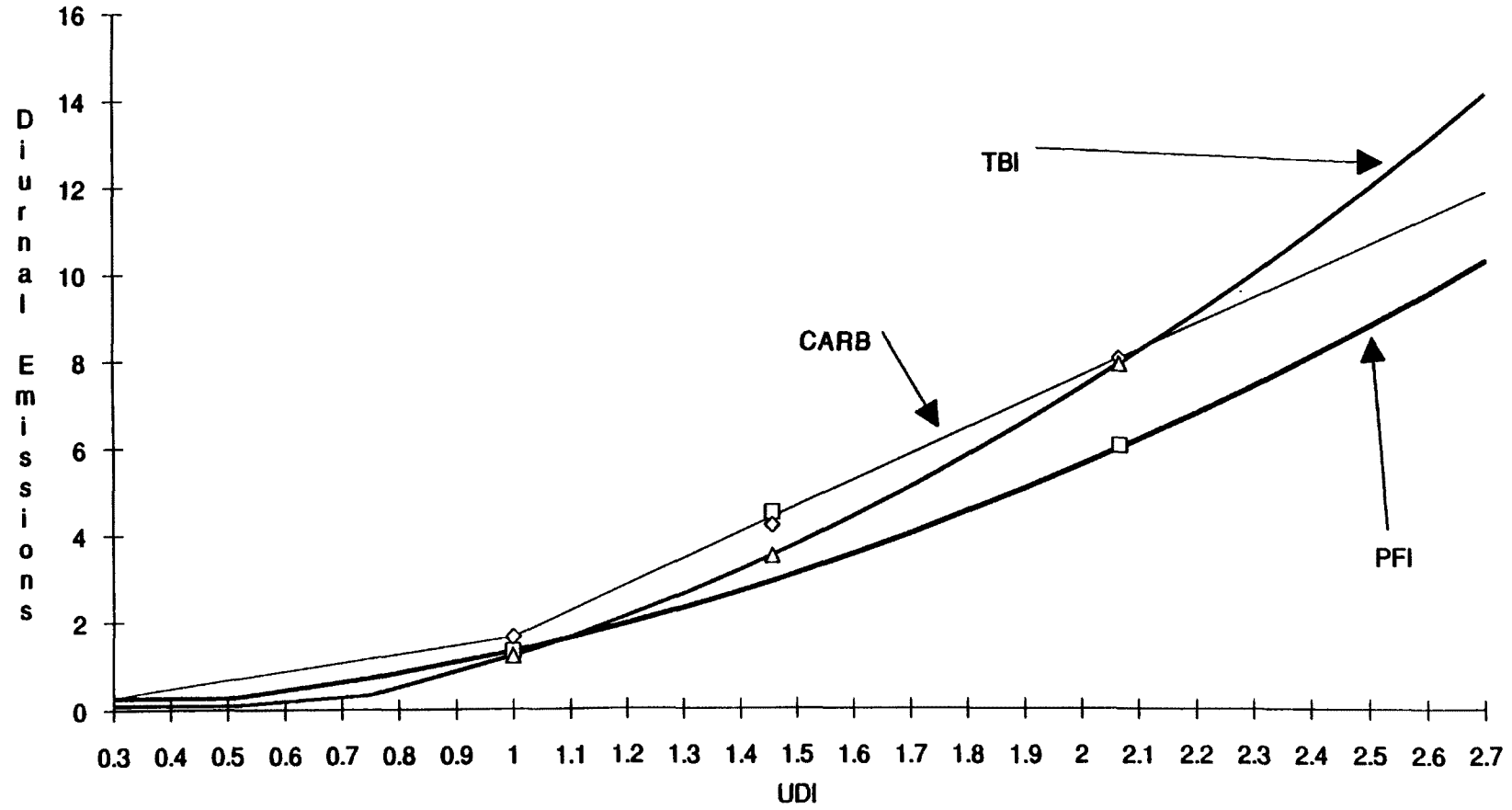


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Figure 2
1981+ Passing Vehicles LDGT Diurnal Emissions (g/test)

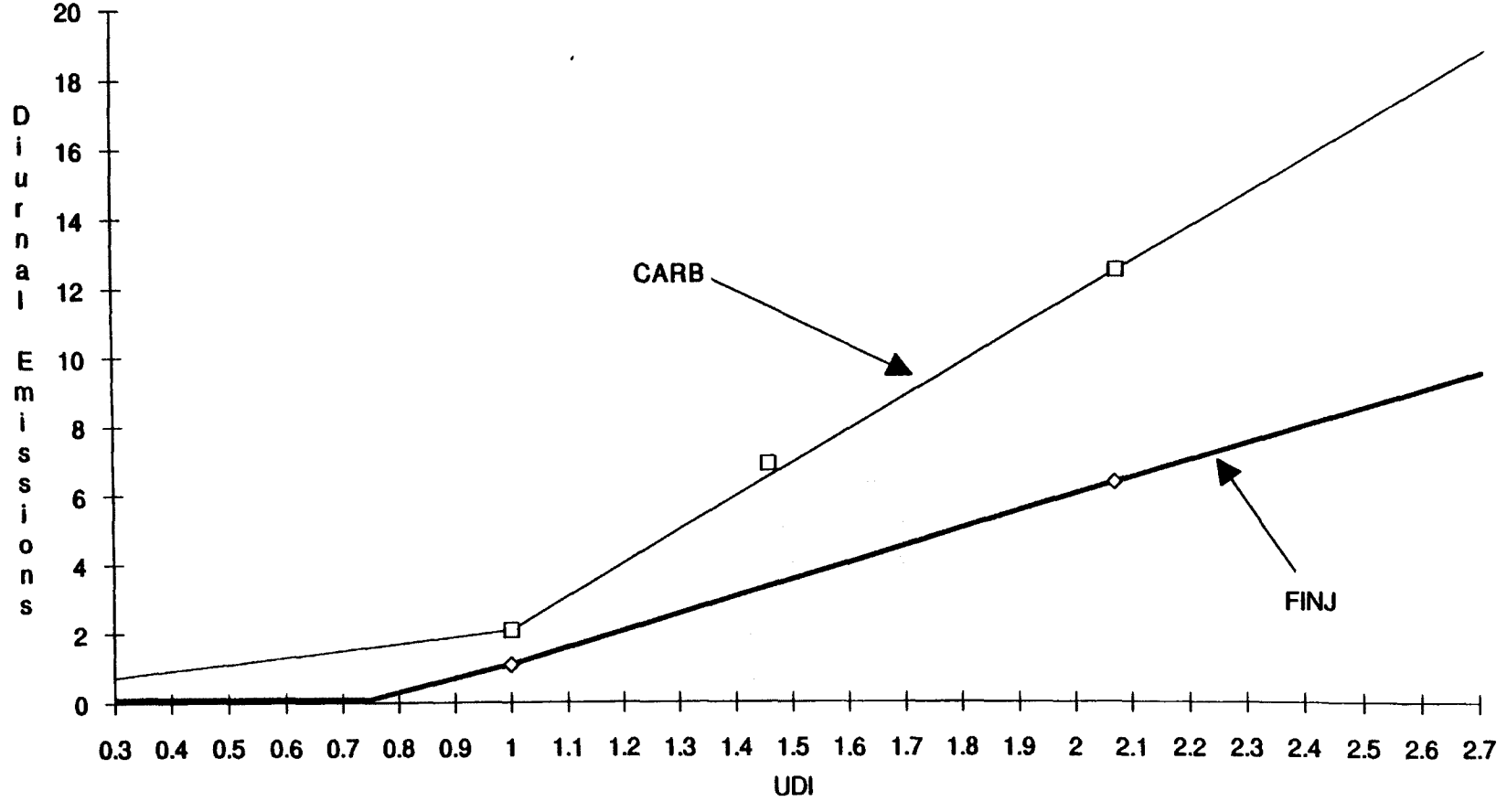




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Figure 3
1981+ Failed Vehicles LDGV Diurnal Emissions (g/test)

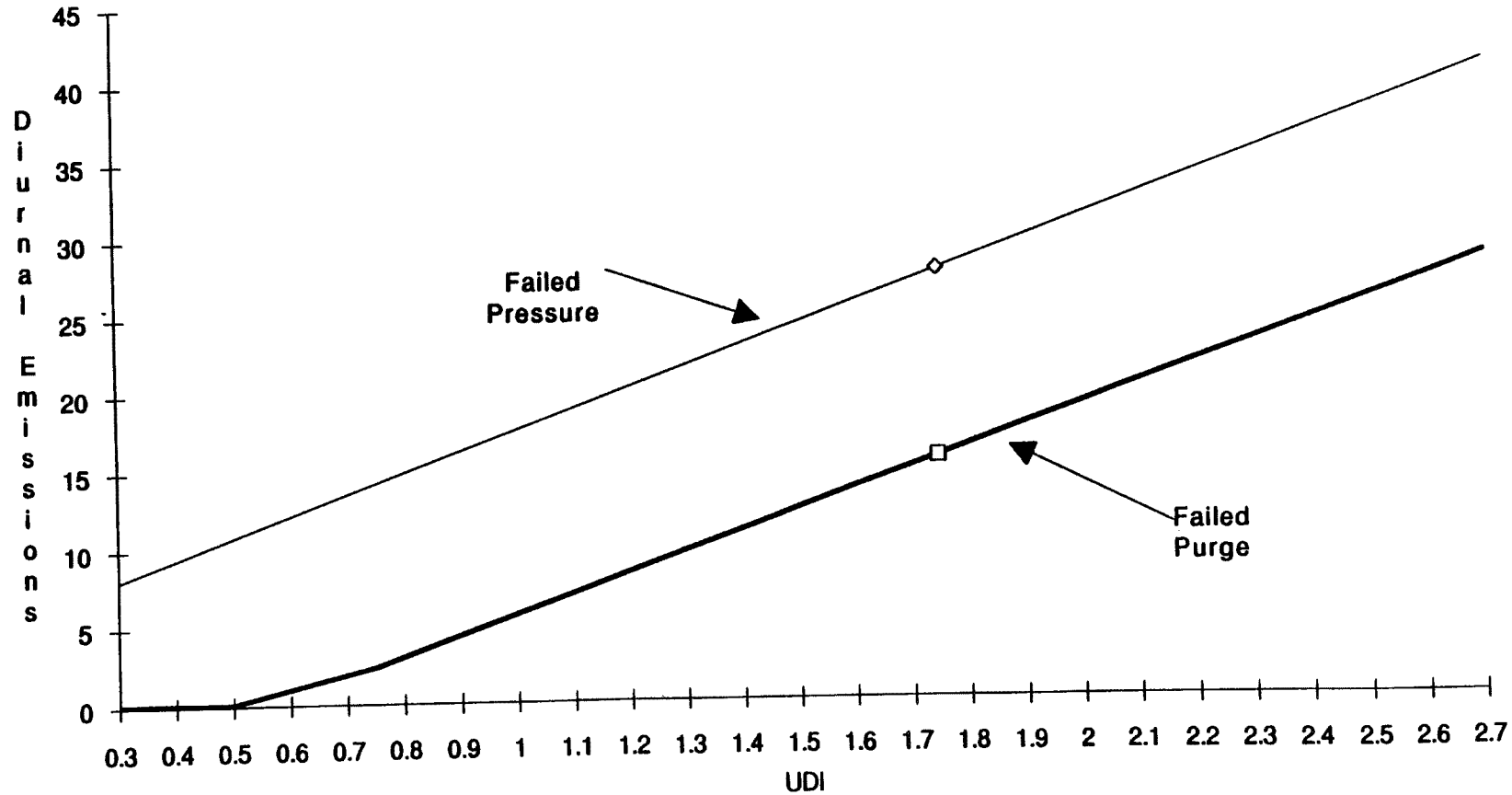


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Figure 4
1981+ Failed Vehicles LDGT Diurnal Emissions (g/test)

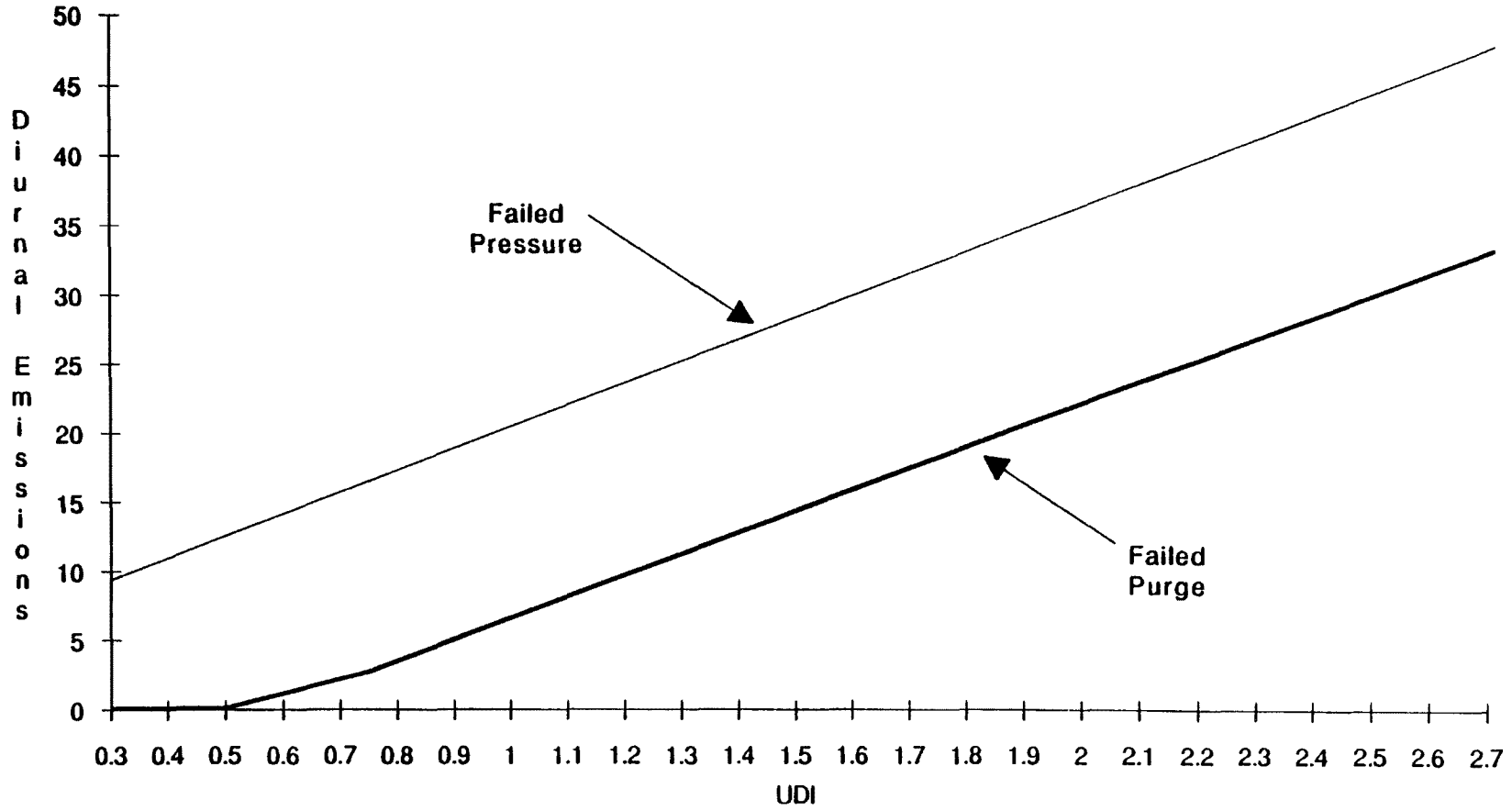


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Figure 5
1981+ Passing Vehicles at 82°F LDGV Hot Soak Emissions (g/test)

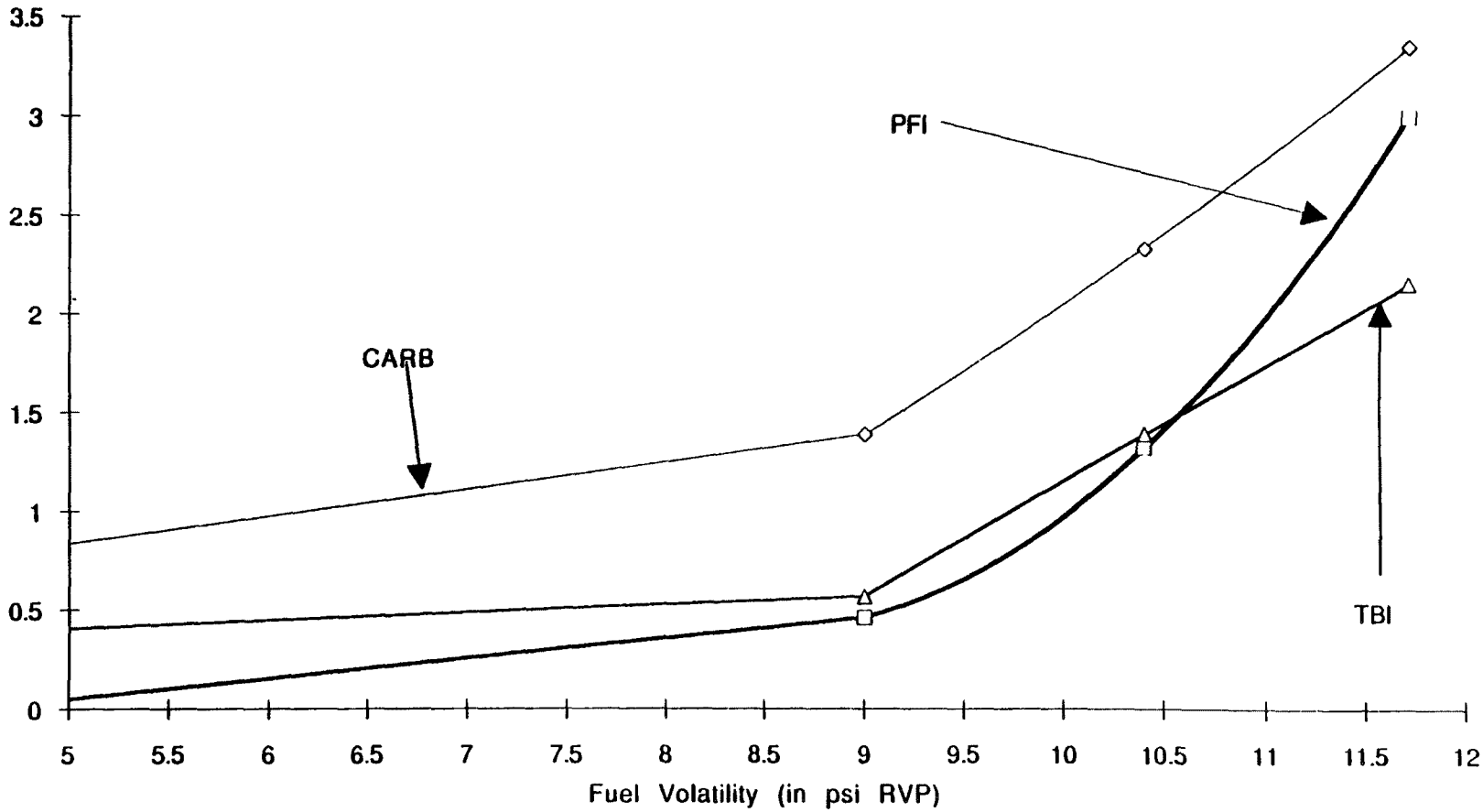




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Figure 6
1981+ Passing Vehicles at 82°F LDGT Hot Soak Emissions (g/test)

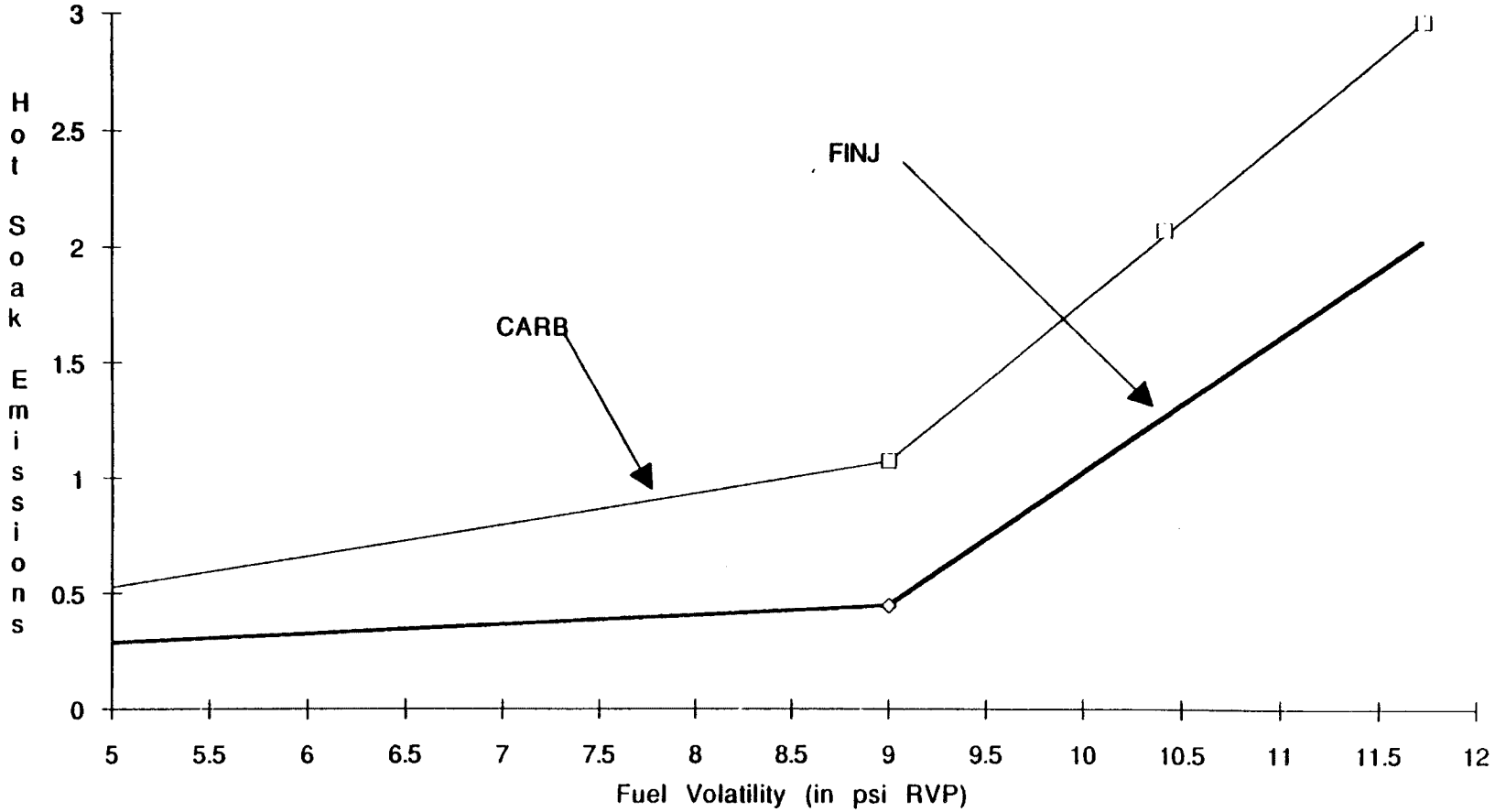




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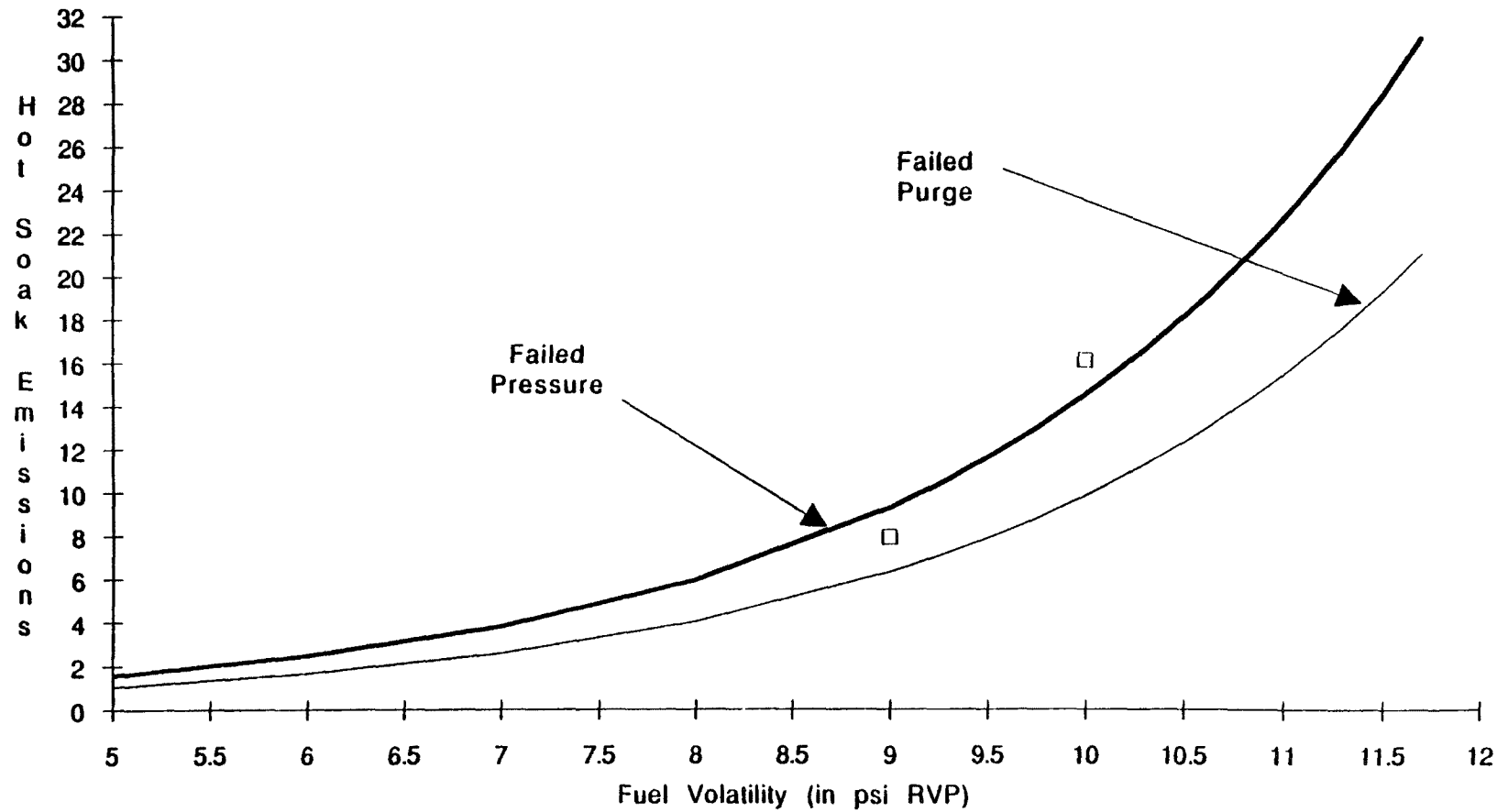
**Figure 7**
**1981+ Failed Vehicles at 82°F LDGV & LDGT Hot Soak Emissions (g/test)**



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# RUNNING LOSS EMISSIONS

## 1.0 Introduction

Running loss emissions test program has been performed and data collected by Automotive Testing Laboratories, Inc. (ATL) located at South Bend, Indiana under EPA's Emission Factors Program contract.

The test program was designed to test in-use vehicles with three different driving cycles:

1) a low speed cycle (known as the New York City Cycle [NYCC]) with an average speed of 7.1 mph,

2) a Federal Testing Procedure (FTP) LA-4 driving cycle with an average speed of 19.6 mph, and,

3) a high speed cycle (or Highway Fuel Economy Test [HFET]) with an average speed of 47.9 mph.

The duration of the running loss test is approximately one hour for each driving cycle. Therefore, the NYC driving cycle is repeated six times (6 bags), the two portions of the LA-4 cycle are repeated three times (6 bags), and the HFET driving cycle is repeated five times (5 bags). The distances, average speeds, and durations of these three driving cycles are summarized in the following:

| Driving Cycle | Bags | Distance in Miles | Speed in mph | Duration in Minutes |
|---|---|---|---|---|
| NYCC | 1 to 6 | 1.18 | 7.1 | 10.0 |
| LA-4 | 1,3,5 | 3.59 | 25.6 | 8.4 |
| | 2,4,6 | 3.89 | 16.2 | 14.4 |
| HFET | 1 to 5 | 10.20 | 47.9 | 12.8 |

Under this test program, many vehicles were tested only on LA-4 cycles. Fewer vehicles were tested on HFET cycle.

The running loss emissions test program was designed to collect data at four levels of fuel volatility (7.0, 9.0, 10.4, 11.7 psi in Reid Vapor Pressure [RVP]) and three levels of ambient temperature (80, 95, and 105°F).

Not all vehicles were tested for all combinations of fuel RVPs and ambient temperatures, however. There is usually no testing at extreme conditions, such as the combinations of high RVP fuel and high ambient (11.7 psi/105°F), and low RVP fuel and low ambient (7.0 psi/80°F), because of their less likely occurrences in the real world. Also, if from a test vehicle the running loss emission results are low (less than 0.5 grams) at certain fuel and temperature combination (for example, 9.0 psi/95°F), it is assumed that at the combinations of lower fuel volatilities and/or lower ambient temperatures (i.e., 7.0 psi/95°F, 9.0 psi/80°F, and, 7.0 psi/80°F), this vehicle would have emissions at a similarly low level. To save resources, the vehicle is not tested for the combinations of lower fuel volatilities and lower ambient temperatures. Further, there has been no testings on 11.7 psi RVP fuel shortly after the issuance of MOBILE4 in 1989.

## 2.0 True Vapor Pressure

In MOBILE4 model, when the test data is not available at certain combinations of fuel volatility and ambient temperature, the g/mi running loss emissions were estimated from a variable called "True Vapor Pressure (TVP)." In MOBILE4.1 model, this TVP is used to correlate with the running loss emissions from failed vehicles. These TVPs by bag are expressed as functions of fuel volatility and fuel tank temperature, and are calculated by the following five steps of equations:

$$U7 = 1.0223*RVP + [0.0357*RVP / (1.0 - 0.0368*RVP)]$$

$$V7 = 66.401 - 12.718*U7 + 1.3067*U7^{**}2 - 0.077934*U7^{**}3 + 0.0018407*U7^{**}4$$

$$T_{Bi} = Tmin + DT_{Bi} \qquad \text{for } i=1,2,\ldots,6$$

$$CD7_{Bi} = 262.0 / [(V7/6.0 + 560.0) - 0.0133] * (100.0 - T_{Bi}) + V7$$

$$TVP_{Bi} = 14.697 - 0.5308*CD7_{Bi} + 0.0077215*CD7_{Bi}^{**}2 - 0.000055631*CD7_{Bi}^{**}3 + 1.769*10^{-7}*CD7_{Bi}^{**}4 \qquad \text{for } i=1,2,\ldots,6$$

where:

$RVP$ = fuel volatility in psi,
$T_{Bi}$ = cumulative tank temperature for bag i in °F,
$Tmin$ = initial tank temperature in °F,
$DT_{Bi}$ = cumulative tank temperature rise for bag i in °F, and,
$TVP_{Bi}$ = calculated bag i TVP value..

The TVP values were calculated for all combinations of fuel volatilities (7.0, 9.0, 10.4, and 11.7 psi RVP) and tank temperature profiles (with the initial tank temperatures at 80, 87, 95, and 105°F).

The tank temperature rises for each bag were estimated from a 44-car tank temperature data collected at Laredo, Texas during the time frames of September 11 through October 23, 1989, by ATL under EPA's contract. In this program, vehicles' tank temperatures were measured and recorded while being driven under the LA-4 driving cycle repeated for three times (thus, a total of six bags). The initial tank temperatures were adjusted to be within $\pm$ 2°F of the ambient temperatures at the start of the test. An ambient temperature of 95°F was used. The fuel tanks were filled at 40% level with 9.0 psi RVP fuel.

The initial and final tank temperatures for each bag from these 44 vehicles were examined and an average tank temperature rise for each bag was calculated. The resulting average tank temperature rises for the six bags are: 5, 9, 4, 5, 2, and 3°F, respectively. The cumulative tank temperature rises (5, 14, 18, 23, 25, and 28°F), then, were used in the above five equations to calculate the corresponding TVP values. Therefore, the initial and final tank temperatures for the four temperature profiles were:

| Initial Tank | Final Tank Temperature in °F | | | | | |
|---|---|---|---|---|---|---|
| Temp in °F | Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
| 80.0 | 85.0 | 94.0 | 98.0 | 103.0 | 105.0 | 108.0 |
| 87.0 | 92.0 | 101.0 | 105.0 | 110.0 | 112.0 | 115.0 |
| 95.0 | 100.0 | 109.0 | 113.0 | 118.0 | 120.0 | 123.0 |
| 105.0 | 110.0 | 119.0 | 123.0 | 128.0 | 130.0 | 133.0 |

Table 1 summarizes the calculated TVP values for each bag under each fuel volatility level and each initial ambient (tank) temperature.

## 3.0 Running Loss Emissions Data

Similar to EPA's Hammond program, all vehicles under the running loss emissions test program since FY90 were also checked for pressure and/or purge failures of their evaporative emissions control system. Descriptions of these pressure/purge tests were given in the Evaporative HC Emissions Chapter. Failure rates from either pressure and/or purge test were described as a function of vehicle's age. These failure rates are the same as those used for the diurnal/hot soak emissions model.

Therefore, the MOBILE4.1 running loss emissions model include three portions: emissions for pass vehicles, emissions for vehicles that failed pressure test, and emissions for vehicles that failed purge test.

For vehicles tested prior to the Hammond program, diagnoses and comments from mechanics and their running loss emissions test results at 9.0 psi/95°F were examined to see which category the vehicles should be grouped into. For example, if diagnoses and comments from mechanics indicated that there exists a leakage on one of the evaporative emissions control system components (such as gas cap, filler neck, sending unit, rollover valve, or vent hoses), the vehicle is categorized as "failed pressure test". If there exists an in-operative canister purge solenoid or valve, or disconnected, missing, or damaged purge hoses, the vehicle is grouped as "failed purge test." If there were no problems detected, the vehicle is categorized as "pass vehicle."

Among those pre-Hammond vehicles that had problems detected in their evaporative emissions control system components by the mechanics' diagnoses and comments, some of them had relatively low running loss emissions. Among those pre-Hammond vehicles that had no visible problems detected in their evaporative emissions control system components, some of them had very high running loss emissions. Due to this lack of consistency, it was decided that all LDGVs tested prior to Hammond program be excluded from MOBILE4.1 model. For LDGTs, however, the sample sizes were very limited, their running loss emissions test results were relatively consistent, with no visible problems detected. For these reasons, all LDGT data were used as pass vehicles for the LDGT fleet.

## 3.1 Exception Vehicles

Among the data used for MOBILE4.1 analysis, there were two vehicles with "unusual" test results. One of them is a 1986 Chevrolet Camaro, identified as vehicle #1532, which is equipped with a 5.0L engine, ported fuel injection fuel delivery system, by engine family G1G5.0V8NTA8, and with evaporative emissions control system 6B0-1A. This vehicle, when tested at Hammond I/M lane, passed pressure check but failed purge flow check. The other vehicle is a 1986 Pontiac Sunbird, identified as vehicle #1578, which is equipped with a 1.6L engine, throttle body fuel injection fuel delivery system, by engine family G2G1.8V5TDG2, and with evaporative emissions control system 6A0-2B. This vehicle was found to have a leaking gas cap. It failed pressure check but passed purge flow check.

Two things were observed on these two vehicles: their tank temperature rises were extremely high, and their emission levels were equally high under as-received as well as after repair conditions. As discussed above (in section 2.0), the average tank temperature rise from an initial ambient of 95°F is 28°F. The tank temperature rises for these two vehicles, however, were more than 40°F. The cumulative temperature rises from the six bags were: 12, 22, 33, 40, 44, 47°F for the Camaro, and 9, 26, 32, 37, 41, 43°F for the Sunbird. The following table shows their running loss emissions in total grams (the sum of 6 bags) tested at 9.0 psi/95°F from LA-4 driving cycle:

| Vehicle Number | Status | Total Emissions (Grams) |
|---|---|---|
| 1532 | as-received (failed purge) | 315.5 |
| | after reconnect purge line | 330.8 |
| | after replace gas cap | 319.9 |
| 1578 | as-received (failed pressure) | 263.2 |
| | after repair | 325.5 |

Note that these repair/maintenance steps of reconnecting purge line and replacing gas cap usually will reduce a major portion of the evaporative running loss emissions for most vehicles. The above table has illustrated that for these two vehicles, however, the high levels of emissions may not be caused by either pressure or purge problems in their evaporative emissions control system. The repair work failed to decrease their emissions, even increased the total grams slightly. Thus, their extremely high tank temperature rises could be the main reason why these two vehicles had such high running loss emissions. For these reasons, it was decided that these two vehicles be treated as exceptions. Their average emissions from as-received and after repair are to be included in both the pass and failed vehicle categories.

Market shares of these two engine families for model years 1983 through 1990 were obtained from EPA's Certification files. The "Camaros" included all models of Camaro and Firebird with either 5.0L or 5.7L engines. Their sales ranged from a low 0.46 to a high 2.02 percent, with an average of 1.06 percent. The "Sunbirds" were models under the names of Sunbird, Skyhawk, and Firenza with either 1.8L or 2.0L engines. Their sales ranged from 0.48 to 2.01 percent, with an average of 1.28 percent. An alternative was to derive an estimate based on the sample. As there were a total of 60 LDGVs in the MOBILE4.1 running loss emissions test program sample, weighting factors of 0.01667 each are used to represent the Camaros and the Sunbirds in the fleet (i.e., a weighting factor of 0.96666 is used for the "regular" vehicles).

Table 2 summarizes the calculated TVP values for each bag under each fuel volatility level and each initial ambient temperature for these two exception vehicles. Table 3 shows the running loss emissions (in cumulative grams) of these two vehicles to be used for failed vehicles. Table 6 shows the running loss emissions (in grams per mile) of these two vehicles to be used for pass vehicles.

## 3.2 Pass Vehicles

Among the "regular" vehicles, those that passed both pressure and purge checks are categorized as the "pass" vehicles. For example, there are 32 model year 1981+ pass LDGVs tested at 9.0 psi/95°F for the LA-4 driving cycle.

The running loss emissions for pass vehicles are expressed in unit of grams per mile (g/mi) for each bag (bags 1 through 6) under each driving cycle (NYCC, LA-4, and HFET). Note that there are only five bag testing results from the HFET driving cycle. As the emission levels from five bags under the combinations of 95°F and fuel volatilities of 9.0 and 11.7 psi RVP are relatively stable, the emissions from the sixth bag of the HFET driving cycle are assumed to be the same as the emissions from the fifth bag. Therefore, there are a total of 18 (6 bags * 3 speeds) emission values for the combination of four fuel volatility levels (7.0, 9.0, 10.4, 11.7 psi RVP) and four ambient temperature profiles (80, 87, 95, 105°F).

The g/mi running loss emissions are derived by dividing the total grams by the cumulative trip distances in miles. For example, for bags 1 and 2:

$$RL_{B1,g/mi} = RL_{B1,g} \;/\; D_{B1,mi}$$

$$RL_{B2,g/mi} = (RL_{B1,g} + RL_{B2,g}) \;/\; (D_{B1,mi} + D_{B2,mi})$$

where:

D = trip distance in miles.

The average g/mi running loss emissions for each bag under each driving cycle for 1981+ "regular" pass LDGVs and 1981+ pass LDGTs are given in Tables 7 and 9. Note that the sample sizes for the combinations of fuel volatility and ambient temperature vary, due to the limitation of the test data discussed previously in sections 1.0 and 3.0. When there is no actual test data available, the sample size is denoted as zero ("0"), and the emission values are estimated by linear interpolation/extrapolation. Table 8 summarizes the g/mi emissions used for MOBILE4.1 model 1981+ pass LDGVs, including the "regular" pass vehicles and two exception vehicles.

## 3.3 Failed Vehicles

Due to the limited sample sizes, there is no differentiation made between vehicles that failed pressure test and vehicles that failed purge test. The criteria used to define vehicles that failed either pressure or purge test are the same as those used for hot soak/diurnal emissions model.

The running loss emissions for failed vehicles in the MOBILE4.1 model are expressed in terms of cumulative grams by bag for the combinations of fuel volatilities and ambient temperatures. Based on their similar emission levels in cumulative grams, results from the NYC and LA-4 cycles were combined. The emissions are also used for HFET cycle. The emissions in cumulative grams are to be converted onto grams per mile unit (and adjusted for speed) in the MOBILE4.1 model, as to be discussed later in section 4.0. Emissions for failed LDGVs are used also for LDGTs, due to a lack of LDGT data. Further, failed emission levels are also used for vehicles made during the pre-control era.

Table 4 summarizes the running loss emissions used for "regular" failed vehicles. The actual test data by each bag were used to fit equations as a function of True Vapor Pressure (as discussed in section 2.0). The predicted emissions in cumulative grams are used in MOBILE4.1 model for the failed emission levels. Table 5 shows failed emissions used for LDGVs and LDGTs, including the "regular" failed vehicles and two exception vehicles.

## 4.0 Driving Characteristics

In MOBILE4, a VMT weighted urban type driving characteristics was built into the running loss emissions model so that the emission rates were independent of the vehicle speed. This set of urban VMT weighting factors was derived from tabulated frequencies by trip distance in miles and average speed in mph matching the three driving cycle characteristics used in the running loss emissions test program. The data sources were the 1979 GM-NPD Survey Data, and an Operational Characteristics Study sponsored by EPA in Columbus, Ohio.

In MOBILE4.1, however, a VMT weighted driving characteristics in terms of trip duration alone is used in the model so that the emission rates can be adjusted by any given vehicle speed. The 1979 GM-NPD Survey Data again are used. The frequency table was based on trip durations in 10-minute intervals, and the deriving VMT weighting factors are:

| Trip Duration in minutes | Corresponding Bag # | Percent VMT |
|---|---|---|
| 10 and less | 1 | 33.227 |
| 11 - 20 | 2 | 32.883 |
| 21 - 30 | 3 | 14.871 |
| 31 - 40 | 4 | 7.886 |
| 41 - 50 | 5 | 3.645 |
| 52 and up | 6 | 7.488 |
| | Total: | 100.0 |

This new set of percent VMT weighting factors is used to represent each bag of the three driving cycles.

## 4.1 Pass Vehicles

For pass vehicles in the MOBILE4.1 model, the running loss emissions are given for all six bags of the three driving cycles in grams per mile unit, for each of the four fuel volatilities and four ambient temperatures. The speed adjustment algorithm for pass vehicles are described in the following.

At any given average vehicle speed between 7.1 and 47.9 mph, the emissions are calculated by linear interpolation between the emission rates at the two adjacent default vehicle speeds. For example, emissions at 10.0 mph are to be calculated based on emissions at 7.1 mph (NYCC) and emissions at 19.6 mph (LA-4), and emissions at 30.0 mph are based on emissions at 19.6 mph (LA-4) and emissions at 47.9 mph (HFET):

$$ADJ = (SPD - SPD1) / (SPD2 - SPD1) \quad (4.1)$$

where:

ADJ = calculated speed adjustment factor,
SPD = user input speed in mph, which is between 7.0 and 47.9 mph,
SPD1 = average speed in mph for the default driving cycle 1 (either NYCC or LA-4),
SPD2 = average speed in mph for the default driving cycle 2 (either LA-4 or HFET).

Then, with the calculated speed adjustment factor, the g/mi running loss emissions are estimated by subtracting the resting loss emissions, and weighted by the VMT weighting factors:

$$RESTL_{g/mi} = RESTL_{g/hr} / (6.0 * SPD_{mi/hr}) \quad (4.2)$$

$$RL_{Bi,SPD} = [RL_{Bi,SPD1} + ADJ * (RL_{Bi,SPD2} - RL_{Bi,SPD1}) - RESTL_{g/mi}] * VMT_{Bi} \quad \text{for } i=1,2,\ldots,6 \quad (4.3)$$

where:

RESTL = resting loss emissions,
$RL_{Bi,SPD}$ = calculated g/mi bag i running loss emissions at speed SPD,
$RL_{Bi,SPD1}$ = g/mi bag i running loss emissions for the default driving cycle 1 (either NYCC or LA-4),
$RL_{Bi,SPD2}$ = g/mi bag i running loss emissions for the default driving cycle 2 (either LA-4 or HFET),
$VMT_{Bi}$ = bag i VMT weighting factor.

For any average speed below 7.1 mph but greater than 2.5 mph, the emissions are calculated from the emissions at 7.1 mph and an adjustment factor calculated from the ratio of the two speeds (the input speed divided by 7.1 mph). This same algorithm is applicable to where the speed is above 47.9 mph but less than 65.0 mph. Therefore, equations (4.1) and (4.3) above are now reformulated as:

$$ADJ = SPD / SPD1$$

$$RL_{Bi,SPD} = [RL_{Bi,SPD1} + ADJ * RL_{Bi,SPD1} - RESTL_{g/mi}] * VMT_{Bi} \quad \text{for } i=1,2,\ldots,6$$

where:

SPD = user input speed in mph, which is either between 2.5 and 7.1 mph, or between 47.9 and 65.0 mph,

SPD1 = average speed of 7.1 mph from NYC driving cycle if SPD is less than 7.0 mph, or average speed of 47.9 mph from HFET driving cycle if SPD is greater than 47.9 mph,

$RL_{Bi,SPD1}$ = g/mi bag i running loss emissions from NYC driving cycle if SPD is below 7.1 mph, or those from HFET driving cycle if SPD is above 47.9 mph.

Finally, the running loss emissions are the total of the g/mi emissions over the six bags:

$$RL = RL_{B1,SPD} + RL_{B2,SPD} + RL_{B3,SPD} + RL_{B4,SPD} + RL_{B5,SPD} + RL_{B6,SPD} \quad (4.4)$$

## 4.2 Failed Vehicles

The running loss emissions for failed vehicles in the MOBILE4.1 model are expressed in cumulative grams. For each combination of fuel volatility and ambient temperature, there are only six emission values, each representing the cumulative bag emissions for all three driving cycles. The speed adjustment algorithm for failed vehicles are based on the following two assumptions:

1) the durations for each bag of each driving cycle are approximately the same, (i.e., about 10 minutes),

2) the cumulative emissions in grams by bag under each driving cycle from failed vehicles are the same.

For failed vehicles, the speed and VMT adjustment algorithm includes converting the emissions from cumulative grams onto grams per mile unit by the given speed, as well as subtracting off the resting loss emissions and multiplying VMT weighting factor:

$$RESTL_{g/10\ min} = RESTL_{g/hr} / 6.0_{10\ min/hr}$$

$$RL_{B1,g/mi} = [(RL_{B1,g} - RESTL) * VMT_{B1}] / D_{B1,mi} = (RL_{B1,g} - RESTL) * VMT_{B1} * 6 / SPD$$

$$RL_{B2,g/mi} = [(RL_{B2,g} - RESTL) * VMT_{B2}] / (D_{B1,mi} + D_{B2,mi}) = (RL_{B2,g} - RESTL) * VMT_{B2} / (2 * D_{B1,mi}) = (RL_{B2,g} - RESTL) * VMT_{B2} * 6 / (2 * SPD)$$

then,

$$RL_{Bi,g/mi} = (RL_{Bi,g} - RESTL) * VMT_{Bi} * 6 / (i * SPD) \quad \text{for } i = 1,2,\ldots,6$$

and,

$$RL_{SPD} = RL_{B1,g/mi} + RL_{B2,g/mi} + RL_{B3,g/mi} + RL_{B4,g/mi} + RL_{B5,g/mi} + RL_{B6,g/mi}$$

where:

$RESTL$ = resting loss emissions,
$RL_{Bi,g/mi}$ = calculated g/mi bag i running loss emissions at speed SPD,
$RL_{Bi,g}$ = bag i cumulative grams running loss emissions,
$VMT_{Bi}$ = bag i VMT weighting factor,
$D_{Bi,mi}$ = trip distance in miles for bag i, and,
$SPD$ = user input speed in mph.

## 5.0 Other Model Years and Other Vehicle Types

The running loss emissions data described in Tables 5, 7, and 9 are used in MOBILE4.1 for other model year groups and other vehicle types according to the following mapping:

| Data | Pass/ Fail | Vehicle Type | | | |
|---|---|---|---|---|---|
| | | LDGV | LDGT1 | LDGT2 | HDGV |
| 1981+ Pass LDGV | Pass | 1972-77 | | | 1985+ |
| | Pass | 1978-80 | | | |
| | Pass | 1981+ | | | |
| 1981+ Pass LDGT1 | Pass | | 1972-77 | | |
| | Pass | | 1978-80 | 1979-80 | |
| | Pass | | 1981+ | 1981+ | |
| 1981+ Failed LDGV | All | Pre-1972 | Pre-1972 | Pre-1979 | Pre-1985 |
| | Failed | 1972+ | 1972+ | 1979+ | 1985+ |

Table 1

True Vapor Pressure
Regular Vehicles

| Fuel RVP in psi | Initial Ambient Temp °F | True Vapor Pressure | | | | | |
|---|---|---|---|---|---|---|---|
| | | Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
| 7.0 | 80.0 | 5.58 | 6.67 | 7.21 | 7.94 | 8.24 | 8.72 |
| | 87.0 | 6.42 | 7.64 | 8.24 | 9.04 | 9.38 | 9.91 |
| | 95.0 | 7.50 | 8.88 | 9.56 | 10.46 | 10.84 | 11.44 |
| | 105.0 | 9.04 | 10.65 | 11.44 | 12.48 | 12.92 | 13.60 |
| 9.0 | 80.0 | 7.28 | 8.63 | 9.30 | 10.19 | 10.56 | 11.14 |
| | 87.0 | 8.32 | 9.82 | 10.56 | 11.54 | 11.95 | 12.60 |
| | 95.0 | 9.64 | 11.34 | 12.17 | 13.27 | 13.73 | 14.45 |
| | 105.0 | 11.54 | 13.50 | 14.45 | 15.71 | 16.24 | 17.06 |
| 10.4 | 80.0 | 8.63 | 10.19 | 10.95 | 11.96 | 12.39 | 13.05 |
| | 87.0 | 9.82 | 11.55 | 12.39 | 13.50 | 13.97 | 14.70 |
| | 95.0 | 11.34 | 13.27 | 14.21 | 15.46 | 15.98 | 16.80 |
| | 105.0 | 13.50 | 15.72 | 16.80 | 18.22 | 18.82 | 19.74 |
| 11.7 | 80.0 | 9.76 | 11.47 | 12.31 | 13.42 | 13.89 | 14.61 |
| | 87.0 | 11.07 | 12.96 | 13.89 | 15.11 | 15.63 | 16.43 |
| | 95.0 | 12.74 | 14.86 | 15.89 | 17.26 | 17.83 | 18.71 |
| | 105.0 | 15.11 | 17.54 | 18.71 | 20.27 | 20.92 | 21.93 |

Table 2

True Vapor Pressure
Exception Vehicles

| Fuel RVP in psi | Initial Ambient Temp °F | True Vapor Pressure Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
|---|---|---|---|---|---|---|---|
| | | | Camaro | | | | |
| 7.0 | 80.0 | 6.42 | 7.79 | 9.56 | 10.84 | 11.64 | 12.27 |
| | 87.0 | 7.35 | 8.88 | 10.84 | 12.27 | 13.14 | 13.84 |
| | 95.0 | 8.55 | 10.28 | 12.48 | 14.07 | 15.05 | 15.82 |
| | 105.0 | 10.28 | 12.27 | 14.80 | 16.63 | 17.75 | 18.63 |
| 9.0 | 80.0 | 8.32 | 10.00 | 12.17 | 13.73 | 14.69 | 15.45 |
| | 87.0 | 9.47 | 11.34 | 13.73 | 15.45 | 16.51 | 17.34 |
| | 95.0 | 10.94 | 13.04 | 15.71 | 17.62 | 18.80 | 19.72 |
| | 105.0 | 13.04 | 15.45 | 18.50 | 20.68 | 22.02 | 23.07 |
| 10.4 | 80.0 | 9.82 | 11.75 | 14.21 | 15.98 | 17.07 | 17.93 |
| | 87.0 | 11.14 | 13.27 | 15.98 | 17.93 | 19.12 | 20.06 |
| | 95.0 | 12.82 | 15.21 | 18.22 | 20.38 | 21.70 | 22.74 |
| | 105.0 | 15.21 | 17.93 | 21.37 | 23.81 | 25.31 | 26.48 |
| 11.7 | 80.0 | 11.07 | 13.19 | 15.89 | 17.83 | 19.02 | 19.95 |
| | 87.0 | 12.52 | 14.86 | 17.83 | 19.95 | 21.25 | 22.27 |
| | 95.0 | 14.37 | 16.97 | 20.27 | 22.62 | 24.06 | 25.18 |
| | 105.0 | 16.97 | 19.95 | 23.69 | 26.35 | 27.97 | 29.24 |
| | | | Sunbird | | | | |
| 7.0 | 80.0 | 6.05 | 8.40 | 9.38 | 10.28 | 11.04 | 11.44 |
| | 87.0 | 6.94 | 9.56 | 10.65 | 11.64 | 12.48 | 12.92 |
| | 95.0 | 8.09 | 11.04 | 12.27 | 13.37 | 14.31 | 14.80 |
| | 105.0 | 9.73 | 13.14 | 14.56 | 15.82 | 16.90 | 17.46 |
| 9.0 | 80.0 | 7.86 | 10.75 | 11.95 | 13.04 | 13.96 | 14.45 |
| | 87.0 | 8.96 | 12.17 | 13.50 | 14.69 | 15.71 | 16.24 |
| | 95.0 | 10.37 | 13.96 | 15.45 | 16.78 | 17.91 | 18.50 |
| | 105.0 | 12.38 | 16.51 | 18.21 | 19.72 | 21.01 | 21.68 |
| 10.4 | 80.0 | 9.30 | 12.60 | 13.97 | 15.21 | 16.25 | 16.80 |
| | 87.0 | 10.56 | 14.21 | 15.72 | 17.07 | 18.22 | 18.82 |
| | 95.0 | 12.17 | 16.25 | 17.93 | 19.43 | 20.71 | 21.37 |
| | 105.0 | 14.46 | 19.12 | 21.03 | 22.74 | 24.18 | 24.93 |
| 11.7 | 80.0 | 10.49 | 14.13 | 15.63 | 16.97 | 18.12 | 18.71 |
| | 87.0 | 11.88 | 15.89 | 17.54 | 19.02 | 20.27 | 20.92 |
| | 95.0 | 13.65 | 18.12 | 19.95 | 21.59 | 22.97 | 23.69 |
| | 105.0 | 16.16 | 21.25 | 23.33 | 25.18 | 26.75 | 27.56 |

Table 3

Cumulative Grams Running Loss Emissions
Exception Vehicles

| Fuel RVP in psi | Ambient Temp °F | Running Loss Emissions (Cumulative Grams) Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
|---|---|---|---|---|---|---|---|
| | | | Camaro | | | | |
| 7.0 | 80.0 | 1.83 | 2.27 | 3.83 | 8.06 | 12.55 | 36.78 |
| | 87.0 | 1.96 | 3.99 | 7.98 | 11.20 | 16.73 | 49.04 |
| | 95.0 | 2.15 | 7.00 | 16.62 | 32.01 | 47.79 | 122.60 |
| | 105.0 | 2.47 | 12.07 | 30.78 | 82.27 | 120.61 | 240.39 |
| 9.0 | 80.0 | 2.11 | 4.12 | 5.07 | 33.30 | 50.25 | 100.62 |
| | 87.0 | 2.31 | 8.62 | 19.69 | 45.99 | 67.15 | 134.16 |
| | 95.0 | 2.61 | 15.16 | 40.76 | 130.51 | 192.70 | 336.79 |
| | 105.0 | 3.11 | 25.98 | 75.27 | 378.61 | 565.10 | 664.77 |
| 10.4 | 80.0 | 2.38 | 10.12 | 24.59 | 59.71 | 87.34 | 181.88 |
| | 87.0 | 2.65 | 16.13 | 43.92 | 148.49 | 219.75 | 367.54 |
| | 95.0 | 3.05 | 24.80 | 71.58 | 347.42 | 518.46 | 630.51 |
| | 105.0 | 3.71 | 39.04 | 116.55 | 789.42 | 818.00* | 818.00* |
| 11.7 | 80.0 | 2.64 | 15.78 | 42.82 | 142.28 | 210.54 | 357.42 |
| | 87.0 | 2.98 | 23.17 | 66.43 | 305.45 | 455.53 | 582.20 |
| | 95.0 | 3.47 | 33.78 | 100.05 | 614.02 | 818.00* | 818.00* |
| | 105.0 | 4.28 | 51.11 | 154.42 | 818.00* | 818.00* | 818.00* |
| | | | Sunbird | | | | |
| 7.0 | 80.0 | 0.71 | 2.00 | 4.24 | 6.68 | 10.05 | 16.20 |
| | 87.0 | 1.40 | 4.66 | 5.43 | 17.12 | 25.76 | 41.53 |
| | 95.0 | 2.42 | 8.48 | 12.92 | 43.89 | 66.05 | 94.39 |
| | 105.0 | 4.10 | 22.72 | 34.93 | 87.78 | 132.10 | 178.09 |
| 9.0 | 80.0 | 1.52 | 6.73 | 17.02 | 18.73 | 28.42 | 41.96 |
| | 87.0 | 2.97 | 15.79 | 21.95 | 48.02 | 72.88 | 107.60 |
| | 95.0 | 5.10 | 28.93 | 51.91 | 123.67 | 185.66 | 241.92 |
| | 105.0 | 8.66 | 50.59 | 139.24 | 247.17 | 369.14 | 460.06 |
| 10.4 | 80.0 | 3.45 | 18.83 | 26.83 | 65.67 | 99.29 | 139.12 |
| | 87.0 | 5.41 | 30.89 | 58.18 | 135.05 | 202.69 | 262.23 |
| | 95.0 | 8.26 | 48.24 | 128.15 | 234.04 | 349.77 | 437.11 |
| | 105.0 | 13.01 | 76.64 | 283.75 | 394.43 | 587.29 | 719.06 |
| 11.7 | 80.0 | 5.29 | 30.19 | 55.95 | 131.16 | 196.95 | 255.44 |
| | 87.0 | 7.72 | 44.99 | 113.31 | 215.68 | 322.60 | 404.86 |
| | 95.0 | 11.24 | 66.18 | 221.83 | 335.71 | 500.51 | 616.16 |
| | 105.0 | 17.07 | 100.64 | 441.95 | 529.16 | 719.06* | 719.06* |

*An upper limit based on actual test results.

Table 4

Cumulative Grams Running Loss Emissions
Failed Vehicles

| Fuel RVP in psi | Ambient Temp °F | Running Loss Emissions (Cumulative Grams) Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
|---|---|---|---|---|---|---|---|
| 7.0 | 80.0 | 0.50 | 1.44 | 3.26 | 4.33 | 4.91 | 5.83 |
| | 87.0 | 1.02 | 2.48 | 6.80 | 10.07 | 12.27 | 15.34 |
| | 95.0 | 1.52 | 7.27 | 11.34 | 17.37 | 21.52 | 27.40 |
| | 105.0 | 3.25 | 14.13 | 26.24 | 44.20 | 58.84 | 77.40 |
| 9.0 | 80.0 | 1.23 | 6.32 | 9.28 | 13.69 | 16.41 | 20.58 |
| | 87.0 | 2.52 | 10.92 | 19.29 | 31.71 | 41.49 | 54.20 |
| | 95.0 | 3.76 | 16.79 | 32.04 | 54.63 | 73.37 | 96.87 |
| | 105.0 | 4.79 | 25.13 | 50.13 | 87.09 | 118.47 | 157.15 |
| 10.4 | 80.0 | 2.85 | 12.34 | 22.37 | 37.28 | 49.25 | 64.60 |
| | 87.0 | 3.90 | 17.59 | 33.79 | 57.80 | 77.78 | 102.78 |
| | 95.0 | 4.72 | 24.28 | 48.28 | 83.80 | 113.91 | 151.10 |
| | 105.0 | 4.90 | 33.74 | 68.78 | 120.49 | 164.85 | 219.11 |
| 11.7 | 80.0 | 3.85 | 17.30 | 33.15 | 56.67 | 76.21 | 100.70 |
| | 87.0 | 4.62 | 23.08 | 45.69 | 79.17 | 107.49 | 142.53 |
| | 95.0 | 4.97 | 30.42 | 61.58 | 107.64 | 147.02 | 195.33 |
| | 105.0 | 6.66 | 40.78 | 83.99 | 147.69 | 202.59 | 269.48 |

Table 5

Cumulative Grams Running Loss Emissions
1981+ Failed LDGVs and LDGTs

| Fuel RVP in psi | Ambient Temp °F | Running Loss Emissions (Cumulative Grams) Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
|---|---|---|---|---|---|---|---|
| 7.0 | 80.0 | 0.53 | 1.46 | 3.29 | 4.43 | 5.12 | 6.52 |
| | 87.0 | 1.04 | 2.54 | 6.80 | 10.21 | 12.57 | 16.34 |
| | 95.0 | 1.55 | 7.29 | 11.45 | 18.06 | 22.70 | 30.10 |
| | 105.0 | 3.25 | 14.24 | 26.46 | 45.56 | 61.09 | 81.80 |
| 9.0 | 80.0 | 1.25 | 6.29 | 9.34 | 14.10 | 17.17 | 22.27 |
| | 87.0 | 2.52 | 10.96 | 19.34 | 32.22 | 42.44 | 56.42 |
| | 95.0 | 3.76 | 16.97 | 32.52 | 57.05 | 77.23 | 103.29 |
| | 105.0 | 4.83 | 25.57 | 52.04 | 94.62 | 130.10 | 170.66 |
| 10.4 | 80.0 | 2.85 | 12.41 | 22.48 | 38.13 | 50.72 | 67.80 |
| | 87.0 | 3.90 | 17.79 | 34.37 | 60.60 | 82.23 | 109.85 |
| | 95.0 | 4.75 | 24.69 | 50.00 | 90.70 | 124.59 | 163.86 |
| | 105.0 | 5.02 | 34.54 | 73.16 | 136.21 | 182.78 | 237.42 |
| 11.7 | 80.0 | 3.85 | 17.49 | 33.69 | 59.34 | 80.46 | 107.56 |
| | 87.0 | 4.64 | 23.45 | 47.16 | 85.22 | 116.88 | 154.23 |
| | 95.0 | 5.05 | 31.07 | 64.89 | 119.88 | 164.10 | 212.73 |
| | 105.0 | 6.79 | 41.95 | 91.13 | 165.22 | 222.58 | 287.77 |

Table 6

Grams per Mile Running Loss Emissions
Exception Vehicle: Camaro

| Fuel RVP in psi | Ambient Temp °F | Running Loss Emissions (Grams/Mile) Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
|---|---|---|---|---|---|---|---|
| | | New York City Cycle | | | | | |
| 7.0 | 80.0 | 1.55 | 0.96 | 1.08 | 1.71 | 2.13 | 5.19 |
| | 87.0 | 1.66 | 1.69 | 2.25 | 2.37 | 2.84 | 6.93 |
| | 95.0 | 1.82 | 2.97 | 4.69 | 6.78 | 8.10 | 17.32 |
| | 105.0 | 2.09 | 5.11 | 8.69 | 17.43 | 20.44 | 33.95 |
| 9.0 | 80.0 | 1.79 | 1.75 | 1.43 | 7.06 | 8.52 | 14.21 |
| | 87.0 | 1.96 | 3.65 | 5.56 | 9.74 | 11.38 | 18.95 |
| | 95.0 | 2.21 | 6.42 | 11.51 | 27.65 | 32.66 | 47.57 |
| | 105.0 | 2.64 | 11.01 | 21.26 | 80.21 | 95.78 | 93.89 |
| 10.4 | 80.0 | 2.02 | 4.29 | 6.95 | 12.65 | 14.80 | 25.69 |
| | 87.0 | 2.25 | 6.83 | 12.41 | 31.46 | 37.25 | 51.91 |
| | 95.0 | 2.58 | 10.51 | 20.22 | 73.61 | 87.87 | 89.06 |
| | 105.0 | 3.14 | 16.54 | 32.92 | 167.25 | 138.64* | 115.54* |
| 11.7 | 80.0 | 2.24 | 6.69 | 12.10 | 30.14 | 35.68 | 50.48 |
| | 87.0 | 2.53 | 9.82 | 18.77 | 64.71 | 77.21 | 82.23 |
| | 95.0 | 2.94 | 14.31 | 28.26 | 130.09 | 138.64* | 115.54* |
| | 105.0 | 3.63 | 21.66 | 43.62 | 173.31 | 138.64* | 115.54* |
| | | LA-4 Driving Cycle | | | | | |
| 7.0 | 80.0 | 0.51 | 0.30 | 0.35 | 0.54 | 0.68 | 1.63 |
| | 87.0 | 0.55 | 0.53 | 0.72 | 0.75 | 0.90 | 2.18 |
| | 95.0 | 0.60 | 0.93 | 1.50 | 2.13 | 2.57 | 5.45 |
| | 105.0 | 0.69 | 1.61 | 2.78 | 5.48 | 6.49 | 10.68 |
| 9.0 | 80.0 | 0.59 | 0.55 | 0.46 | 2.22 | 2.70 | 4.47 |
| | 87.0 | 0.64 | 1.15 | 1.78 | 3.07 | 3.61 | 5.96 |
| | 95.0 | 0.73 | 2.02 | 3.68 | 8.70 | 10.37 | 14.97 |
| | 105.0 | 0.87 | 3.46 | 6.79 | 25.24 | 30.40 | 29.55 |
| 10.4 | 80.0 | 0.66 | 1.35 | 2.22 | 3.98 | 4.70 | 8.08 |
| | 87.0 | 0.74 | 2.15 | 3.96 | 9.90 | 11.82 | 16.34 |
| | 95.0 | 0.85 | 3.31 | 6.45 | 23.16 | 27.89 | 28.02 |
| | 105.0 | 1.03 | 5.21 | 10.51 | 52.63 | 44.00* | 36.36* |
| 11.7 | 80.0 | 0.74 | 2.10 | 3.86 | 9.49 | 11.33 | 15.89 |
| | 87.0 | 0.83 | 3.09 | 5.99 | 20.63 | 24.50 | 25.88 |
| | 95.0 | 0.97 | 4.50 | 9.02 | 40.93 | 44.00* | 36.36* |
| | 105.0 | 1.19 | 6.81 | 13.92 | 54.53 | 44.00* | 36.36* |

Table 6 (Continued)

Grams per Mile Running Loss Emissions
Exception Vehicle: Sunbird

| Fuel RVP in psi | Ambient Temp °F | Running Loss Emissions (Grams/Mile) Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
|---|---|---|---|---|---|---|---|
| | | New York City Cycle | | | | | |
| 7.0 | 80.0 | 0.60 | 0.85 | 1.20 | 1.42 | 1.70 | 2.29 |
| | 87.0 | 1.19 | 1.97 | 1.53 | 3.63 | 4.37 | 5.87 |
| | 95.0 | 2.05 | 3.59 | 3.65 | 9.30 | 11.19 | 13.33 |
| | 105.0 | 3.47 | 9.63 | 9.87 | 18.60 | 22.39 | 25.15 |
| 9.0 | 80.0 | 1.29 | 2.85 | 4.81 | 3.97 | 4.82 | 5.93 |
| | 87.0 | 2.52 | 6.69 | 6.20 | 10.17 | 12.35 | 15.20 |
| | 95.0 | 4.32 | 12.26 | 14.66 | 26.20 | 31.47 | 34.17 |
| | 105.0 | 7.34 | 21.44 | 39.33 | 52.37 | 62.57 | 64.98 |
| 10.4 | 80.0 | 2.92 | 7.98 | 7.58 | 13.91 | 16.83 | 19.65 |
| | 87.0 | 4.58 | 13.09 | 16.44 | 28.61 | 34.35 | 37.04 |
| | 95.0 | 7.00 | 20.44 | 36.20 | 49.58 | 59.28 | 61.74 |
| | 105.0 | 11.03 | 32.47 | 80.16 | 83.57 | 99.54 | 101.56* |
| 11.7 | 80.0 | 4.48 | 12.79 | 15.81 | 27.79 | 33.38 | 36.08 |
| | 87.0 | 6.54 | 19.06 | 32.01 | 45.69 | 54.68 | 57.18 |
| | 95.0 | 9.53 | 28.04 | 62.66 | 71.13 | 84.83 | 87.03 |
| | 105.0 | 14.47 | 42.64 | 124.84 | 112.11 | 133.28 | 101.56* |
| | | LA-4 Driving Cycle | | | | | |
| 7.0 | 80.0 | 0.20 | 0.27 | 0.38 | 0.45 | 0.54 | 0.72 |
| | 87.0 | 0.39 | 0.62 | 0.49 | 1.14 | 1.39 | 1.85 |
| | 95.0 | 0.67 | 1.13 | 1.17 | 2.93 | 3.55 | 4.20 |
| | 105.0 | 1.14 | 3.03 | 3.15 | 5.85 | 7.11 | 7.92 |
| 9.0 | 80.0 | 0.42 | 0.90 | 1.53 | 1.25 | 1.53 | 1.86 |
| | 87.0 | 0.83 | 2.11 | 1.98 | 3.20 | 3.92 | 4.78 |
| | 95.0 | 1.42 | 3.86 | 4.68 | 8.24 | 9.99 | 10.75 |
| | 105.0 | 2.41 | 6.75 | 12.56 | 16.48 | 19.86 | 20.45 |
| 10.4 | 80.0 | 0.96 | 2.51 | 2.42 | 4.38 | 5.34 | 6.18 |
| | 87.0 | 1.51 | 4.12 | 5.25 | 9.00 | 10.90 | 11.65 |
| | 95.0 | 2.30 | 6.43 | 11.56 | 15.60 | 18.81 | 19.43 |
| | 105.0 | 3.62 | 10.22 | 25.59 | 26.30 | 31.59 | 31.96* |
| 11.7 | 80.0 | 1.47 | 4.03 | 5.05 | 8.74 | 10.59 | 11.35 |
| | 87.0 | 2.15 | 6.00 | 10.22 | 14.38 | 17.35 | 17.99 |
| | 95.0 | 3.13 | 8.82 | 20.00 | 22.38 | 26.92 | 27.38 |
| | 105.0 | 4.75 | 13.42 | 39.85 | 35.28 | 42.30 | 31.96* |

Table 7

Grams per Mile Running Loss Emissions
Regular Pass Vehicles

| Fuel RVP psi | Ambient Temp °F | Sample Size | Running Loss Emissions (Grams/Mile) Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
|---|---|---|---|---|---|---|---|---|
| | | | New York City Cycle | | | | | |
| 7.0 | 80.0 | 0 | 0.28 | 0.30 | 0.31 | 0.31 | 0.30 | 0.30 |
| | 87.0 | 0 | 0.28 | 0.30 | 0.31 | 0.31 | 0.30 | 0.30 |
| | 95.0 | 12 | 0.28 | 0.30 | 0.31 | 0.31 | 0.30 | 0.30 |
| | 105.0 | 12 | 0.29 | 0.31 | 0.32 | 0.33 | 0.32 | 0.32 |
| 9.0 | 80.0 | 0 | 0.28 | 0.30 | 0.31 | 0.31 | 0.30 | 0.30 |
| | 87.0 | 0 | 0.29 | 0.31 | 0.32 | 0.32 | 0.31 | 0.31 |
| | 95.0 | 8 | 0.33 | 0.35 | 0.37 | 0.38 | 0.53 | 0.63 |
| | 105.0 | 14 | 0.67 | 0.91 | 1.72 | 2.80 | 3.90 | 4.87 |
| 10.4 | 80.0 | 0 | 0.29 | 0.31 | 0.32 | 0.32 | 0.31 | 0.31 |
| | 87.0 | 0 | 0.36 | 0.40 | 0.50 | 0.61 | 0.85 | 1.04 |
| | 95.0 | 0 | 0.63 | 0.85 | 1.58 | 2.55 | 3.55 | 4.45 |
| | 105.0 | 0 | 1.37 | 2.25 | 6.09 | 13.71 | 22.93 | 29.25 |
| 11.7 | 80.0 | 0 | 0.35 | 0.38 | 0.45 | 0.53 | 0.74 | 0.73 |
| | 87.0 | 0 | 0.59 | 0.77 | 1.39 | 2.20 | 3.08 | 3.85 |
| | 95.0 | 0 | 1.10 | 1.73 | 4.40 | 9.53 | 15.63 | 19.88 |
| | 105.0 | 0 | 1.95 | 3.35 | 9.65 | 22.60 | 38.43 | 49.17 |
| | | | LA-4 Driving Cycle | | | | | |
| 7.0 | 80.0 | 0 | 0.07 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| | 87.0 | 0 | 0.07 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| | 95.0 | 12 | 0.07 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| | 105.0 | 12 | 0.09 | 0.11 | 0.18 | 0.11 | 0.11 | 0.11 |
| 9.0 | 80.0 | 0 | 0.07 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| | 87.0 | 0 | 0.08 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| | 95.0 | 32 | 0.12 | 0.17 | 0.18 | 0.21 | 0.23 | 0.30 |
| | 105.0 | 14 | 0.12 | 0.22 | 0.29 | 0.34 | 0.65 | 1.00 |
| 10.4 | 80.0 | 4 | 0.08 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| | 87.0 | 0 | 0.12 | 0.17 | 0.19 | 0.22 | 0.27 | 0.36 |
| | 95.0 | 0 | 0.12 | 0.22 | 0.28 | 0.33 | 0.61 | 0.92 |
| | 105.0 | 0 | 0.25 | 0.42 | 1.32 | 4.23 | 6.28 | 7.58 |
| 11.7 | 80.0 | 0 | 0.12 | 0.17 | 0.19 | 0.22 | 0.26 | 0.34 |
| | 87.0 | 0 | 0.12 | 0.21 | 0.27 | 0.31 | 0.55 | 0.82 |
| | 95.0 | 0 | 0.20 | 0.34 | 0.92 | 2.74 | 4.12 | 5.05 |
| | 105.0 | 0 | 0.36 | 0.58 | 2.16 | 7.40 | 10.86 | 12.96 |

Table 7 (Continued)

Grams per Mile Running Loss Emissions
Regular Pass Vehicles

| Fuel RVP psi | Ambient Temp °F | Sample Size | Running Loss Emissions (Grams/Mile) Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
|---|---|---|---|---|---|---|---|---|
| | | | Highway Fuel Economy Test | | | | | |
| 7.0 | 80.0 | 0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 87.0 | 0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 95.0 | 0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 105.0 | 0 | 0.06 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 9.0 | 80.0 | 0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 87.0 | 0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 95.0 | 7 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 105.0 | 0 | 0.09 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 10.4 | 80.0 | 0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 87.0 | 0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 95.0 | 0 | 0.08 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 105.0 | 0 | 0.09 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 11.7 | 80.0 | 0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 87.0 | 0 | 0.05 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| | 95.0 | 7 | 0.09 | 0.05 | 0.04 | 0.03 | 0.03 | 0.03 |
| | 105.0 | 0 | 0.09 | 0.05 | 0.04 | 0.03 | 0.03 | 0.03 |

Table 8

Grams per Mile Running Loss Emissions
1981+ Pass LDGVs

| Fuel RVP in psi | Ambient Temp °F | Running Loss Emissions (Grams/Mile) Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
|---|---|---|---|---|---|---|---|
| | | New York City Cycle | | | | | |
| 7.0 | 80.0 | 0.31 | 0.32 | 0.34 | 0.35 | 0.35 | 0.41 |
| | 87.0 | 0.32 | 0.35 | 0.36 | 0.40 | 0.41 | 0.50 |
| | 95.0 | 0.34 | 0.40 | 0.44 | 0.57 | 0.61 | 0.80 |
| | 105.0 | 0.37 | 0.55 | 0.62 | 0.92 | 1.02 | 1.29 |
| 9.0 | 80.0 | 0.32 | 0.37 | 0.40 | 0.48 | 0.51 | 0.63 |
| | 87.0 | 0.35 | 0.47 | 0.50 | 0.64 | 0.70 | 0.87 |
| | 95.0 | 0.43 | 0.65 | 0.79 | 1.27 | 1.58 | 1.97 |
| | 105.0 | 0.81 | 1.42 | 2.67 | 4.92 | 6.41 | 7.36 |
| 10.4 | 80.0 | 0.36 | 0.50 | 0.55 | 0.76 | 0.83 | 1.06 |
| | 87.0 | 0.46 | 0.72 | 0.96 | 1.59 | 2.02 | 2.49 |
| | 95.0 | 0.77 | 1.34 | 2.47 | 4.52 | 5.89 | 6.82 |
| | 105.0 | 1.56 | 2.99 | 7.78 | 17.42 | 26.14 | 31.89 |
| 11.7 | 80.0 | 0.45 | 0.70 | 0.90 | 1.48 | 1.87 | 2.15 |
| | 87.0 | 0.72 | 1.23 | 2.19 | 3.97 | 5.18 | 6.05 |
| | 95.0 | 1.27 | 2.38 | 5.77 | 12.57 | 18.83 | 22.59 |
| | 105.0 | 2.18 | 4.31 | 12.14 | 26.60 | 41.68 | 55.39 |
| | | LA-4 Driving Cycle | | | | | |
| 7.0 | 80.0 | 0.08 | 0.10 | 0.10 | 0.10 | 0.11 | 0.13 |
| | 87.0 | 0.08 | 0.11 | 0.11 | 0.12 | 0.13 | 0.15 |
| | 95.0 | 0.09 | 0.12 | 0.13 | 0.17 | 0.19 | 0.25 |
| | 105.0 | 0.12 | 0.18 | 0.21 | 0.30 | 0.33 | 0.42 |
| 9.0 | 80.0 | 0.08 | 0.11 | 0.12 | 0.14 | 0.16 | 0.19 |
| | 87.0 | 0.10 | 0.15 | 0.16 | 0.20 | 0.22 | 0.28 |
| | 95.0 | 0.15 | 0.26 | 0.31 | 0.49 | 0.56 | 0.72 |
| | 105.0 | 0.17 | 0.38 | 0.60 | 1.02 | 1.47 | 1.80 |
| 10.4 | 80.0 | 0.11 | 0.17 | 0.18 | 0.24 | 0.27 | 0.34 |
| | 87.0 | 0.15 | 0.27 | 0.34 | 0.53 | 0.64 | 0.82 |
| | 95.0 | 0.17 | 0.37 | 0.57 | 0.96 | 1.37 | 1.68 |
| | 105.0 | 0.32 | 0.66 | 1.88 | 5.40 | 7.33 | 8.47 |
| 11.7 | 80.0 | 0.15 | 0.27 | 0.33 | 0.51 | 0.61 | 0.79 |
| | 87.0 | 0.17 | 0.35 | 0.53 | 0.88 | 1.23 | 1.53 |
| | 95.0 | 0.26 | 0.55 | 1.37 | 3.70 | 5.17 | 5.94 |
| | 105.0 | 0.44 | 0.90 | 2.98 | 8.65 | 11.94 | 13.74 |

Table 8 (Continued)

Grams per Mile Running Loss Emissions
1981+ Pass LDGVs

| Fuel RVP in psi | Ambient Temp °F | Running Loss Emissions (Grams/Mile) Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
|---|---|---|---|---|---|---|---|
| | | Highway Fuel Economy Test | | | | | |
| 7.0 | 80.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 87.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 95.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 105.0 | 0.06 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 9.0 | 80.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 87.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 95.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 105.0 | 0.09 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 10.4 | 80.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 87.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 95.0 | 0.08 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 105.0 | 0.09 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 11.7 | 80.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 87.0 | 0.05 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| | 95.0 | 0.09 | 0.05 | 0.04 | 0.03 | 0.03 | 0.03 |
| | 105.0 | 0.09 | 0.05 | 0.04 | 0.03 | 0.03 | 0.03 |

Table 9

Grams per Mile Running Loss Emissions
1981+ Pass LDGTs

| Fuel RVP in psi | Ambient Temp °F | Running Loss Emissions (Grams/Mile) Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
|---|---|---|---|---|---|---|---|
| | | New York City Cycle | | | | | |
| 7.0 | 80.0 | 0.45 | 0.41 | 0.34 | 0.29 | 0.29 | 0.32 |
| | 87.0 | 0.49 | 0.45 | 0.41 | 0.37 | 0.39 | 0.44 |
| | 95.0 | 0.55 | 0.50 | 0.48 | 0.45 | 0.43 | 0.42 |
| | 105.0 | 0.37 | 0.55 | 0.62 | 0.92 | 1.02 | 1.29 |
| 9.0 | 80.0 | 0.61 | 0.61 | 0.77 | 0.85 | 0.99 | 1.21 |
| | 87.0 | 0.60 | 0.54 | 0.62 | 0.67 | 0.78 | 0.93 |
| | 95.0 | 0.56 | 0.46 | 0.53 | 0.61 | 0.71 | 0.78 |
| | 105.0 | 0.81 | 1.42 | 2.67 | 4.92 | 6.41 | 7.36 |
| 10.4 | 80.0 | 0.62 | 0.56 | 0.66 | 0.74 | 0.88 | 1.05 |
| | 87.0 | 0.71 | 0.63 | 0.86 | 1.07 | 1.34 | 1.66 |
| | 95.0 | 0.80 | 0.71 | 1.14 | 1.57 | 2.08 | 2.67 |
| | 105.0 | 1.56 | 2.99 | 7.78 | 17.42 | 26.14 | 31.89 |
| 11.7 | 80.0 | 0.66 | 0.57 | 0.72 | 0.82 | 1.11 | 1.66 |
| | 87.0 | 0.77 | 0.74 | 1.23 | 1.96 | 2.78 | 3.80 |
| | 95.0 | 0.89 | 0.90 | 1.74 | 3.09 | 4.40 | 5.93 |
| | 105.0 | 2.18 | 4.31 | 12.14 | 26.60 | 41.68 | 55.39 |
| | | LA-4 Driving Cycle | | | | | |
| 7.0 | 80.0 | 0.12 | 0.14 | 0.11 | 0.07 | 0.06 | 0.05 |
| | 87.0 | 0.13 | 0.14 | 0.11 | 0.08 | 0.07 | 0.07 |
| | 95.0 | 0.09 | 0.12 | 0.13 | 0.17 | 0.19 | 0.25 |
| | 105.0 | 0.23 | 0.25 | 0.22 | 0.23 | 0.26 | 0.32 |
| 9.0 | 80.0 | 0.12 | 0.12 | 0.11 | 0.12 | 0.11 | 0.11 |
| | 87.0 | 0.10 | 0.10 | 0.09 | 0.09 | 0.09 | 0.11 |
| | 95.0 | 0.10 | 0.10 | 0.09 | 0.09 | 0.09 | 0.11 |
| | 105.0 | 0.25 | 0.18 | 0.15 | 0.28 | 0.35 | 0.51 |
| 10.4 | 80.0 | 0.15 | 0.15 | 0.13 | 0.14 | 0.14 | 0.16 |
| | 87.0 | 0.16 | 0.15 | 0.14 | 0.18 | 0.20 | 0.24 |
| | 95.0 | 0.18 | 0.16 | 0.16 | 0.24 | 0.28 | 0.39 |
| | 105.0 | 0.18 | 0.16 | 0.16 | 0.26 | 0.31 | 0.43 |
| 11.7 | 80.0 | 0.17 | 0.12 | 0.10 | 0.09 | 0.08 | 0.11 |
| | 87.0 | 0.16 | 0.16 | 0.19 | 0.41 | 0.57 | 0.95 |
| | 95.0 | 0.16 | 0.16 | 0.23 | 0.53 | 0.74 | 1.07 |
| | 105.0 | 0.23 | 0.16 | 0.21 | 0.58 | 0.91 | 1.72 |

Table 9 (Continued)

Grams per Mile Running Loss Emissions
1981+ Pass LDGTs

| Fuel RVP in psi | Ambient Temp °F | Running Loss Emissions (Grams/Mile) Bag 1 | Bag 2 | Bag 3 | Bag 4 | Bag 5 | Bag 6 |
|---|---|---|---|---|---|---|---|
| | | Highway Fuel Economy Test | | | | | |
| 7.0 | 80.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 87.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 95.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 105.0 | 0.06 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 9.0 | 80.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 87.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 95.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 105.0 | 0.09 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 10.4 | 80.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 87.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 95.0 | 0.08 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 105.0 | 0.09 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 11.7 | 80.0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 87.0 | 0.05 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| | 95.0 | 0.09 | 0.05 | 0.04 | 0.03 | 0.03 | 0.03 |
| | 105.0 | 0.09 | 0.05 | 0.04 | 0.03 | 0.03 | 0.03 |

# MOBILE4.1
## Technology Distribution for Gasoline Light-Duty Trucks

| Model Year | CLLP 3way Carb | CLLP 3way MPFI | CLLP 3way TBI | Oplp 3way Carb | Oplp 3way MPFI | Oplp 3way TBI | CLLP Ox3way Carb | CLLP Ox3way MPFI | CLLP Ox3way TBI | Oplp Ox3way Carb | Oplp Ox3way MPFI | Oplp Ox3way TBI | Oplp Oxid | Oplp None |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | 0 | 0 | 0 | 13589 | 0 | 0 | 26593 | 0 | 0 | 0 | 0 | 0 | 1429888 | 46007 |
| 1982 | 57339 | 0 | 0 | 0 | 0 | 0 | 906 | 0 | 0 | 0 | 0 | 0 | 1429253 | 0 |
| 1983 | 74447 | 3438 | 0 | 0 | 0 | 0 | 183194 | 0 | 0 | 0 | 0 | 0 | 1658258 | 51277 |
| 1984 | 109748 | 65296 | 0 | 20757 | 0 | 0 | 631304 | 0 | 0 | 51116 | 0 | 0 | 2081626 | 0 |
| 1985 | 255529 | 206437 | 144973 | 15454 | 0 | 0 | 546263 | 0 | 368 | 66837 | 0 | 0 | 1868467 | 0 |
| 1986 | 167151 | 861000 | 328016 | 17780 | 0 | 0 | 308664 | 0 | 163878 | 0 | 0 | 0 | 1776740 | 0 |
| 1987 | 260447 | 716266 | 780032 | 48058 | 0 | 0 | 188653 | 429429 | 202385 | 64044 | 0 | 0 | 814666 | 0 |
| 1988 | 260231 | 1099548 | 1455516 | 15860 | 0 | 38829 | 101129 | 534243 | 283427 | 69315 | 0 | 0 | 72566 | 0 |
| 1989 | 174645 | 1544412 | 1435056 | 10998 | 0 | 0 | 185103 | 974850 | 288728 | 0 | 0 | 0 | 53200 | 0 |
| 1990 | 7985 | 1948880 | 1533017 | 9998 | 0 | 0 | 87597 | 884251 | 200673 | 0 | 0 | 0 | 40500 | 4969 |
| 1991 | 21900 | 2177487 | 1815964 | 6000 | 0 | 0 | 53055 | 712782 | 223736 | 0 | 0 | 0 | 0 | 0 |

| Model Year | CLLP 3way Carb | CLLP 3way MPFI | CLLP 3way TBI | Oplp 3way Carb | Oplp 3way MPFI | Oplp 3way TBI | CLLP Ox3way Carb | CLLP Ox3way MPFI | CLLP Ox3way TBI | Oplp Ox3way Carb | Oplp Ox3way MPFI | Oplp Ox3way TBI | Oplp Oxid | Oplp None |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | 0.0% | 0.0% | 0.0% | 0.9% | 0.0% | 0.0% | 1.8% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 94.3% | 3.0% |
| 1982 | 3.9% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 96.1% | 0.0% |
| 1983 | 3.8% | 0.2% | 0.0% | 0.0% | 0.0% | 0.0% | 9.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 84.1% | 2.6% |
| 1984 | 3.7% | 2.2% | 0.0% | 0.7% | 0.0% | 0.0% | 21.3% | 0.0% | 0.0% | 1.7% | 0.0% | 0.0% | 70.3% | 0.0% |
| 1985 | 8.2% | 6.6% | 4.7% | 0.5% | 0.0% | 0.0% | 17.6% | 0.0% | 0.0% | 2.2% | 0.0% | 0.0% | 60.2% | 0.0% |
| 1986 | 4.6% | 23.8% | 9.1% | 0.5% | 0.0% | 0.0% | 8.5% | 0.0% | 4.5% | 0.0% | 0.0% | 0.0% | 49.0% | 0.0% |
| 1987 | 7.4% | 20.4% | 22.3% | 1.4% | 0.0% | 0.0% | 5.4% | 12.3% | 5.8% | 1.8% | 0.0% | 0.0% | 23.2% | 0.0% |
| 1988 | 6.6% | 28.0% | 37.0% | 0.4% | 0.0% | 1.0% | 2.6% | 13.6% | 7.2% | 1.8% | 0.0% | 0.0% | 1.8% | 0.0% |
| 1989 | 3.7% | 33.1% | 30.7% | 0.2% | 0.0% | 0.0% | 4.0% | 20.9% | 6.2% | 0.0% | 0.0% | 0.0% | 1.1% | 0.0% |
| 1990 | 0.2% | 41.3% | 32.5% | 0.2% | 0.0% | 0.0% | 1.9% | 18.7% | 4.3% | 0.0% | 0.0% | 0.0% | 0.9% | 0.1% |
| 1991 | 0.4% | 43.5% | 36.2% | 0.1% | 0.0% | 0.0% | 1.1% | 14.2% | 4.5% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |

| Model Year | CLLP Carb | CLLP MPFI | CLLP TBI | Oplp Any |
|---|---|---|---|---|
| 1981 | 1.8% | 0.0% | 0.0% | 98.2% |
| 1982 | 3.9% | 0.0% | 0.0% | 96.1% |
| 1983 | 13.1% | 0.2% | 0.0% | 86.8% |
| 1984 | 25.0% | 2.2% | 0.0% | 72.8% |
| 1985 | 25.8% | 6.6% | 4.7% | 62.8% |
| 1986 | 13.1% | 23.8% | 13.6% | 49.5% |
| 1987 | 12.8% | 32.7% | 28.0% | 26.4% |
| 1988 | 9.2% | 41.6% | 44.2% | 5.0% |
| 1989 | 7.7% | 54.0% | 36.9% | 1.4% |
| 1990 | 2.0% | 60.1% | 36.7% | 1.2% |
| 1991 | 1.5% | 57.7% | 40.7% | 0.1% |

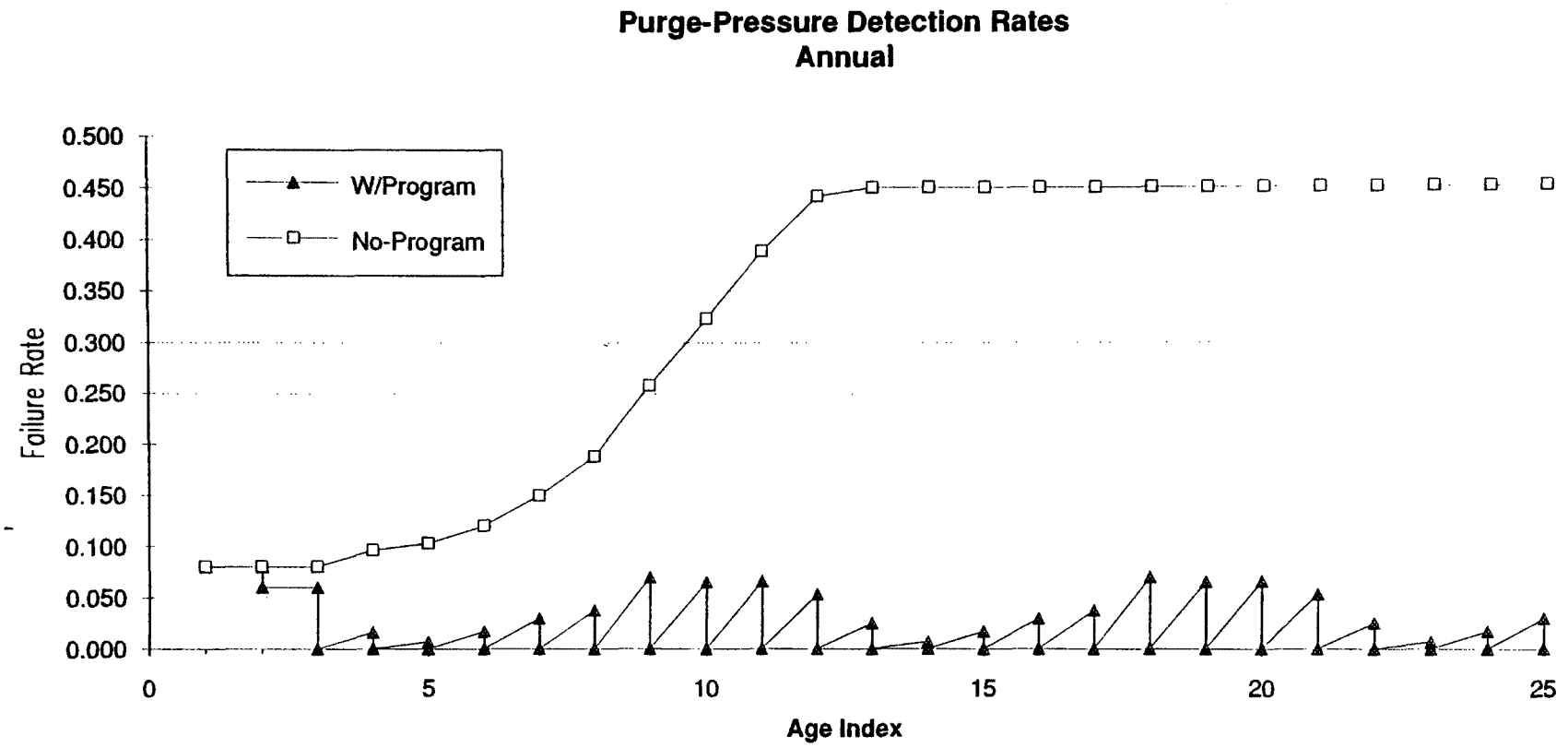
| Model Year | Any Carb | Any MPFI | Any TBI |
|---|---|---|---|
| 1981 | 100.0% | 0.0% | 0.0% |
| 1982 | 100.0% | 0.0% | 0.0% |
| 1983 | 99.8% | 0.2% | 0.0% |
| 1984 | 97.8% | 2.2% | 0.0% |
| 1985 | 88.7% | 6.6% | 4.7% |
| 1986 | 62.7% | 23.8% | 13.6% |
| 1987 | 39.3% | 32.7% | 28.0% |
| 1988 | 13.2% | 41.6% | 45.2% |
| 1989 | 9.1% | 54.0% | 36.9% |
| 1990 | 3.2% | 60.1% | 36.7% |
| 1991 | 1.6% | 57.7% | 40.7% |

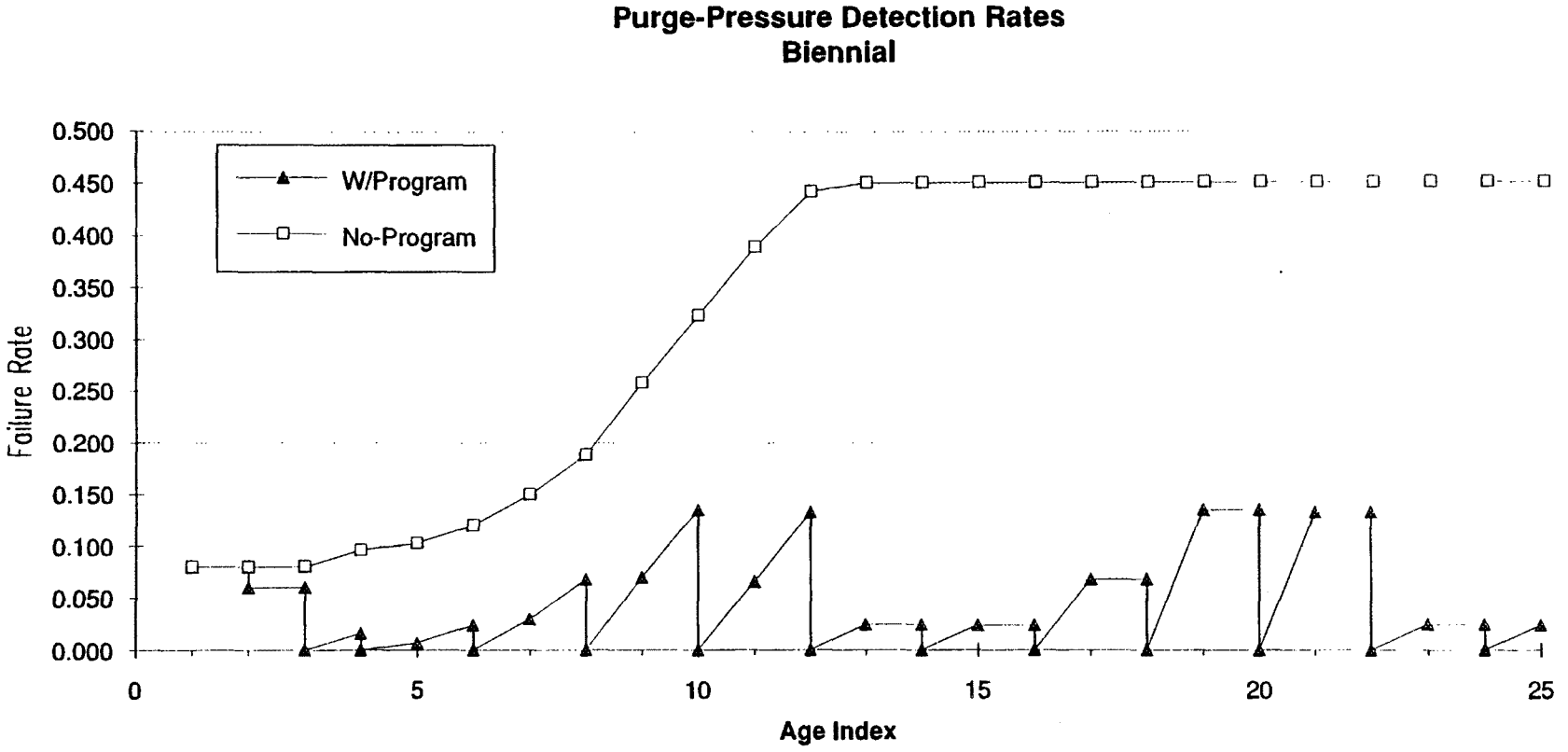
| Model Year | Any 3way | Any Ox3way | Any Oxid |
|---|---|---|---|
| 1981 | 0.9% | 1.8% | 94.3% |
| 1982 | 3.9% | 0.1% | 96.1% |
| 1983 | 4.0% | 9.3% | 84.1% |
| 1984 | 6.6% | 23.1% | 70.3% |
| 1985 | 20.0% | 19.8% | 60.2% |
| 1986 | 37.9% | 13.0% | 49.0% |
| 1987 | 51.5% | 25.2% | 23.2% |
| 1988 | 73.0% | 25.1% | 1.8% |
| 1989 | 67.8% | 31.0% | 1.1% |
| 1990 | 74.2% | 24.9% | 0.9% |
| 1991 | 80.3% | 19.7% | 0.0% |

All vehicle counts taken from CAFE estimates, except 1989 and newer model years, which are from General Label predictions.

# APPENDIX D

## PURGE AND PRESSURE TEST EFFECTIVENESS FIGURES AND SPREADSHEET


Purge-Pressure Detection Rates
Annual
W/Program
No-Program
Failure Rate
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0
5
10
15
20
25
Age Index


Purge-Pressure Detection Rates
Biennial
W/Program
No-Program
Failure Rate
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0
5
10
15
20
25
Age Index

Revised Purge/Pressure Failure Rates for MOBILE4.1

| ANNUAL | | | | | |
|---|---|---|---|---|---|
| Age Index | In-lane No-program fail rate | New Detect Rate | Annual After | Annual average | Annual % benefit |
| 1 | 0.080 | 0.0800 | 0.0800 | 0.0800 | 0.000 |
| 2 | 0.080 | 0.0800 | 0.0600 | 0.0600 | 0.238 |
| 3 | 0.080 | 0.0600 | 0.0000 | 0.0080 | 0.853 |
| 4 | 0.096 | 0.0160 | 0.0000 | 0.0035 | 0.910 |
| 5 | 0.103 | 0.0070 | 0.0000 | 0.0085 | 0.836 |
| 6 | 0.120 | 0.0170 | 0.0000 | 0.0150 | 0.789 |
| 7 | 0.150 | 0.0300 | 0.0000 | 0.0190 | 0.765 |
| 8 | 0.188 | 0.0380 | 0.0000 | 0.0350 | 0.732 |
| 9 | 0.258 | 0.0700 | 0.0000 | 0.0325 | 0.798 |
| 10 | 0.323 | 0.0650 | 0.0000 | 0.0330 | 0.837 |
| 11 | 0.389 | 0.0660 | 0.0000 | 0.0265 | 0.903 |
| 12 | 0.442 | 0.0530 | 0.0000 | 0.0125 | 0.967 |
| 13 | 0.451 | 0.0250 | 0.0000 | 0.0035 | 0.992 |
| 14 | 0.451 | 0.0070 | 0.0000 | 0.0085 | 0.981 |
| 15 | 0.451 | 0.0170 | 0.0000 | 0.0150 | 0.967 |
| 16 | 0.451 | 0.0300 | 0.0000 | 0.0190 | 0.958 |
| 17 | 0.451 | 0.0380 | 0.0000 | 0.0350 | 0.922 |
| 18 | 0.451 | 0.0700 | 0.0000 | 0.0325 | 0.928 |
| 19 | 0.451 | 0.0650 | 0.0000 | 0.0330 | 0.927 |
| 20 | 0.451 | 0.0660 | 0.0000 | 0.0265 | 0.941 |
| 21 | 0.451 | 0.0530 | 0.0000 | 0.0125 | 0.972 |
| 22 | 0.451 | 0.0250 | 0.0000 | 0.0035 | 0.992 |
| 23 | 0.451 | 0.0070 | 0.0000 | 0.0085 | 0.981 |
| 24 | 0.451 | 0.0170 | 0.0000 | 0.0150 | 0.967 |
| 25 | 0.451 | 0.0300 | 0.0000 | 0.0190 | 0.958 |
| | | 0.0380 | | | |
| | | 0.0412 | | Average | 0.908 |

| BIENNIAL | | New Detect 1 | | | |
|---|---|---|---|---|---|
| Age Index | No-program in-lane fail rate | 0 Rate | Bien. After | Bien. average | Bien. % benefit |
| 1 | 0.080 | 0.0800 | 0.0800 | 0.0800 | 0.000 |
| 2 | 0.080 | 0.0800 | 0.0600 | 0.0600 | 0.238 |
| 3 | 0.080 | 0.0600 | 0.0000 | 0.0080 | 0.853 |
| 4 | 0.096 | 0.0160 | 0.0000 | 0.0035 | 0.910 |
| 5 | 0.103 | 0.0070 | 0.0070 | 0.0155 | 0.779 |
| 6 | 0.120 | 0.0240 | 0.0000 | 0.0150 | 0.789 |
| 7 | 0.150 | 0.0300 | 0.0300 | 0.0490 | 0.612 |
| 8 | 0.188 | 0.0680 | 0.0000 | 0.0350 | 0.732 |
| 9 | 0.258 | 0.0700 | 0.0700 | 0.1025 | 0.582 |
| 10 | 0.323 | 0.1350 | 0.0000 | 0.0330 | 0.837 |
| 11 | 0.389 | 0.0660 | 0.0660 | 0.0995 | 0.733 |
| 12 | 0.442 | 0.1330 | 0.0000 | 0.0125 | 0.967 |
| 13 | 0.451 | 0.0250 | 0.0250 | 0.0250 | 0.945 |
| 14 | 0.451 | 0.0250 | 0.0000 | 0.0120 | 0.973 |
| 15 | 0.451 | 0.0240 | 0.0240 | 0.0240 | 0.947 |
| 16 | 0.451 | 0.0240 | 0.0000 | 0.0340 | 0.925 |
| 17 | 0.451 | 0.0680 | 0.0680 | 0.0680 | 0.849 |
| 18 | 0.451 | 0.0680 | 0.0000 | 0.0675 | 0.850 |
| 19 | 0.451 | 0.1350 | 0.1350 | 0.1350 | 0.701 |
| 20 | 0.451 | 0.1350 | 0.0000 | 0.0665 | 0.853 |
| 21 | 0.451 | 0.1330 | 0.1330 | 0.1330 | 0.705 |
| 22 | 0.451 | 0.1330 | 0.0000 | 0.0125 | 0.972 |
| 23 | 0.451 | 0.0250 | 0.0250 | 0.0250 | 0.945 |
| 24 | 0.451 | 0.0250 | 0.0000 | 0.0120 | 0.973 |
| 25 | 0.451 | 0.0240 | 0.0240 | 0.0240 | 0.947 |
| | | 0.0240 | | | |
| | | 0.0630 | | Average | 0.843 |

Revised Purge/Pressure Failure Rates for MOBILE4.1

| ANNUAL | | | | | |
|---|---|---|---|---|---|
| | In-lane | New | | | |
| Age | No-program | Detect | Annual | Annual | Annual |
| Index | fail rate | Rate | After | average | % benefit |
| 1 | 0.08 | =B5 | =V5 | =(W5+V6)/2 | =($L5-X5)/(($L5+$L6)/2) |
| =1+A5 | 0.08 | =B5 | =0.75*V6 | =(W6+V7)/2 | =($L6-X6)/(($L6+$L7)/2) |
| =1+A6 | 0.08 | =N6 | 0 | =(W7+V8)/2 | =($L7-X7)/(($L7+$L8)/2) |
| =1+A7 | 0.096 | =B8-B7 | 0 | =(W8+V9)/2 | =($L8-X8)/(($L8+$L9)/2) |
| =1+A8 | 0.103 | =B9-B8 | 0 | =(W9+V10)/2 | =($L9-X9)/(($L9+$L10)/2) |
| =1+A9 | 0.12 | =B10-B9 | 0 | =(W10+V11)/2 | =($L10-X10)/(($L10+$L11)/2) |
| =1+A10 | 0.15 | =B11-B10 | 0 | =(W11+V12)/2 | =($L11-X11)/(($L11+$L12)/2) |
| =1+A11 | 0.188 | =B12-B11 | 0 | =(W12+V13)/2 | =($L12-X12)/(($L12+$L13)/2) |
| =1+A12 | 0.258 | =B13-B12 | 0 | =(W13+V14)/2 | =($L13-X13)/(($L13+$L14)/2) |
| =1+A13 | 0.323 | =B14-B13 | 0 | =(W14+V15)/2 | =($L14-X14)/(($L14+$L15)/2) |
| =1+A14 | 0.389 | =B15-B14+(B6-B5) | 0 | =(W15+V16)/2 | =($L15-X15)/(($L15+$L16)/2) |
| =1+A15 | 0.442 | =B16-B15+(B7-B6) | 0 | =(W16+V17)/2 | =($L16-X16)/(($L16+$L17)/2) |
| =1+A16 | 0.451 | =B17-B16+(B8-B7) | 0 | =(W17+V18)/2 | =($L17-X17)/(($L17+$L18)/2) |
| =1+A17 | 0.451 | =V9 | 0 | =(W18+V19)/2 | =($L18-X18)/(($L18+$L19)/2) |
| =1+A18 | 0.451 | =V10 | 0 | =(W19+V20)/2 | =($L19-X19)/(($L19+$L20)/2) |
| =1+A19 | 0.451 | =V11 | 0 | =(W20+V21)/2 | =($L20-X20)/(($L20+$L21)/2) |
| =1+A20 | 0.451 | =V12 | 0 | =(W21+V22)/2 | =($L21-X21)/(($L21+$L22)/2) |
| =1+A21 | 0.451 | =V13 | 0 | =(W22+V23)/2 | =($L22-X22)/(($L22+$L23)/2) |
| =1+A22 | 0.451 | =V14 | 0 | =(W23+V24)/2 | =($L23-X23)/(($L23+$L24)/2) |
| =1+A23 | 0.451 | =V15 | 0 | =(W24+V25)/2 | =($L24-X24)/(($L24+$L25)/2) |
| =1+A24 | 0.451 | =V16 | 0 | =(W25+V26)/2 | =($L25-X25)/(($L25+$L26)/2) |
| =1+A25 | 0.451 | =V17 | 0 | =(W26+V27)/2 | =($L26-X26)/(($L26+$L27)/2) |
| =1+A26 | 0.451 | =V18 | 0 | =(W27+V28)/2 | =($L27-X27)/(($L27+$L28)/2) |
| =1+A27 | 0.451 | =V19 | 0 | =(W28+V29)/2 | =($L28-X28)/(($L28+$L29)/2) |
| =1+A28 | 0.451 | =V20 | 0 | =(W29+V30)/2 | =($L29-X29)/(($L29+$L30)/2) |
| | | =V21 | | | |
| | | =AVERAGE(V5:V30) | | Average | =AVERAGE(Y7:Y29) |

| BIENNIAL | | New Detect | | | |
|---|---|---|---|---|---|
| | No-program | 1 | | | |
| Age | in-lane | =1-V56 | Bien. | Bien. | Bien. |
| Index | fail rate | Rate | After | average | % benefit |
| 1 | 0.08 | =B59 | =V59 | =(W59+V60)/2 | =($L59-X59)/(($L59+$L60)/2) |
| =1+A59 | 0.08 | =B59 | =0.25*V$57*V60+(0.75*V60) | =(W60+V61)/2 | =($L60-X60)/(($L60+$L61)/2) |
| =1+A60 | 0.08 | =N60 | =V61*V$57 | =(W61+V62)/2 | =($L61-X61)/(($L61+$L62)/2) |
| =1+A61 | 0.096 | =B62-B61 | =W61+(V$57*(V62-W61)) | =(W62+V63)/2 | =($L62-X62)/(($L62+$L63)/2) |
| =1+A62 | 0.103 | =B63-B62 | =V63 | =(W63+V64)/2 | =($L63-X63)/(($L63+$L64)/2) |
| =1+A63 | 0.12 | =V63+(B64-B63) | =W62+(V$57*(V64-W62)) | =(W64+V65)/2 | =($L64-X64)/(($L64+$L65)/2) |
| =1+A64 | 0.15 | =B65-B64 | =V65 | =(W65+V66)/2 | =($L65-X65)/(($L65+$L66)/2) |
| =1+A65 | 0.188 | =V65+(B66-B65) | =W64+(V$57*(V66-W64)) | =(W66+V67)/2 | =($L66-X66)/(($L66+$L67)/2) |
| =1+A66 | 0.258 | =B67-B66 | =V67 | =(W67+V68)/2 | =($L67-X67)/(($L67+$L68)/2) |
| =1+A67 | 0.323 | =V67+(B68-B67)+(B60-B59) | =W66+(V$57*(V68-W66)) | =(W68+V69)/2 | =($L68-X68)/(($L68+$L69)/2) |
| =1+A68 | 0.389 | =(B69-B68)+(B60-B59) | =V69 | =(W69+V70)/2 | =($L69-X69)/(($L69+$L70)/2) |
| =1+A69 | 0.442 | =V6+(B70-B69)+(B61-B60) | =W68+(V$57*(V70-W68)) | =(W70+V71)/2 | =($L70-X70)/(($L70+$L71)/2) |
| =1+A70 | 0.451 | =(B71-B70)+(B62-B61) | =V71 | =(W71+V72)/2 | =($L71-X71)/(($L71+$L72)/2) |
| =1+A71 | 0.451 | =W71+(V63-W63) | =W70+(V$57*(V72-W70)) | =(W72+V73)/2 | =($L72-X72)/(($L72+$L73)/2) |
| =1+A72 | 0.451 | =W72+(V64-W64) | =V73 | =(W73+V74)/2 | =($L73-X73)/(($L73+$L74)/2) |
| =1+A73 | 0.451 | =W73+(V65-W65) | =W72+(V$57*(V74-W72)) | =(W74+V75)/2 | =($L74-X74)/(($L74+$L75)/2) |
| =1+A74 | 0.451 | =W74+(V66-W66) | =V75 | =(W75+V76)/2 | =($L75-X75)/(($L75+$L76)/2) |
| =1+A75 | 0.451 | =W75+(V67-W67) | =W74+(V$57*(V76-W74)) | =(W76+V77)/2 | =($L76-X76)/(($L76+$L77)/2) |
| =1+A76 | 0.451 | =W76+(V68-W68) | =V77 | =(W77+V78)/2 | =($L77-X77)/(($L77+$L78)/2) |
| =1+A77 | 0.451 | =W77+(V69-W69) | =W76+(V$57*(V78-W76)) | =(W78+V79)/2 | =($L78-X78)/(($L78+$L79)/2) |
| =1+A78 | 0.451 | =W78+(V70-W70) | =V79 | =(W79+V80)/2 | =($L79-X79)/(($L79+$L80)/2) |
| =1+A79 | 0.451 | =W79+(V71-W71) | =W78+(V$57*(V80-W78)) | =(W80+V81)/2 | =($L80-X80)/(($L80+$L81)/2) |
| =1+A80 | 0.451 | =W80+(V72-W72) | =V81 | =(W81+V82)/2 | =($L81-X81)/(($L81+$L82)/2) |
| =1+A81 | 0.451 | =W81+(V73-W73) | =W80+(V$57*(V82-W80)) | =(W82+V83)/2 | =($L82-X82)/(($L82+$L83)/2) |
| =1+A82 | 0.451 | =W82+(V74-W74) | =V83 | =(W83+V84)/2 | =($L83-X83)/(($L83+$L84)/2) |
| | | =W83+(V75-W75) | | | |
| | | =AVERAGE(V59:V84) | | Average | =AVERAGE(Y61:Y83) |

# APPENDIX E

## REGRESSION ANALYSES AND SCATTER PLOTS FOR FUEL-INJECTED 1983 AND LATER VEHICLES

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# IM240 VEHICLES TESTED TO DATE

12/13/91

| | Test | As Received In Micro | | RM #1 In Micro | | RM #2 In Micro | | RM #3 In Micro | |
|---|---|---|---|---|---|---|---|---|---|
| | | Indiana | Ann Arbor | Indiana | Ann Arbor | Indiana | Ann Arbor | Indiana | Ann Arbor |
| | FTP | 453 | 314 | 213 | 75 | 35 | 9 | 3 | 0 |
| **Lane IM240** | | | | | | | | | |
| | IM240 Lane | 7313 | NA | 73 | NA | 10 | NA | 2 | NA |
| | Change of Owner | 6 | NA | 0 | NA | 0 | NA | 0 | NA |
| | MISC Repeat | 14 | NA | 0 | NA | 0 | NA | 0 | NA |
| **Tank Fuel IM240** | | | | | | | | | |
| | Tank Fuel IM240 | 435 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | After Exhust Repair | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Diagnostic IM240** | | NA | NA | 14 | 0 | 0 | 0 | 0 | 0 |
| **Non CITP IM240** | | | | | | | | | |
| | *IM 240 Performed in Lab, Independent of all other tests.* | 28 | 267 | 5 | 70 | 2 | 9 | 0 | 0 |
| **Indolene CITP-A** | | | | | | | | | |
| | IM240-A (A) | 378 | 30 | 188 | 15 | 29 | 1 | 3 | 0 |
| | CDH226-A (B) | 369 | 31 | 180 | 15 | 29 | 1 | 3 | 0 |
| | Steady State-A | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Indolene CITP-B** | | | | | | | | | |
| | IM240-B (D) | 365 | 31 | 180 | 15 | 29 | 1 | 3 | 0 |
| | CDH226-B (C) | 366 | 31 | 179 | 15 | 29 | 1 | 3 | 0 |
| | Steady State-B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Regression Analyses - Port Fuel-Injected Vehicle Sample:**

As part of EPA's regression analysis, FTP results for HC and CO emissions were each regressed against the corresponding emission results on the Lane IM240, the second chance 2500/Idle Test, and the Idle Test. Regressions were also performed comparing NOx results for the FTP and Lane IM240 (NOx emissions are not measured as part of either Idle Test and are therefore not included in this comparison). Lastly, FTP results for HC, CO, and NOx were each regressed against corresponding emissions from Lab IM240s run on Indolene fuel at the ATL lab in South Bend and at MVEL in Ann Arbor. This section provides the results of these regressions performed on a sample of port fuel injected (PFI) vehicles recruited as part of the Hammond study.

EPA removed thirteen vehicles from its sample of PFI vehicles. Three were removed because they received repairs for exhaust leaks during the interim between receiving an I/M test at the Hammond lane and being FTP tested at the lab. The ten remaining PFI vehicles were excluded due to inconsistent dynamometer settings for the Lane IM240 and the FTP. Vehicles were only removed if the horsepower or inertia weight settings were at least 15% different between the lab and the lane.

These differences in dynamometer settings arose from the use of different dynamometer look-up tables at the lane and lab. Traditional certification test car lists used for emission factor testing are too detailed for efficient use in the I/M lane. After becoming aware of the differences in the two tables, EPA opted to use the look-up table that had been simplified for lane use at both testing sites to avoid future inconsistencies. The resulting sample consisted of 74 '83 and newer PFI vehicles.

**Selecting One Score From the Second Chance 2500/Idle Test:**

To illustrate the correlation of FTP HC and CO results to the corresponding results on the second chance 2500/Idle Test, we had to select an HC score and CO score from the first chance or second chance test, and from the 2500 rpm mode or the idle mode. Concerning the first chance versus second chance results, we chose the better results relative to the HC/CO cutpoint being evaluated.

For the 2500 rpm versus idle modes, we chose the larger of the corresponding emissions measured. This approach is based on the assumption that the same cutpoints would be used on each of the modes. Hence, a vehicle would pass the two mode test if and only if the higher of its HC scores (whether Idle or 2500 rpm) met the HC cutpoint (with the same also following for the CO results).

**Graphing the Data:**

On each of the graphs comparing HC emissions, the three horizontal dotted lines are positioned at the boundaries separating:

- the normal emitters from the high emitters (0.82 g/mi),
- the high emitters from the very high emitters (1.64 g/mi), and
- the very high emitters from the super emitters (10.00 g/mi).

Similarly, on each of the graphs comparing CO emissions, the three horizontal dotted lines are positioned at the boundaries separating:

- the normal emitters from the high emitters (10.2 g/mi),
- the high emitters from the very high emitters (13.6 g/mi), and
- the very high emitters from the super emitters (150.0 g/mi).

## Regression Analyses of FTP HC versus HC Emissions Over: IM240, Idle Test, and 2500/Idle Test For PFI Vehicles

Dependent variable is: HCFTP
R^2 = 80.3%
s = 1.016 with 74 - 2 = 72 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 302.637 | 1 | 303 | 293 |
| Residual | 74.3928 | 72 | 1.03323 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.198655 | 0.1372 | 1.45 |
| HCIM24 | 1.13037 | 0.066 | 17.1 |

Dependent variable is: HCFTP
R^2 = 39.3%
s = 1.784 with 74 - 2 = 72 degrees of freedom

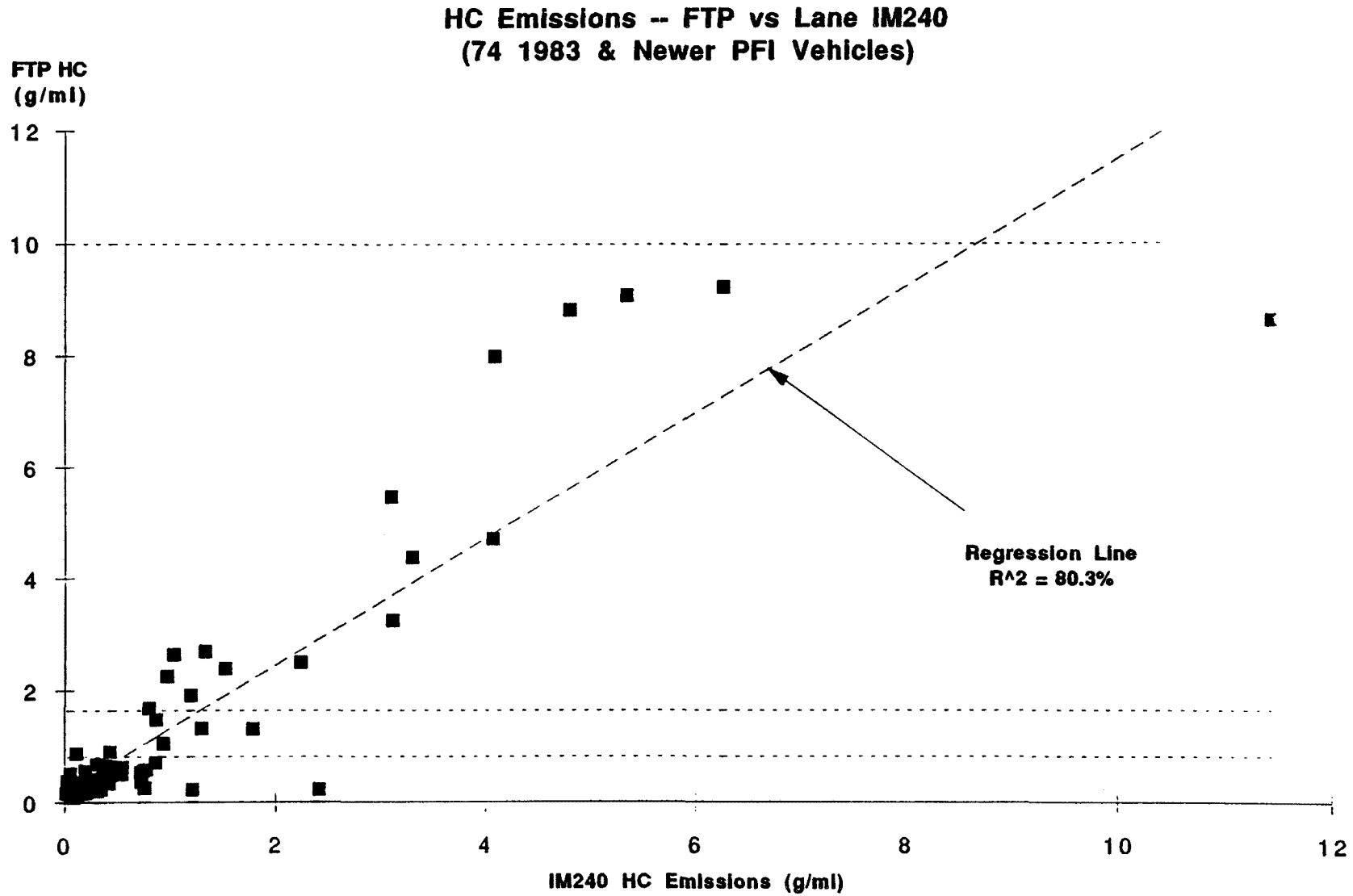
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 148.004 | 1 | 148 | 46.5 |
| Residual | 229.026 | 72 | 3.18092 | |

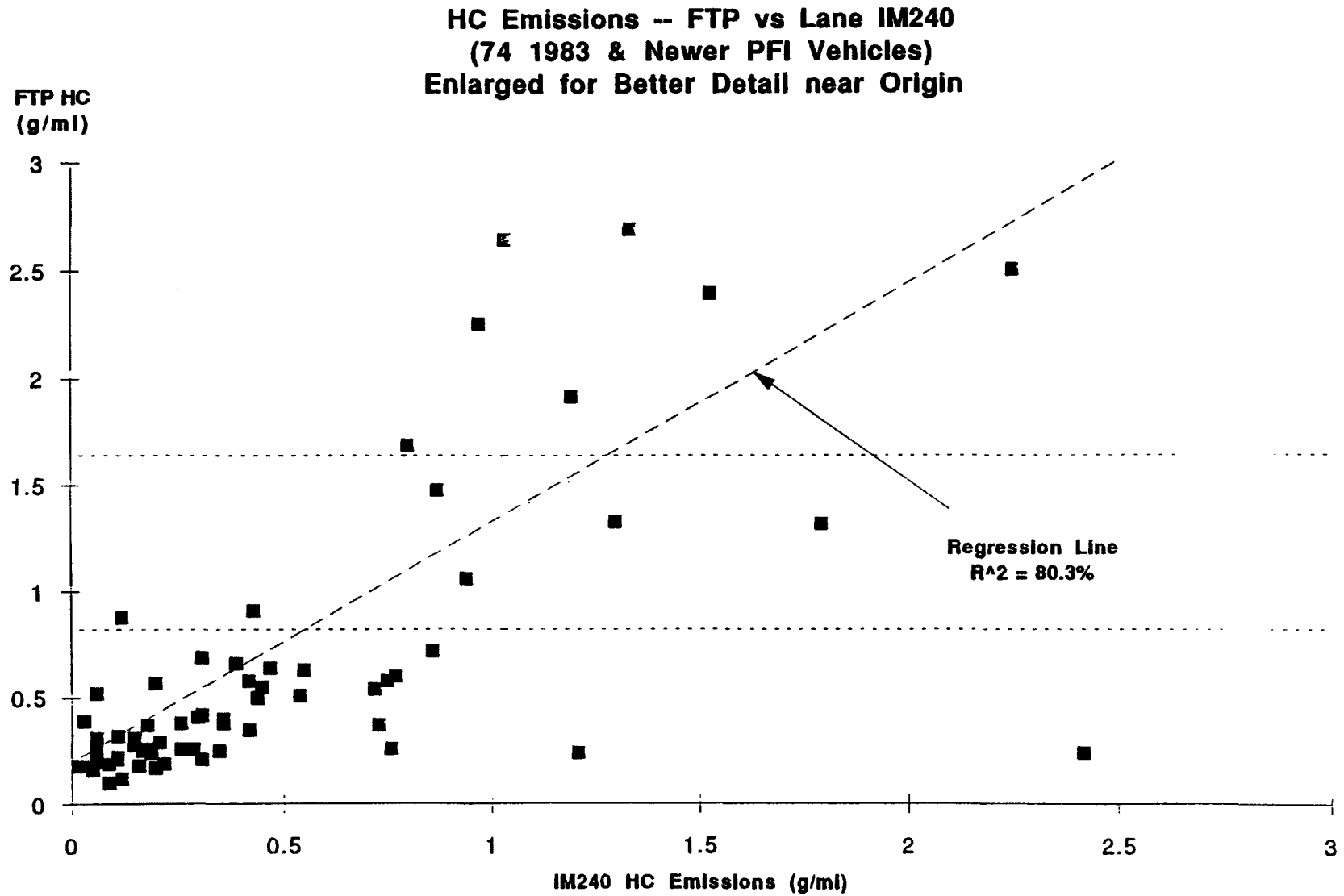
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.692609 | 0.2313 | 2.99 |
| Higher(Idle HC... | 0.003966 | 0.0006 | 6.82 |

Dependent variable is: HCFTP
R^2 = 44.3%
s = 1.709 with 74 - 2 = 72 degrees of freedom

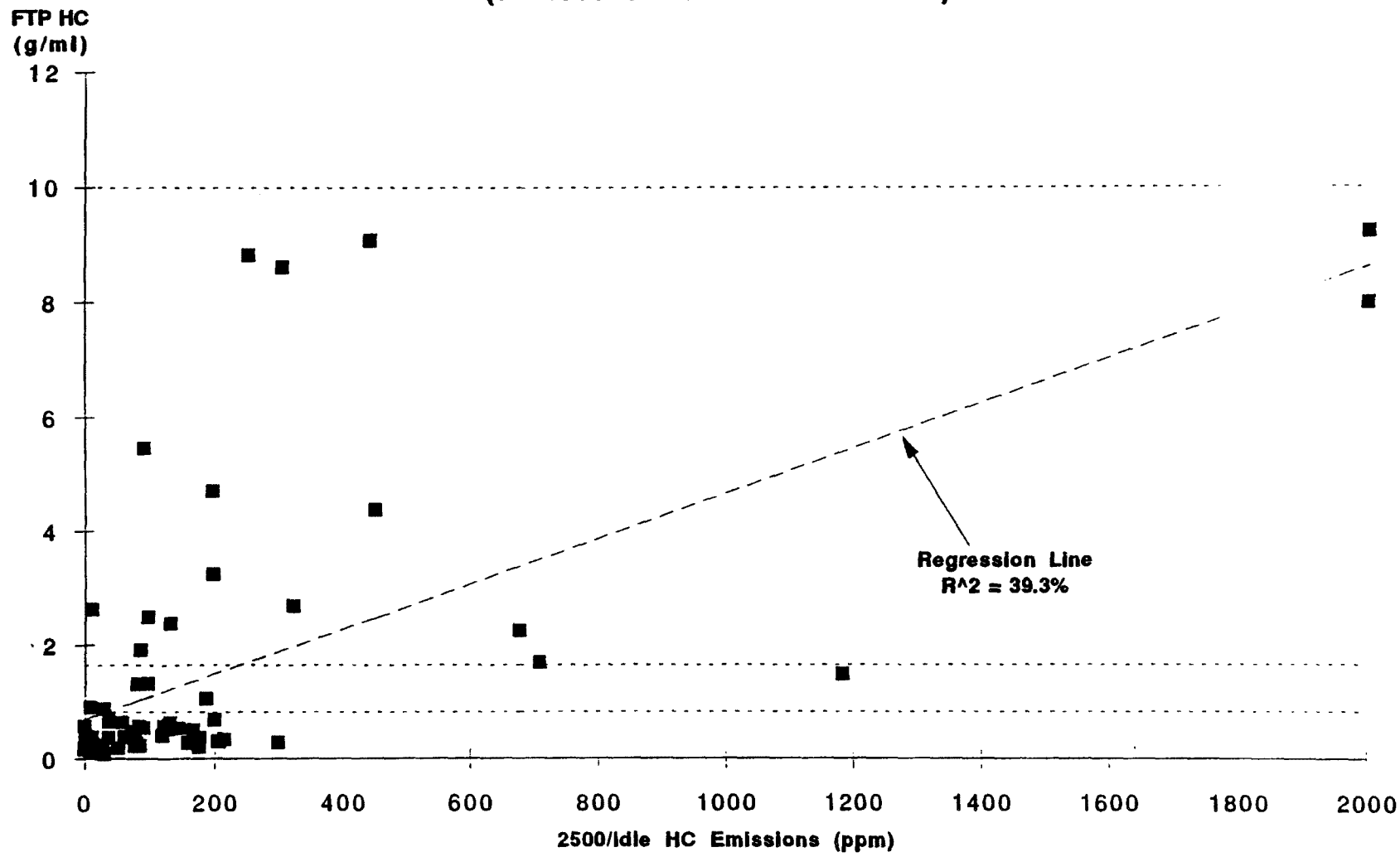
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 166.842 | 1 | 167 | 57.2 |
| Residual | 210.188 | 72 | 2.91927 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.706016 | 0.2184 | 3.23 |
| Idle.HC | 0.004541 | 0.0006 | 7.56 |

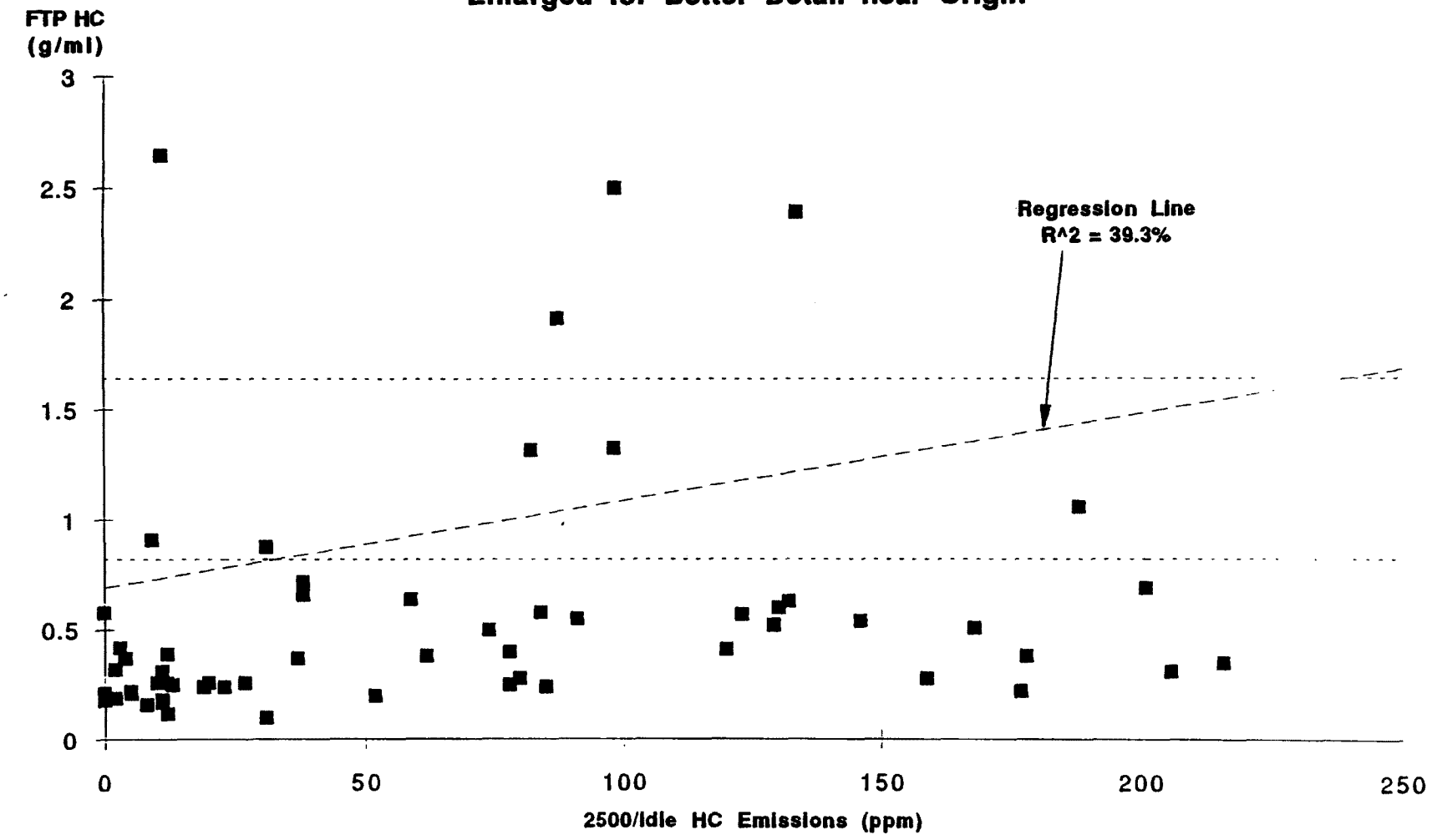

HC Emissions -- FTP vs Lane IM240
(74 1983 & Newer PFI Vehicles)
FTP HC
(g/mi)
12
10
8
6
4
2
0
0
2
4
6
8
10
12
IM240 HC Emissions (g/mi)
Regression Line
R^2 = 80.3%


HC Emissions -- FTP vs Lane IM240
(74 1983 & Newer PFI Vehicles)
Enlarged for Better Detail near Origin
FTP HC
(g/ml)
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
IM240 HC Emissions (g/ml)
Regression Line
R^2 = 80.3%

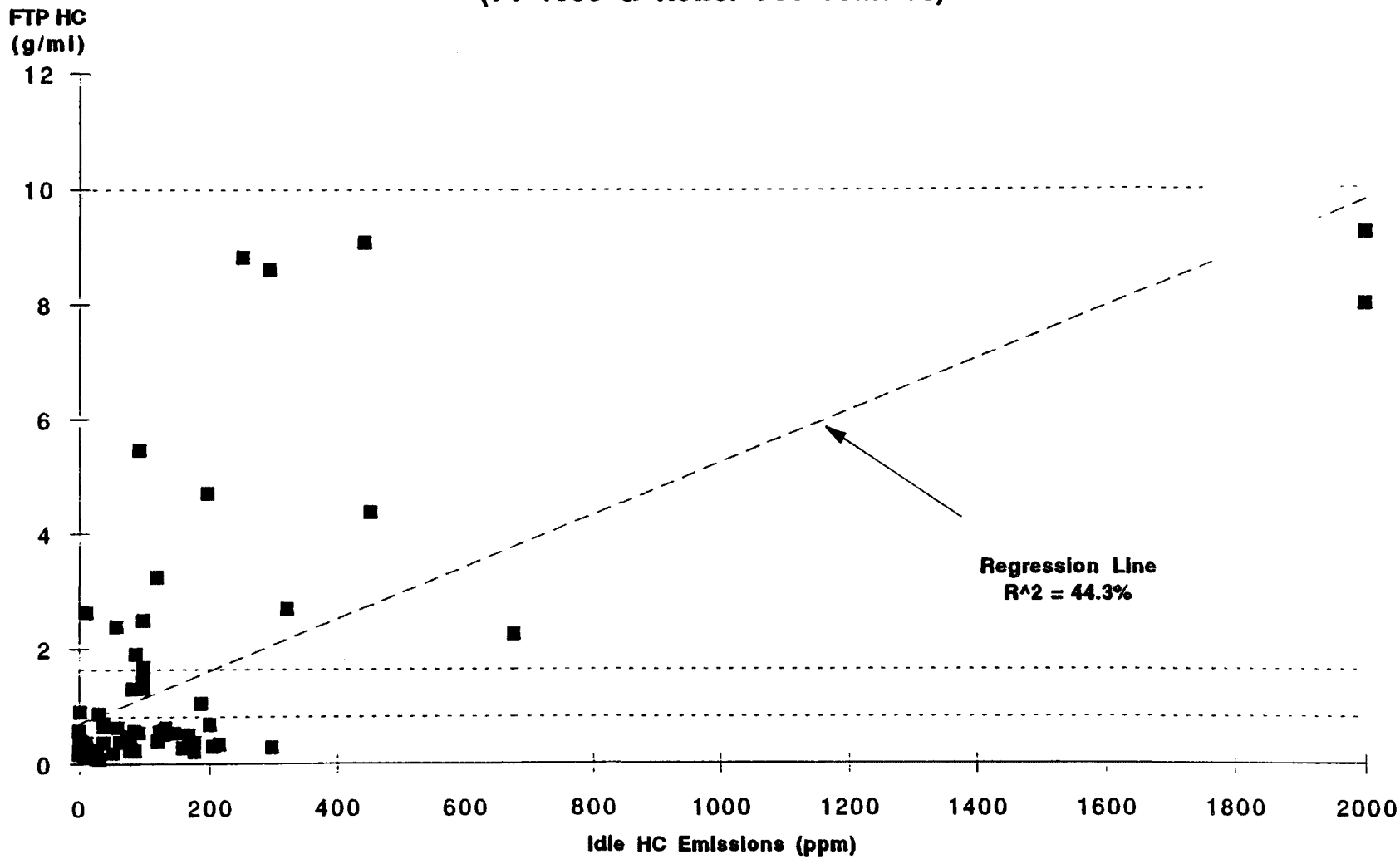
## HC Emissions -- FTP vs Lane 2500/Idle
## (74 1983 & Newer PFI Vehicles)



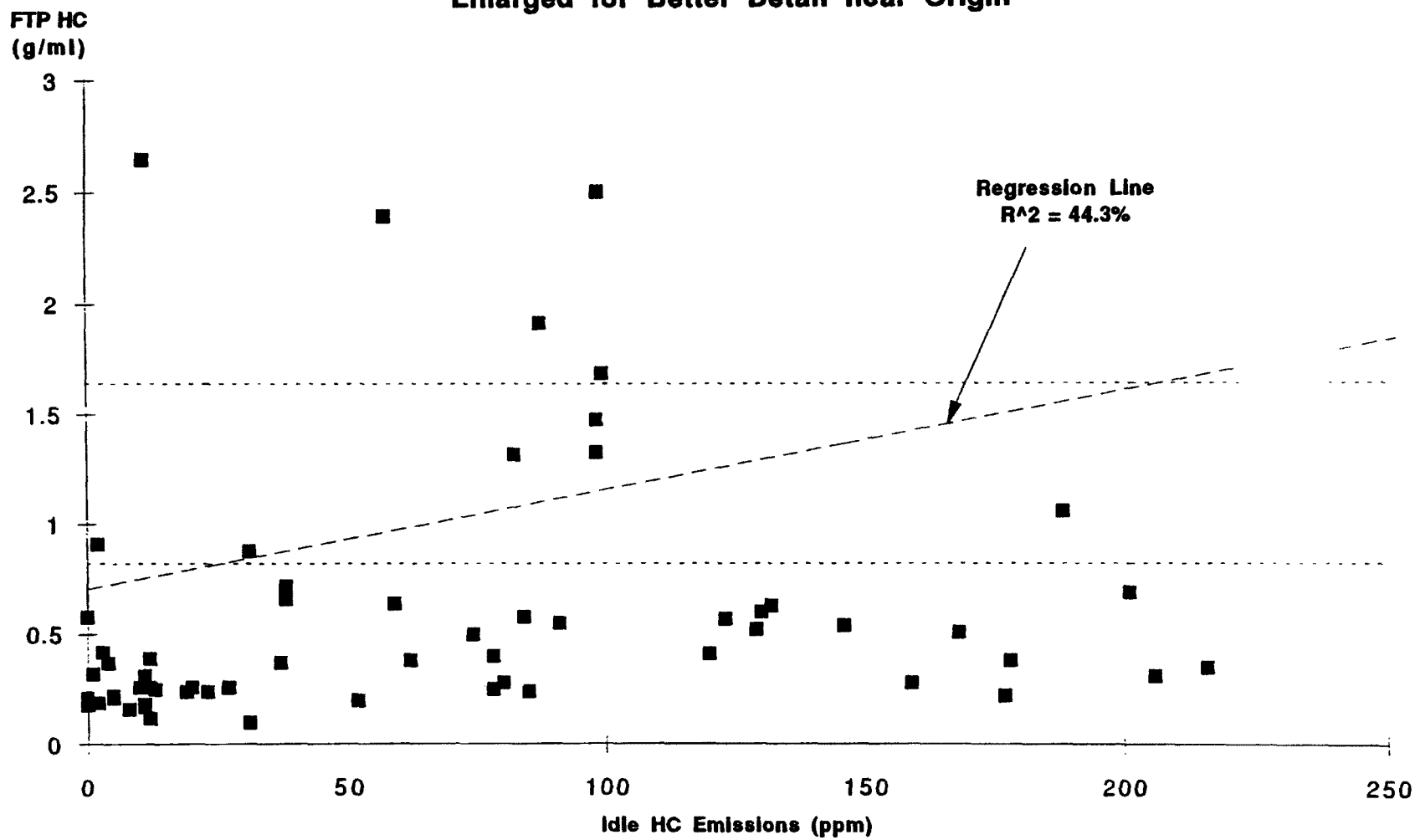
## HC Emissions -- FTP vs Lane 2500/Idle
## (74 1983 & Newer PFI Vehicles)
## Enlarged for Better Detail near Origin



## HC Emissions -- FTP vs Lane Idle
## (74 1983 & Newer PFI Vehicles)



## HC Emissions -- FTP vs Lane Idle
## (74 1983 & Newer PFI Vehicles)
## Enlarged for Better Detail near Origin



## Regression Analyses of FTP CO versus CO Emissions Over: IM240, Idle Test, and 2500/Idle Test For PFI Vehicles

Dependent variable is: COFTP
R^2 = 90.4%
s = 17.10 with 74 - 2 = 72 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 199166 | 1 | 200000 | 681 |
| Residual | 21052.3 | 72 | 292.392 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.446807 | 2.217 | 0.202 |
| COIM24 | 1.05072 | 0.0403 | 26.1 |

Dependent variable is: COFTP
R^2 = 76.3%
s = 26.91 with 74 - 2 = 72 degrees of freedom

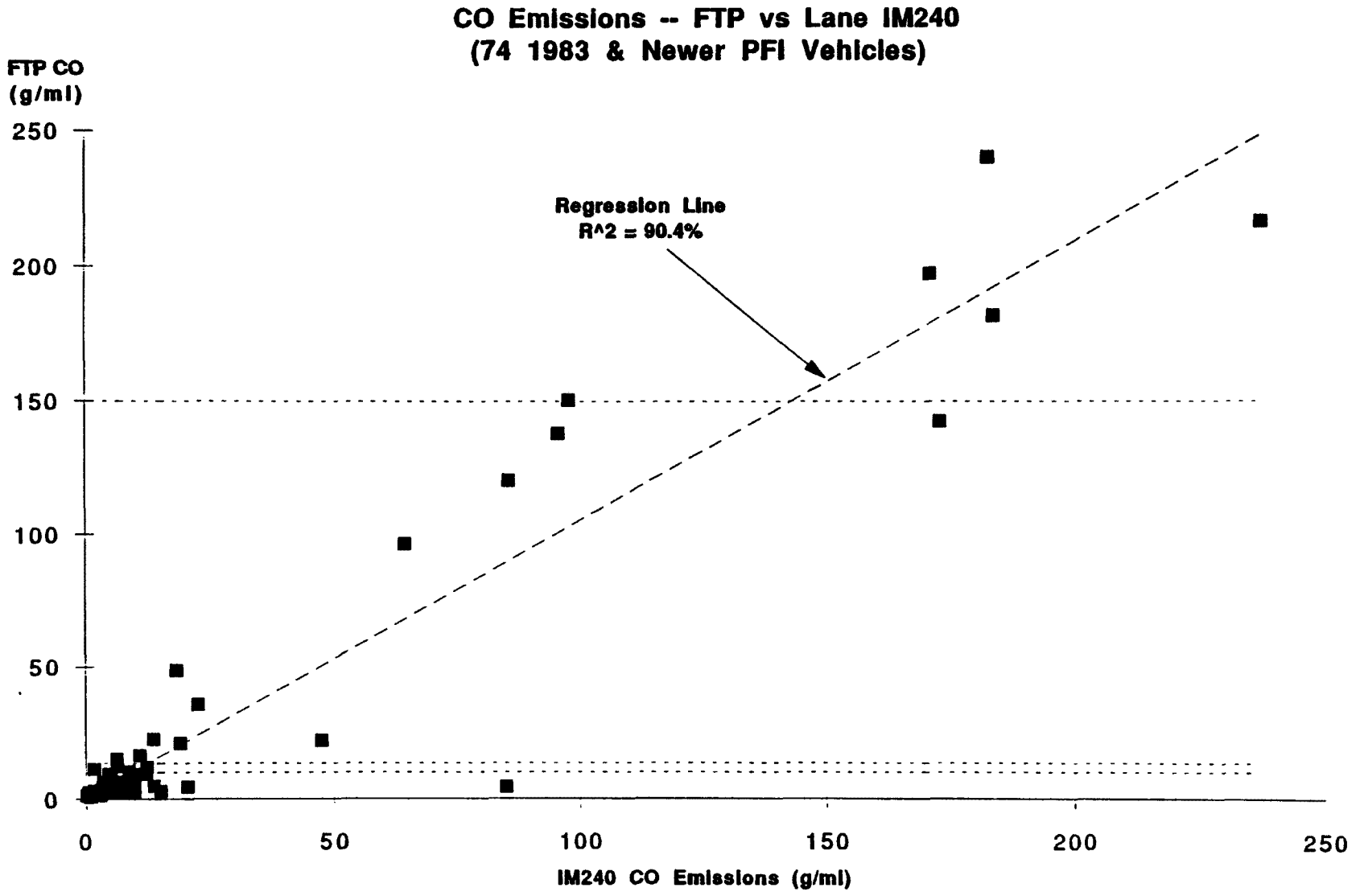
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 168093 | 1 | 200000 | 232 |
| Residual | 52125.7 | 72 | 723.968 | |

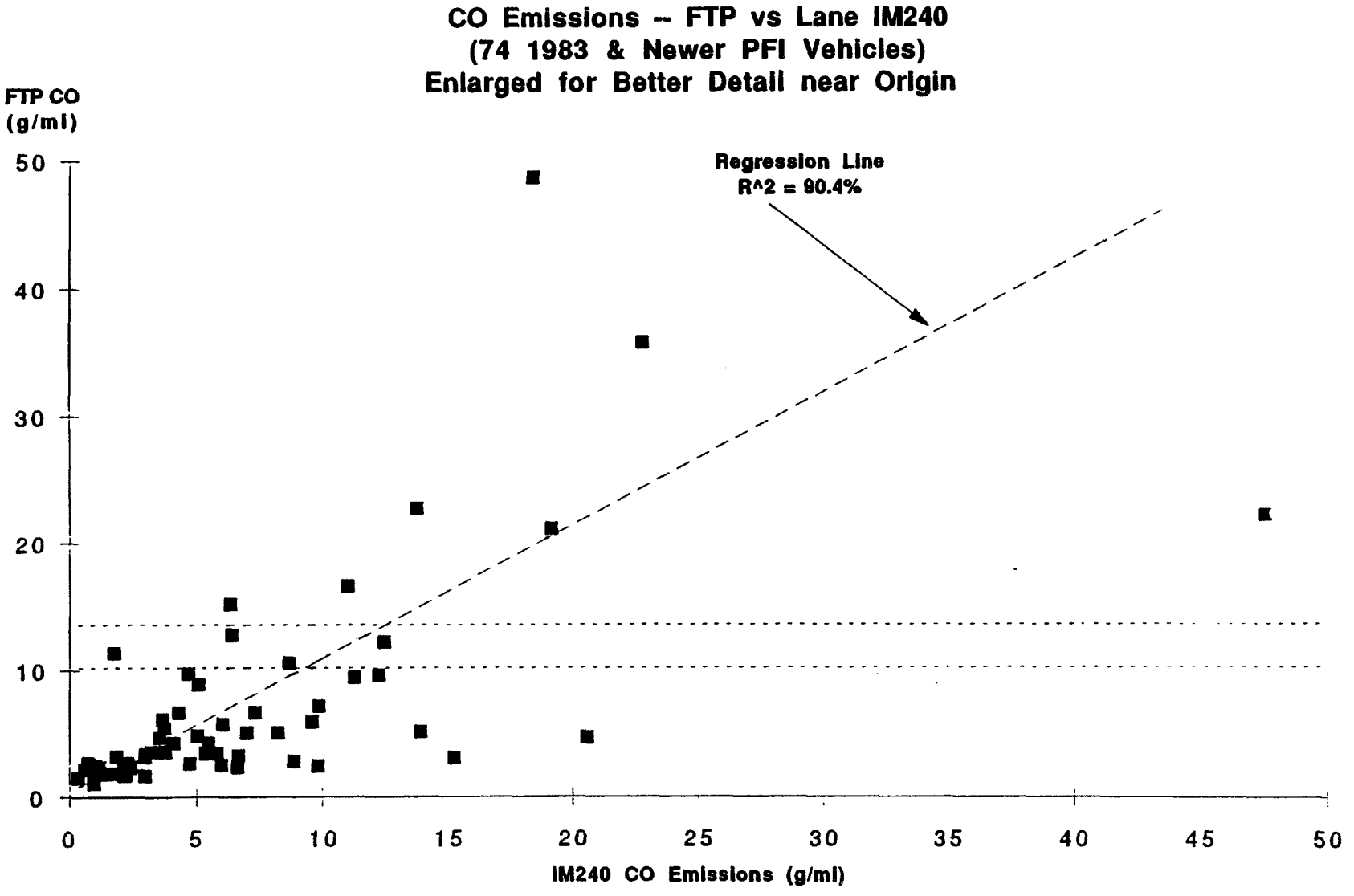
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 4.01842 | 3.446 | 1.17 |
| Higher(Idle CO... | 23.6992 | 1.555 | 15.2 |

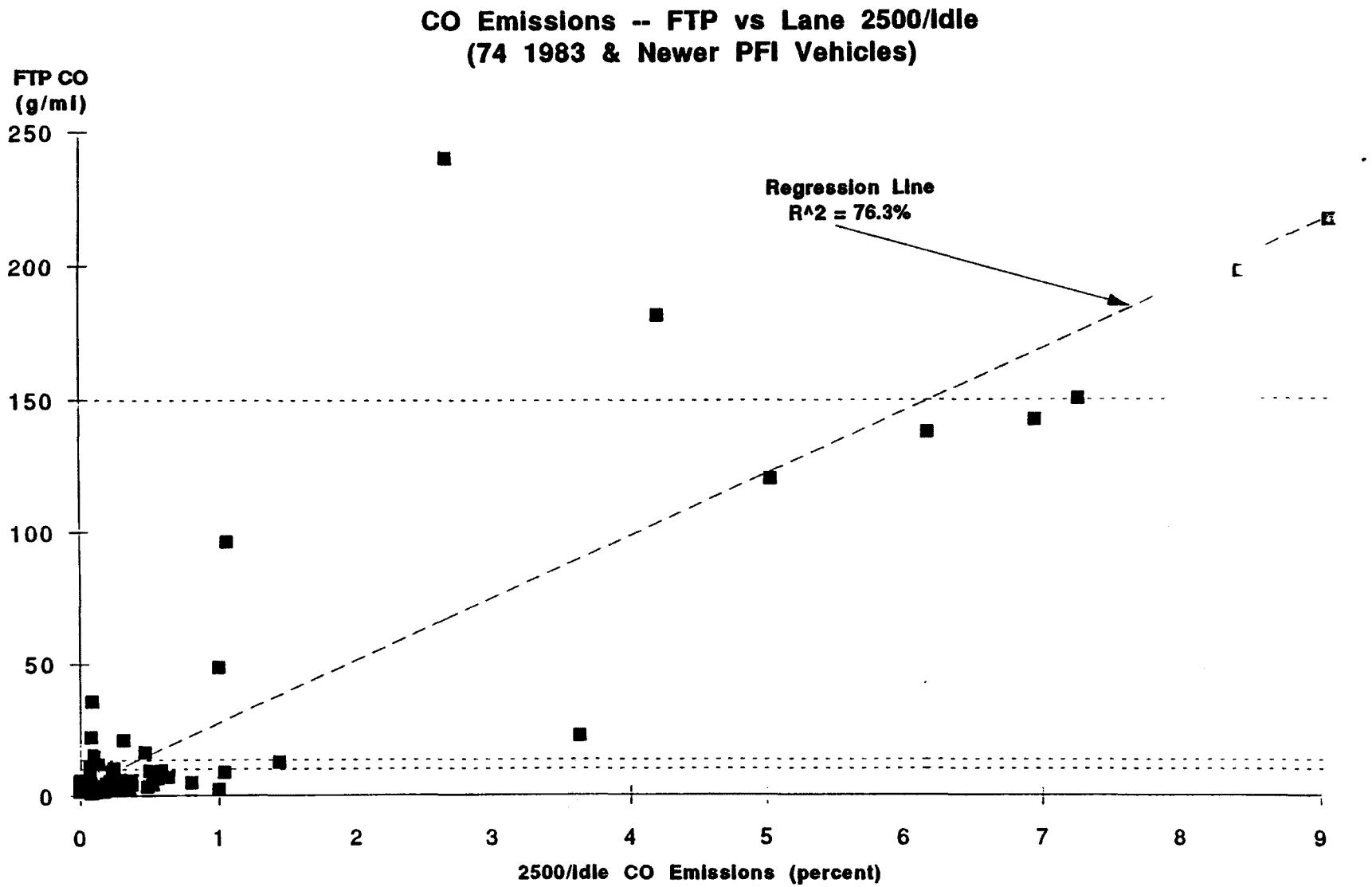
Dependent variable is: COFTP
R^2 = 61.8%
s = 34.19 with 74 - 2 = 72 degrees of freedom

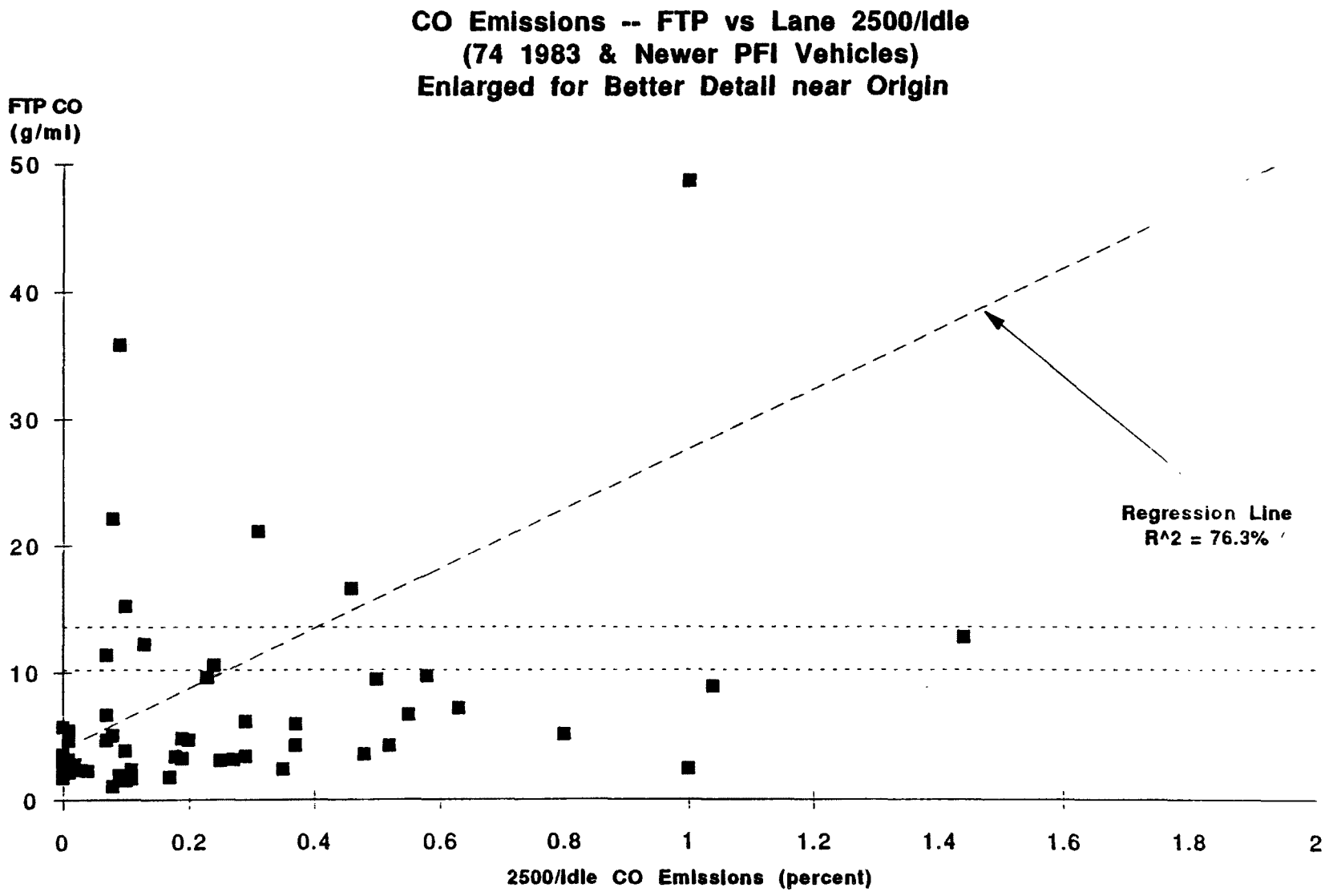
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 136071 | 1 | 100000 | 116 |
| Residual | 84147.5 | 72 | 1168.71 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 8.59165 | 4.291 | 2 |
| Idle.CO | 27.9077 | 2.586 | 10.8 |

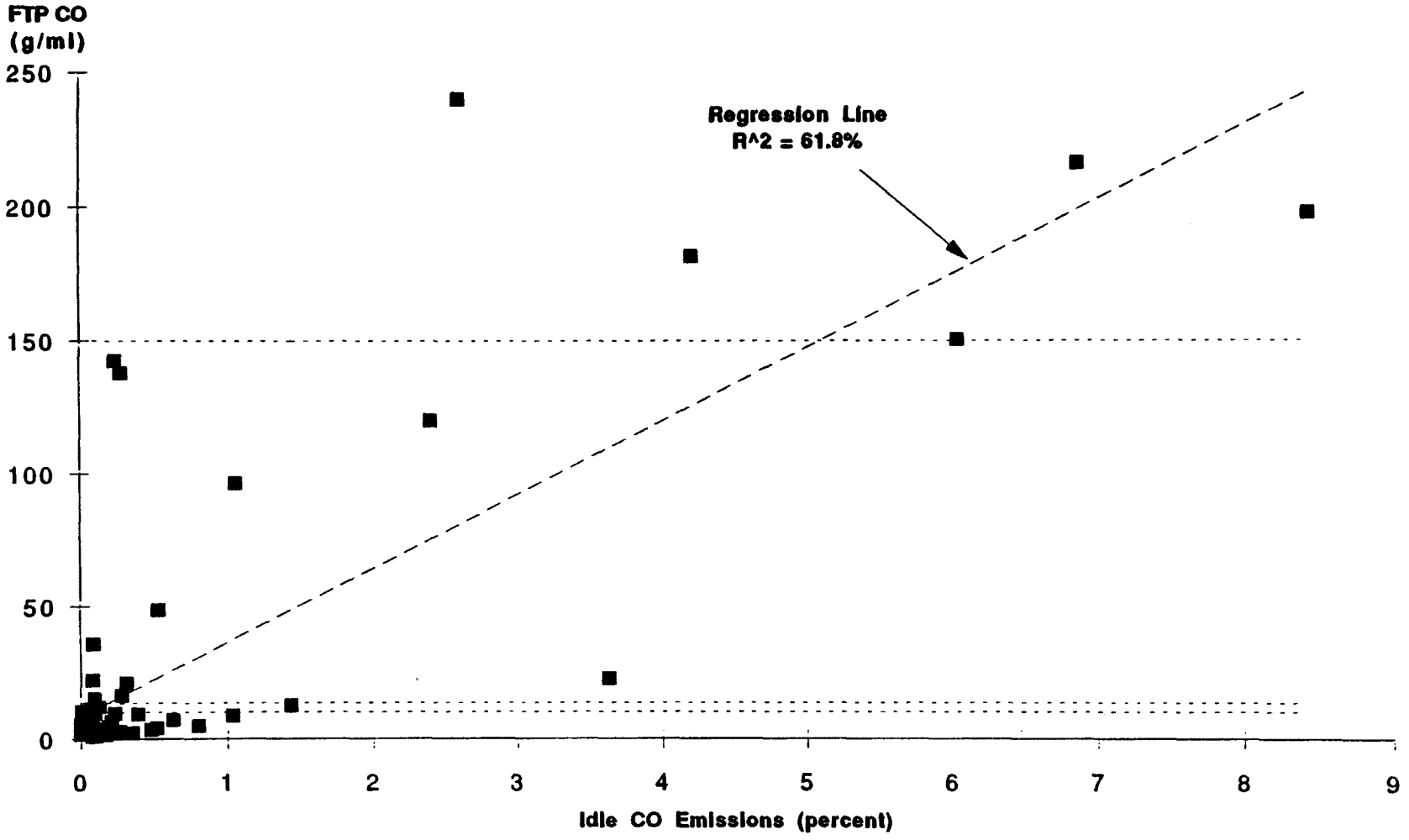

CO Emissions -- FTP vs Lane IM240
(74 1983 & Newer PFI Vehicles)
FTP CO
(g/ml)
250
200
150
100
50
0
Regression Line
R^2 = 90.4%
0
50
100
150
200
250
IM240 CO Emissions (g/ml)

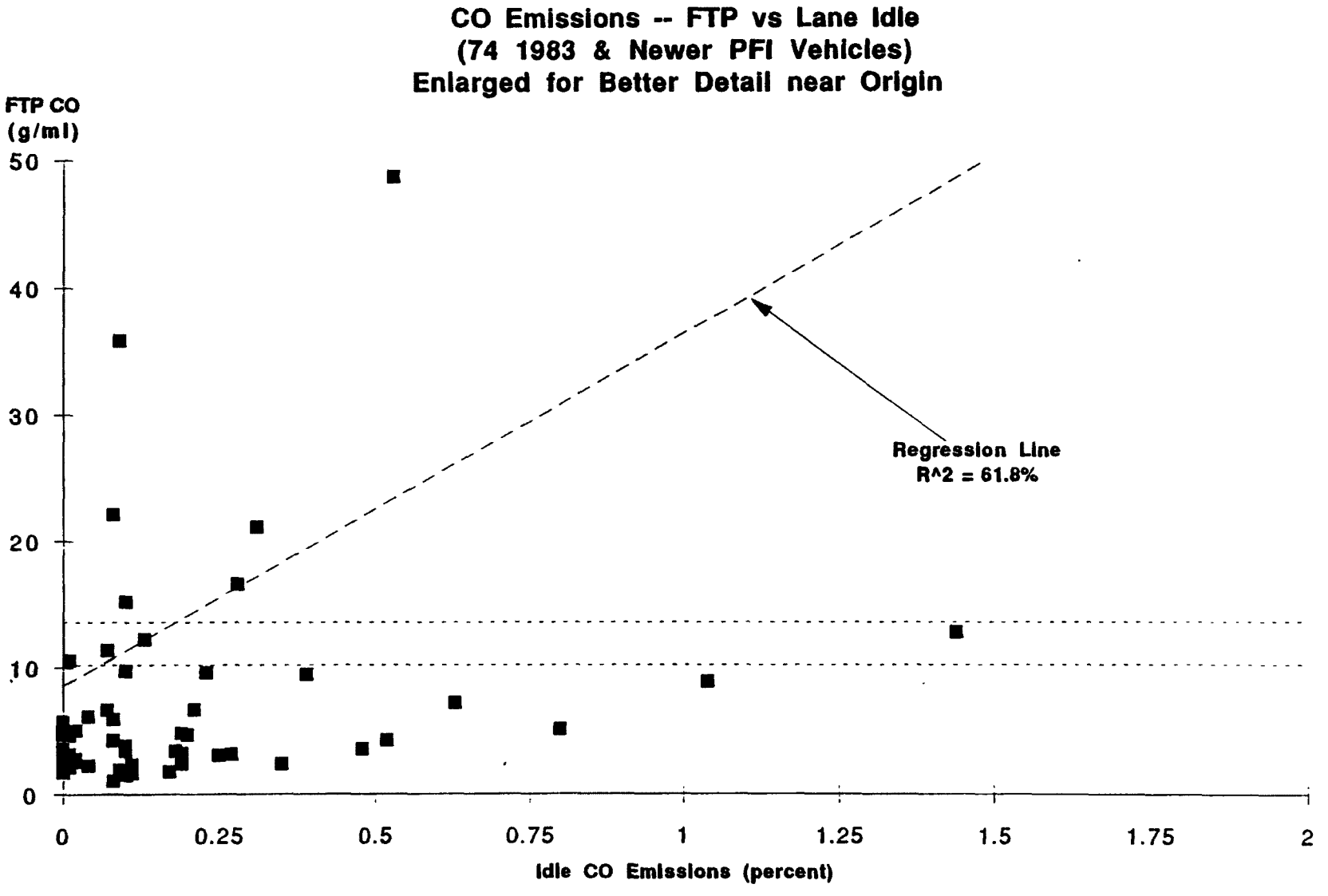

CO Emissions -- FTP vs Lane IM240
(74 1983 & Newer PFI Vehicles)
Enlarged for Better Detail near Origin
FTP CO
(g/mi)
Regression Line
R^2 = 90.4%
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
50
IM240 CO Emissions (g/mi)


CO Emissions -- FTP vs Lane 2500/Idle
(74 1983 & Newer PFI Vehicles)
FTP CO
(g/mi)
250
200
150
100
50
0
Regression Line
R^2 = 76.3%
0
1
2
3
4
5
6
7
8
9
2500/Idle CO Emissions (percent)


CO Emissions -- FTP vs Lane 2500/Idle
(74 1983 & Newer PFI Vehicles)
Enlarged for Better Detail near Origin
FTP CO
(g/mi)
50
40
30
20
10
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2500/Idle CO Emissions (percent)
Regression Line
R^2 = 76.3%

## CO Emissions -- FTP vs Lane Idle
## (74 1983 & Newer PFI Vehicles)



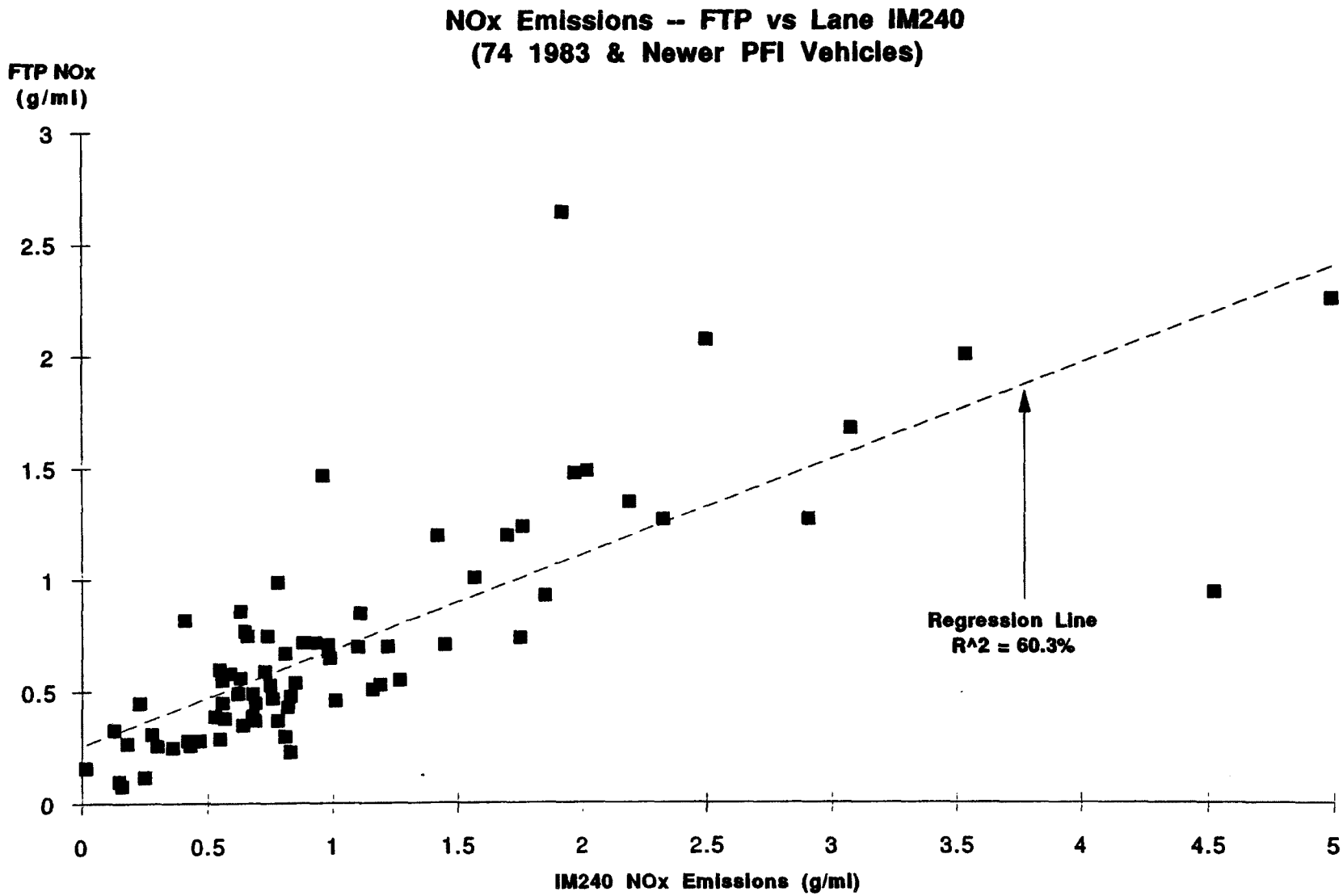

CO Emissions -- FTP vs Lane Idle
(74 1983 & Newer PFI Vehicles)
Enlarged for Better Detail near Origin
FTP CO
(g/mi)
50
40
30
20
10
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
Idle CO Emissions (percent)
Regression Line
R^2 = 61.8%

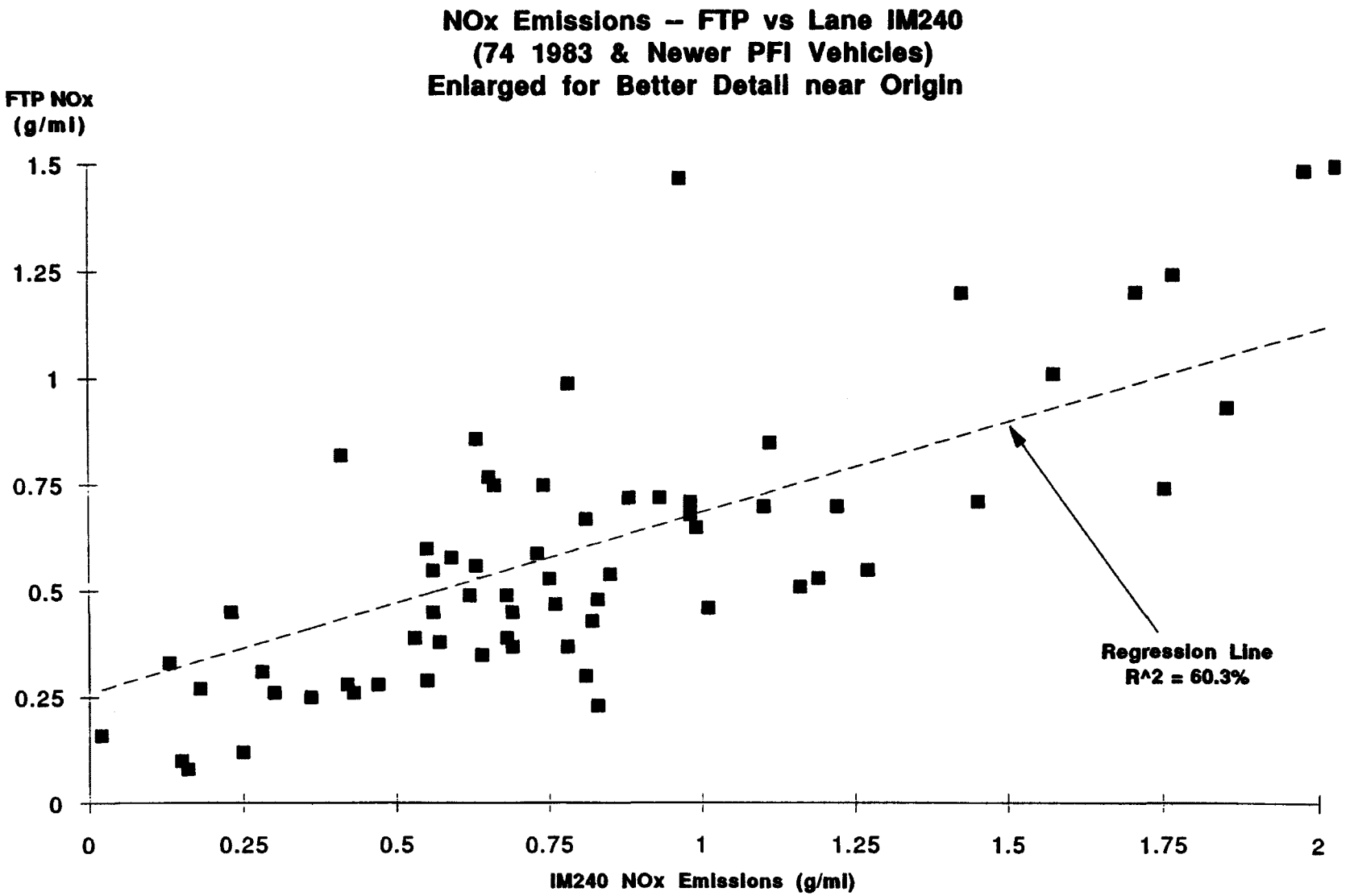
## Regression Analyses of FTP NOx versus IM240 NOx Emissions (Note: NOx is not Measured for the Idle Test)

Dependent variable is: **NOFTP**
R^2 = 60.3%
s = 0.3277 with 74 - 2 = 72 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regressior | 11.758 | 1 | 11.76 | 109 |
| Residual | 7.73394 | 72 | 0.107416 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.259283 | 0.0587 | 4.41 |
| **NOIM24** | 0.427093 | 0.0408 | 10.5 |


NOx Emissions -- FTP vs Lane IM240
(74 1983 & Newer PFI Vehicles)
FTP NOx
(g/mi)
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
IM240 NOx Emissions (g/mi)
Regression Line
R^2 = 60.3%


NOx Emissions -- FTP vs Lane IM240
(74 1983 & Newer PFI Vehicles)
Enlarged for Better Detail near Origin
FTP NOx
(g/mi)
1.5
1.25
1
0.75
0.5
0.25
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
IM240 NOx Emissions (g/mi)
Regression Line
R^2 = 60.3%

## Vehicles Tested by ATL at Southbend, Indiana

### Regressions of FTP vs Indolene-IM240 for 63 1983 & Newer PFI Vehicles

Dependent variable is **HCFTP**
R^2 = 89.2%
s = 0.8037 with 63 - 2 = 61 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 325.428 | 1 | 325 | 504 |
| Residual | 39.4065 | 61 | 0.646008 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.43699 | 0.1132 | 3.86 |
| **HC.IM24.Indo...** | 1.1596 | 0.0517 | 22.4 |

Dependent variable is **COFTP**
R^2 = 90.3%
s = 18.57 with 63 - 2 = 61 degrees of freedom

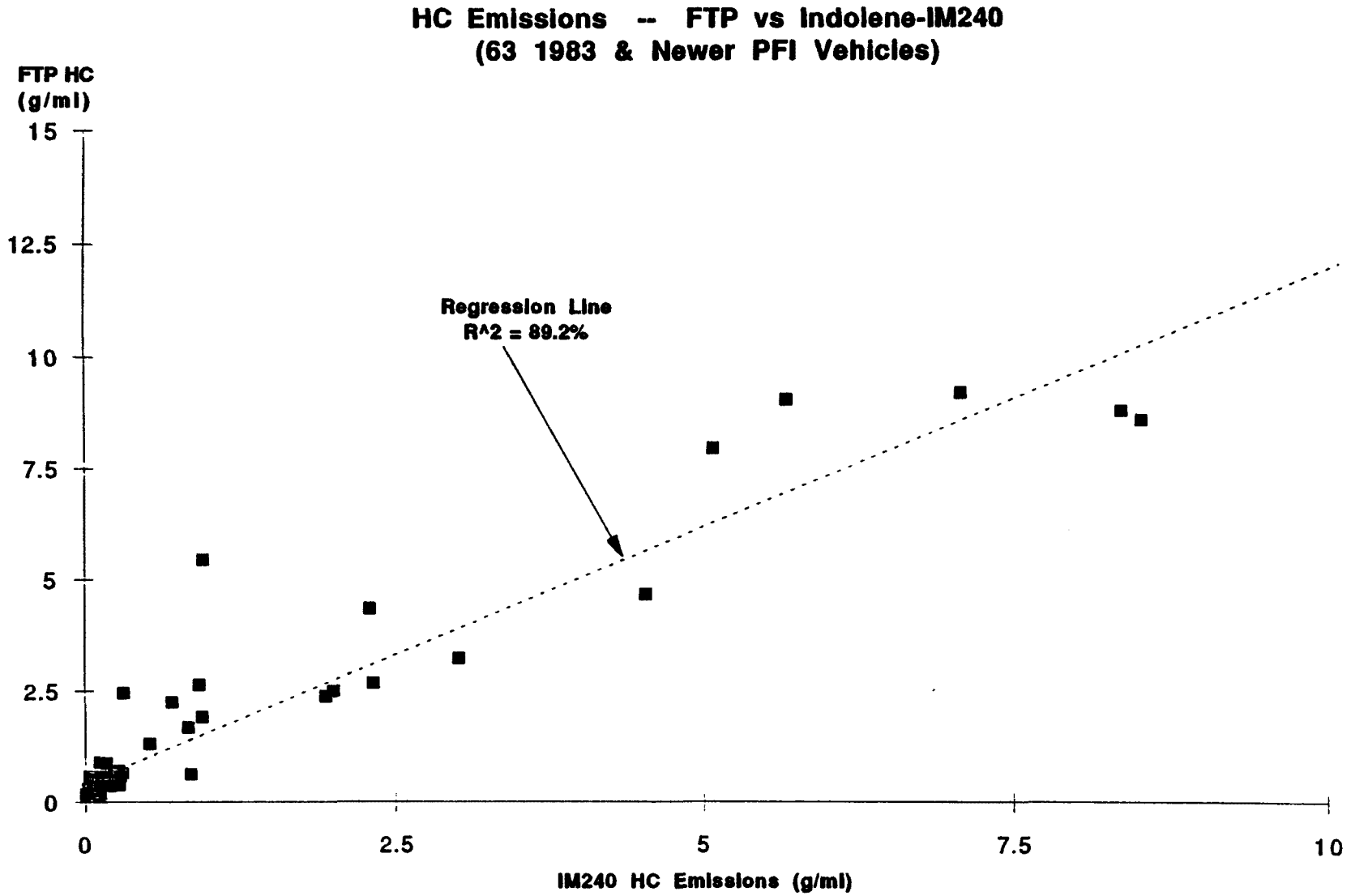
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 195708 | 1 | 200000 | 568 |
| Residual | 21030.6 | 61 | 344.764 | |

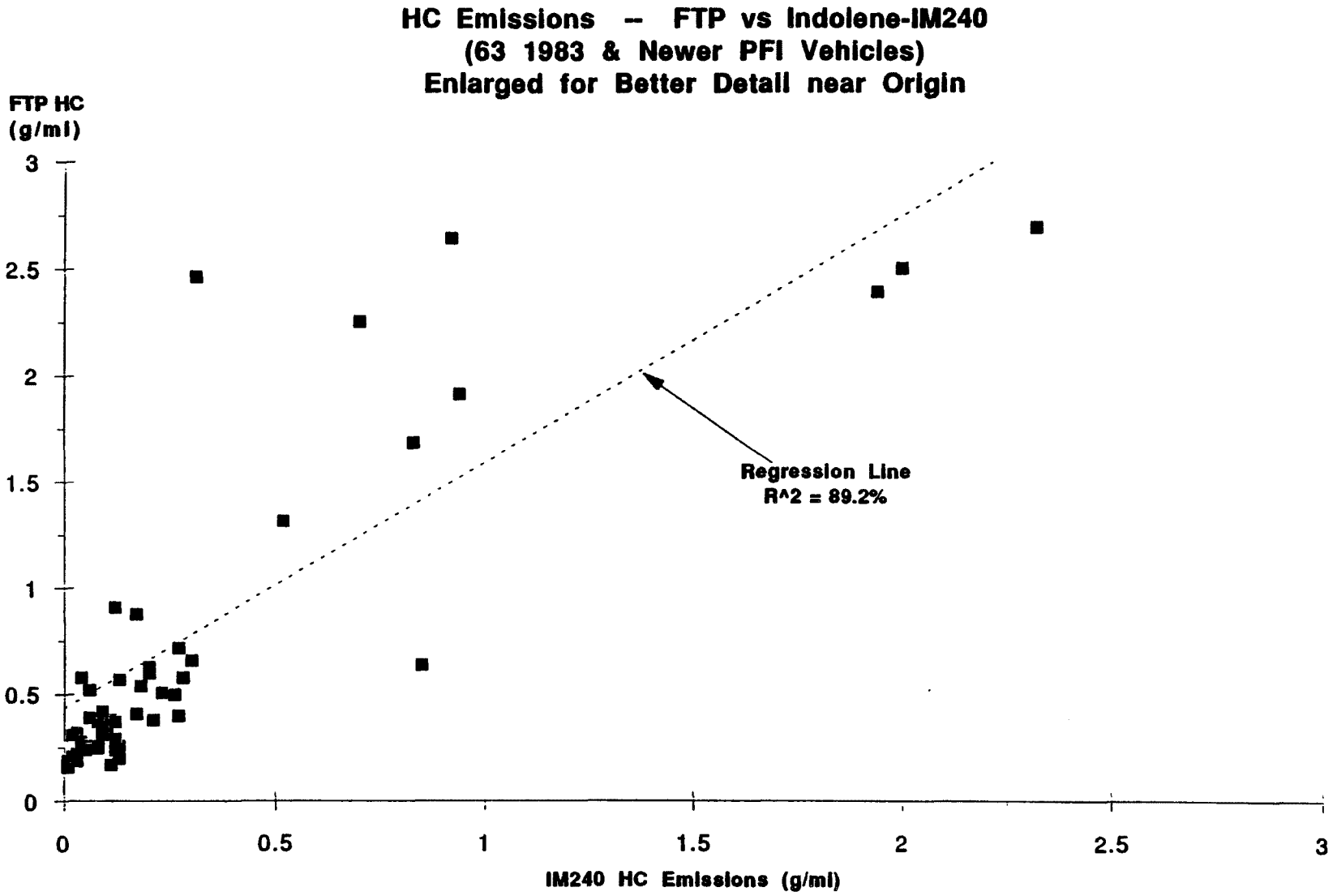
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 5.6588 | 2.571 | 2.2 |
| **CO.IM24.Indo...** | 0.991509 | 0.0416 | 23.8 |

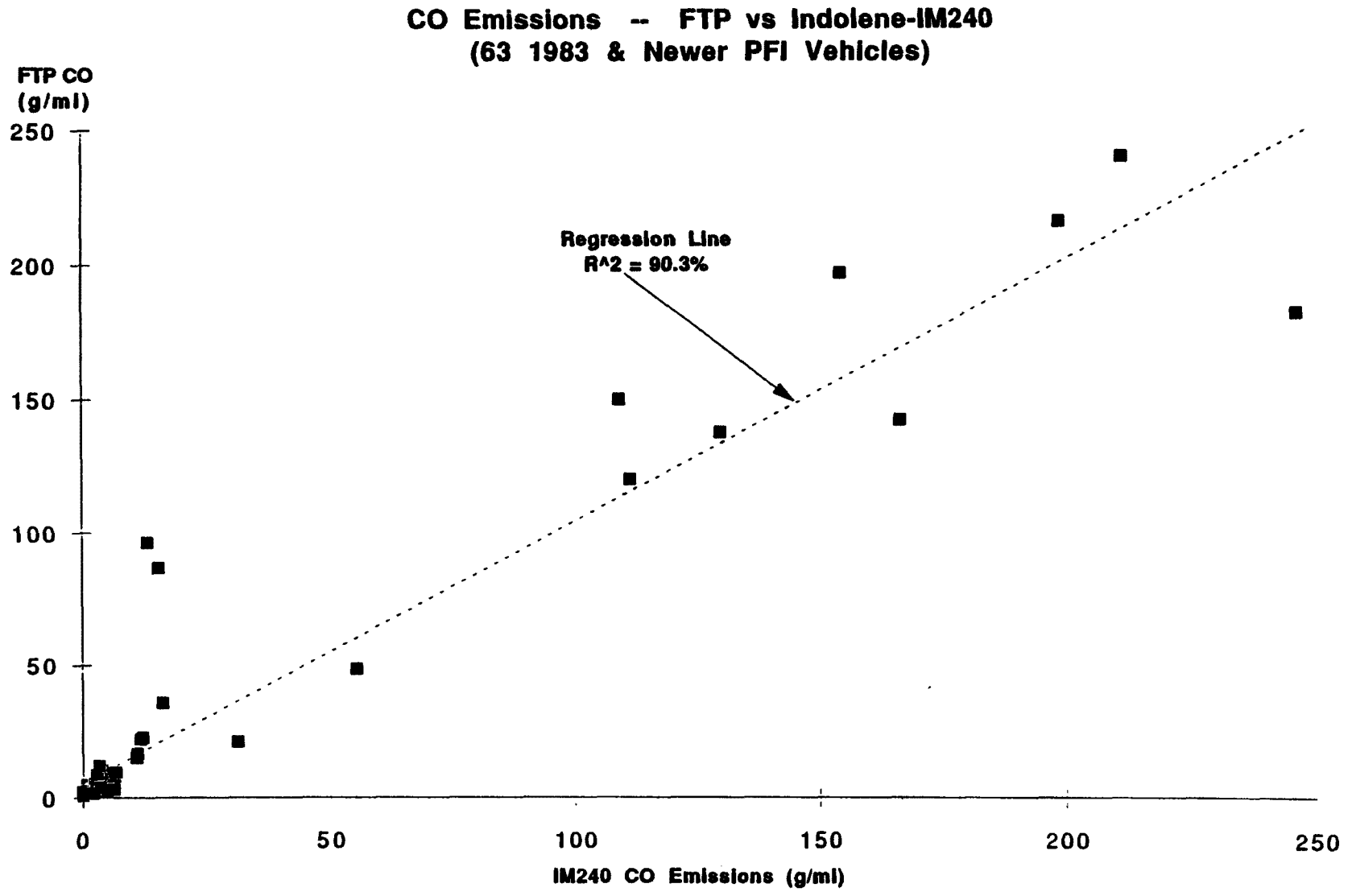
Dependent variable is **NOx.FTP**
R^2 = 89.1%
s = 0.1780 with 63 - 2 = 61 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 15.8477 | 1 | 15.85 | 500 |
| Residual | 1.93337 | 61 | 0.031695 | |

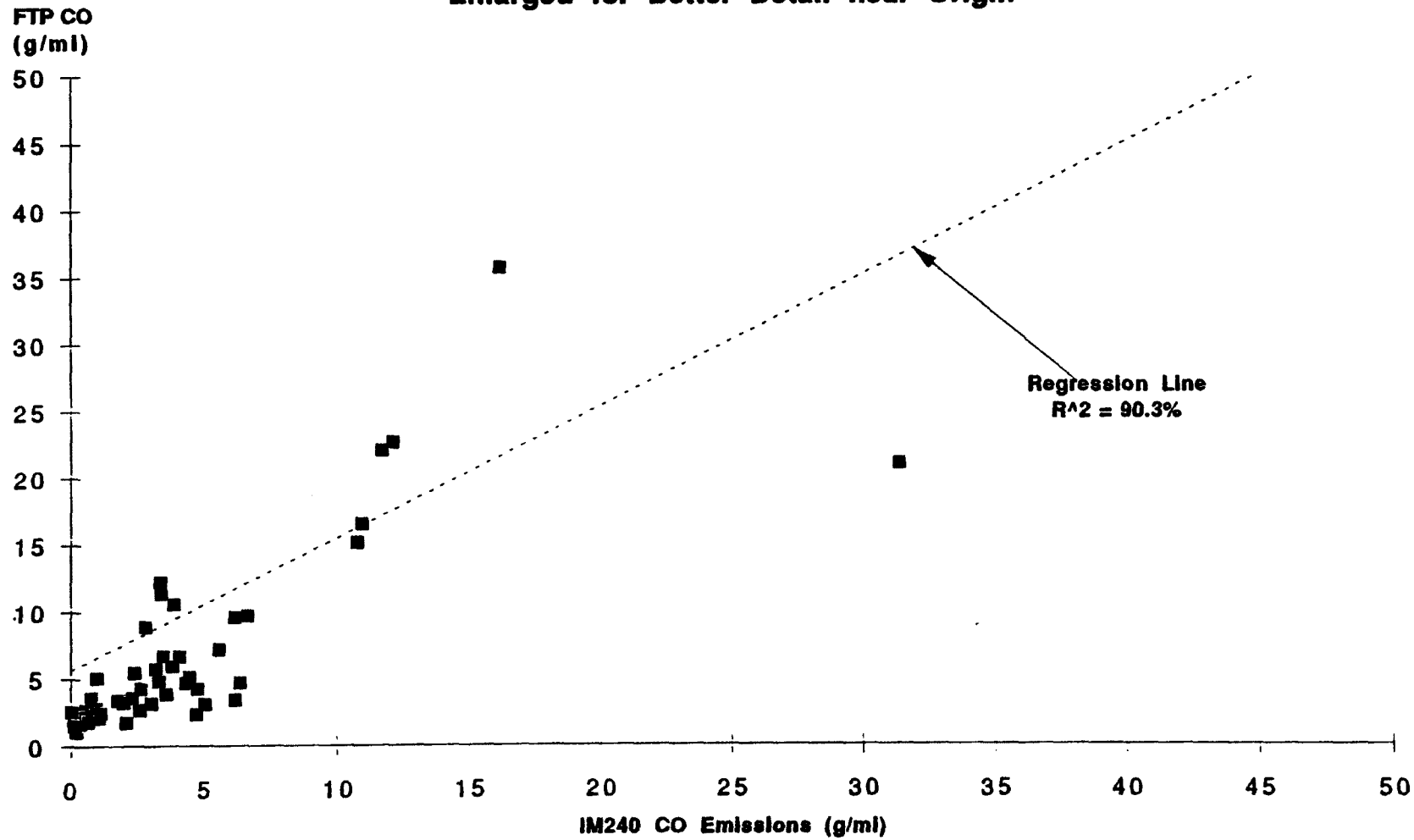
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.145473 | 0.0356 | 4.09 |
| **NOx.IM24.Ind...** | 0.757394 | 0.0339 | 22.4 |

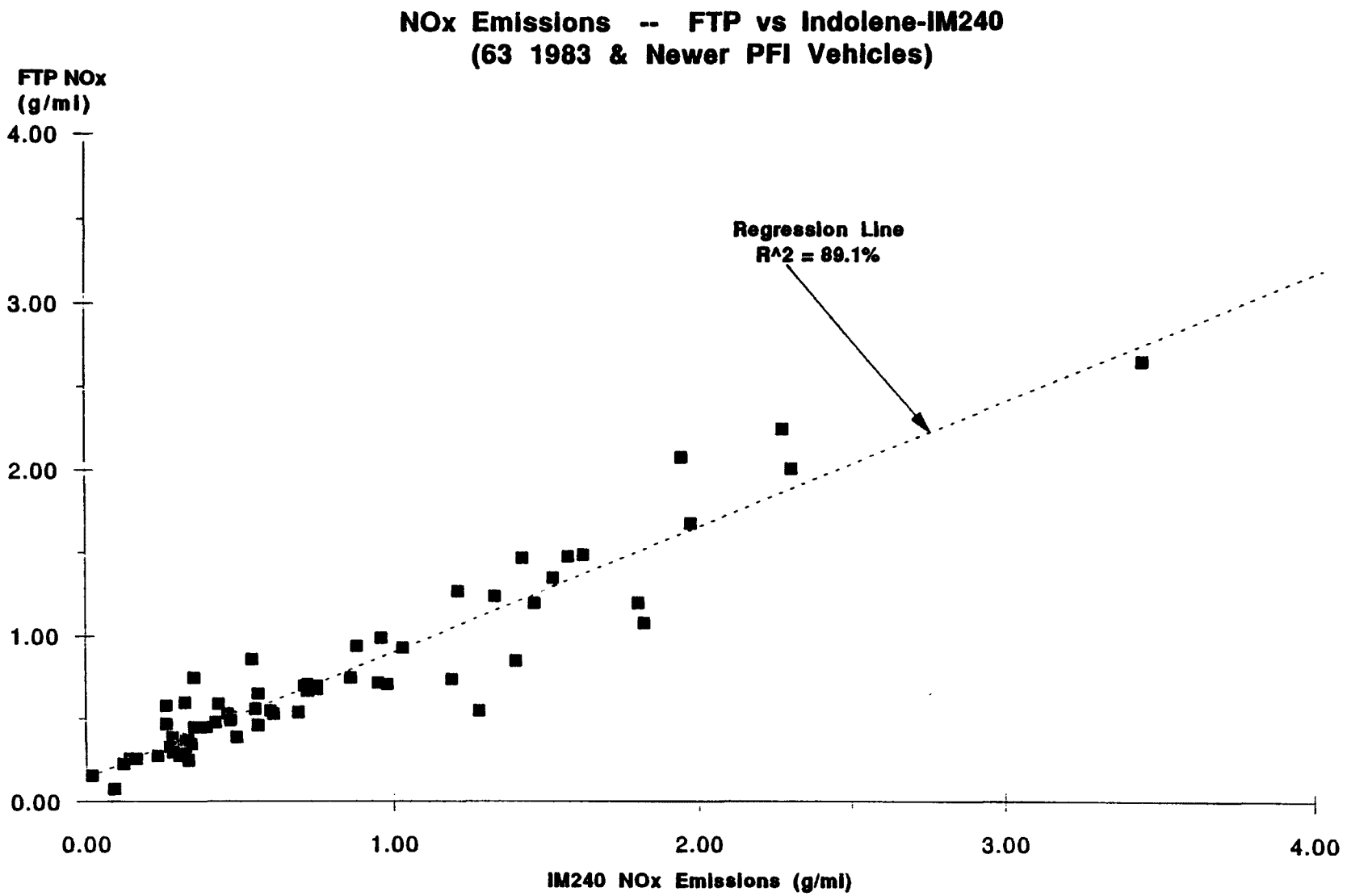

HC Emissions -- FTP vs Indolene-IM240
(63 1983 & Newer PFI Vehicles)
FTP HC
(g/ml)
15
12.5
10
7.5
5
2.5
0
Regression Line
R^2 = 89.2%
0
2.5
5
7.5
10
IM240 HC Emissions (g/ml)

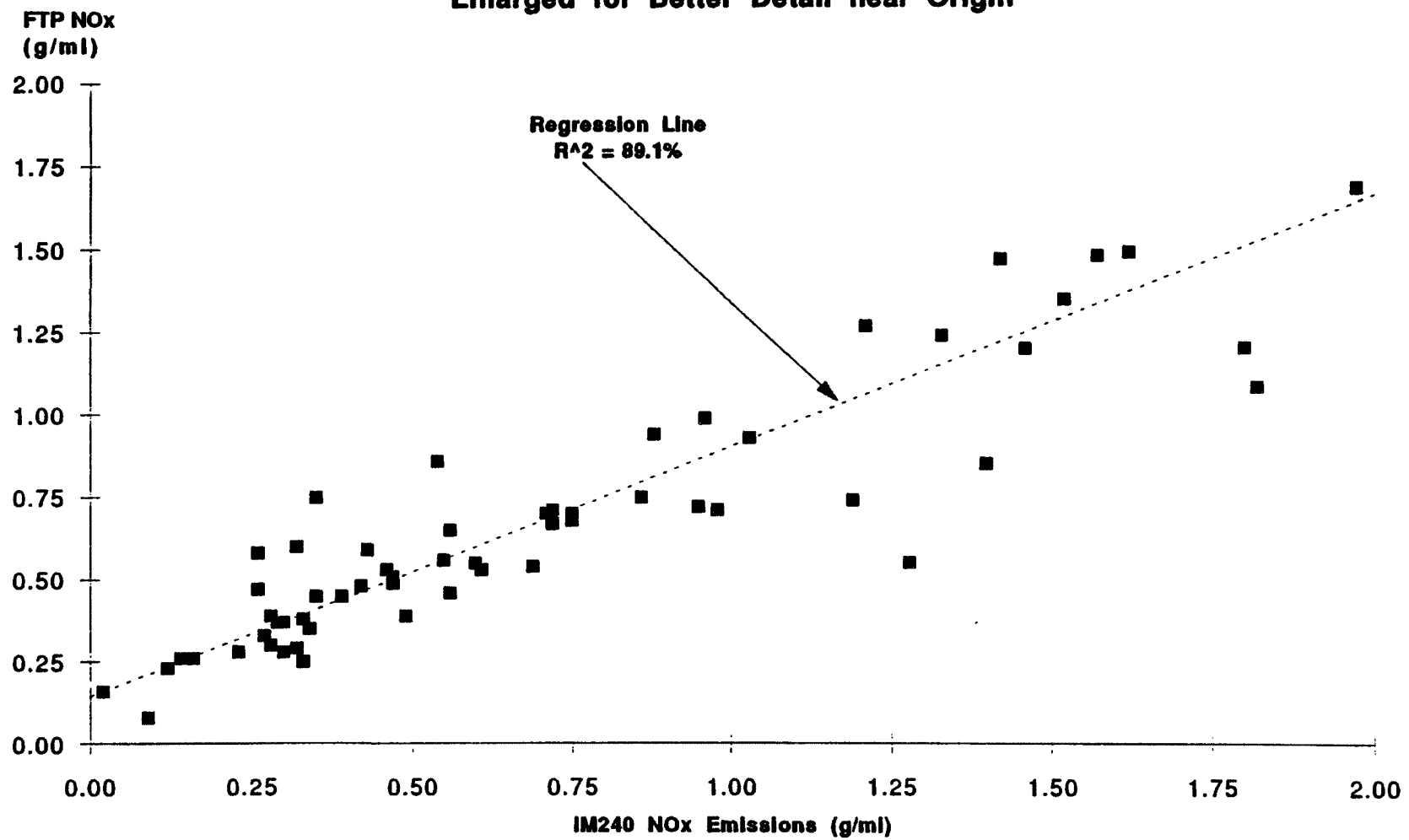

HC Emissions -- FTP vs Indolene-IM240
(63 1983 & Newer PFI Vehicles)
Enlarged for Better Detail near Origin
FTP HC
(g/mi)
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
IM240 HC Emissions (g/mi)
Regression Line
R^2 = 89.2%


CO Emissions -- FTP vs Indolene-IM240
(63 1983 & Newer PFI Vehicles)
FTP CO
(g/mi)
250
200
150
100
50
0
Regression Line
R^2 = 90.3%
0
50
100
150
200
250
IM240 CO Emissions (g/mi)

## CO Emissions -- FTP vs Indolene-IM240
## (63 1983 & Newer PFI Vehicles)
## Enlarged for Better Detail near Origin




NOx Emissions -- FTP vs Indolene-IM240
(63 1983 & Newer PFI Vehicles)
FTP NOx
(g/mi)
4.00
3.00
2.00
1.00
0.00
Regression Line
R^2 = 89.1%
0.00
1.00
2.00
3.00
4.00
IM240 NOx Emissions (g/mi)


NOx Emissions -- FTP vs Indolene-IM240
(63 1983 & Newer PFI Vehicles)
Enlarged for Better Detail near Origin
FTP NOx
(g/mi)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Regression Line
R^2 = 89.1%
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
IM240 NOx Emissions (g/mi)

# EF Vehicles Tested at EPA's MVEL
## Regressions of FTP vs Indolene IM240
## for 143 1985-90 PFI Vehicles

Dependent variable is: **HC.FTP**
R^2 = 95.7%
s = 0.5416 with 143 - 2 = 141 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 927.841 | 1 | 928 | 3163 |
| Residual | 41.3557 | 141 | 0.293303 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.088877 | 0.0472 | 1.88 |
| **HCIM24** | 1.91326 | 0.034 | 56.2 |

Dependent variable is: **CO.FTP**
R^2 = 95.4%
s = 5.335 with 143 - 2 = 141 degrees of freedom

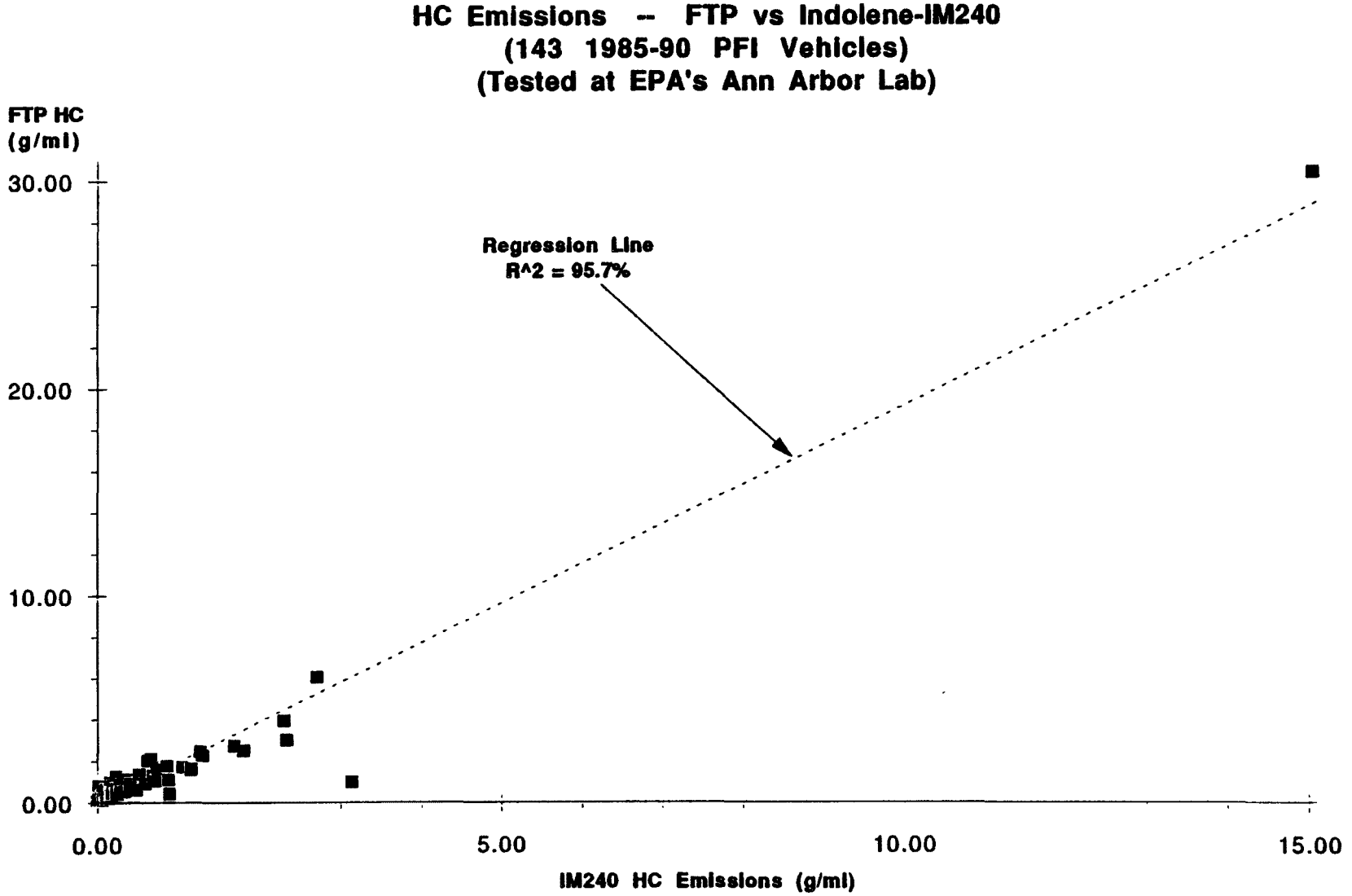
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 83635 | 1 | 83635 | 2939 |
| Residual | 4012.44 | 141 | 28.457 | |

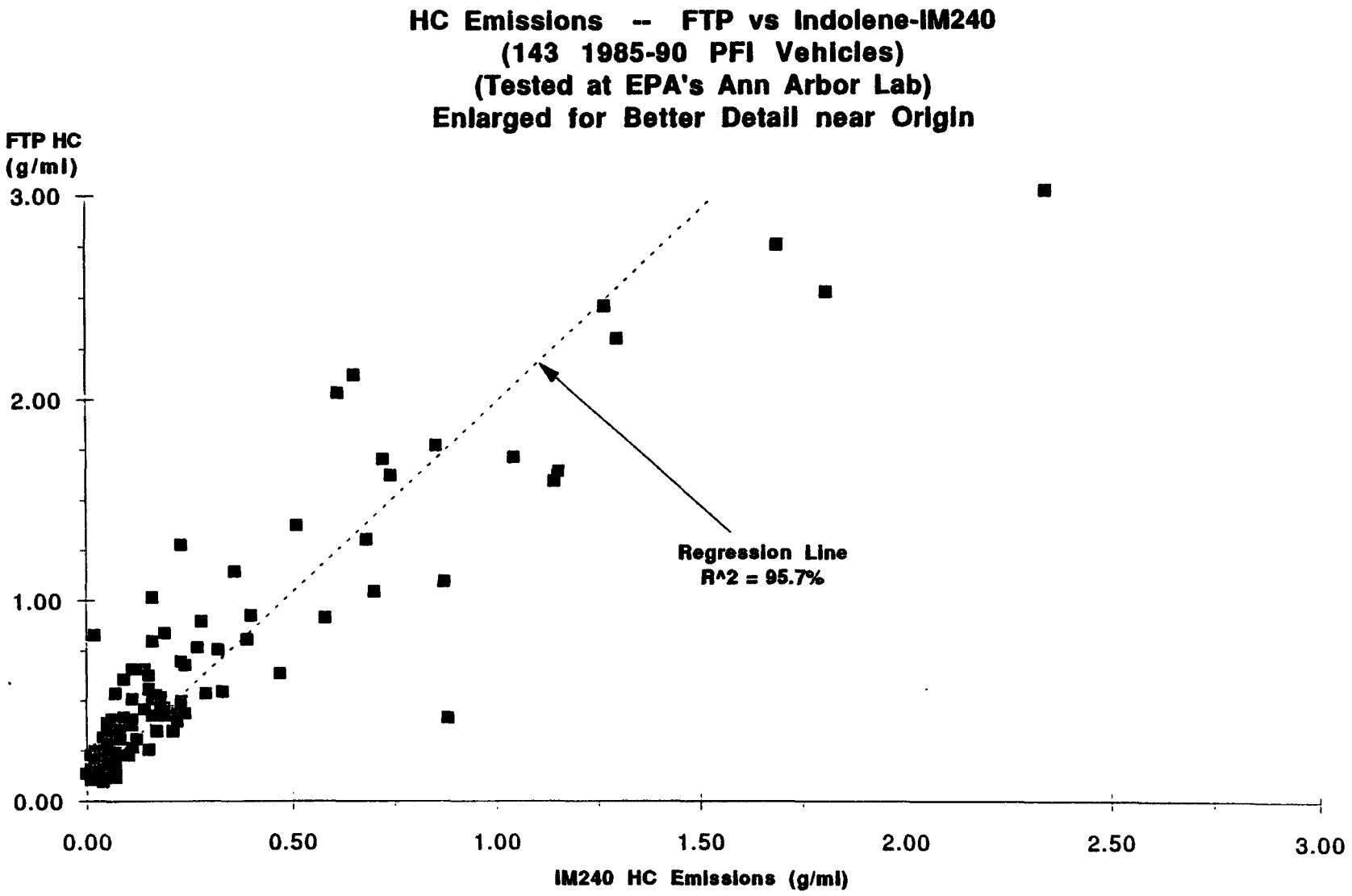
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 1.68729 | 0.4594 | 3.67 |
| **COIM24** | 1.14873 | 0.0212 | 54.2 |

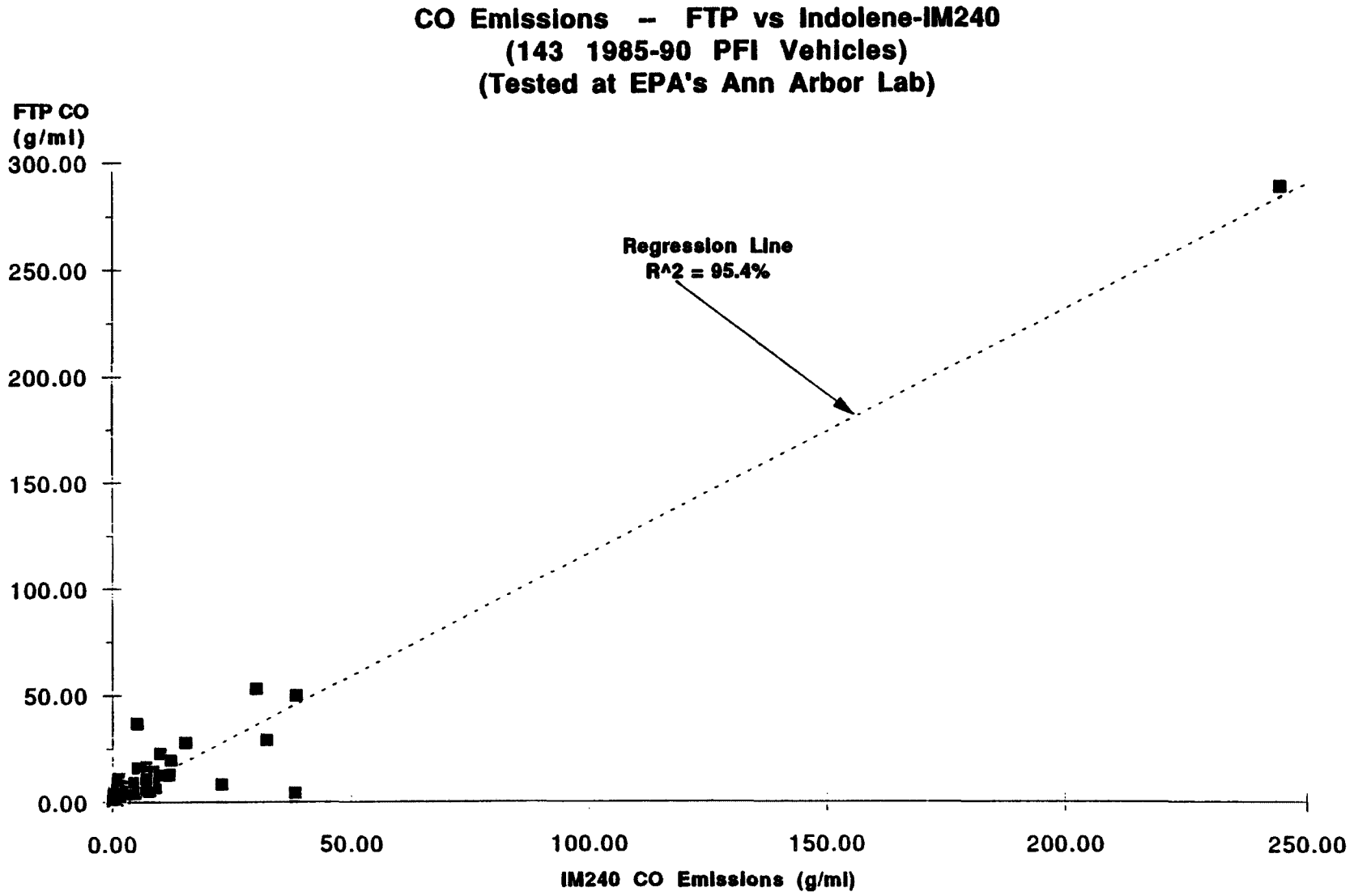
Dependent variable is: **NOx.FTP**
R^2 = 90.5%
s = 0.2012 with 143 - 2 = 141 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 54.6898 | 1 | 54.69 | 1351 |
| Residual | 5.70772 | 141 | 0.04048 | |

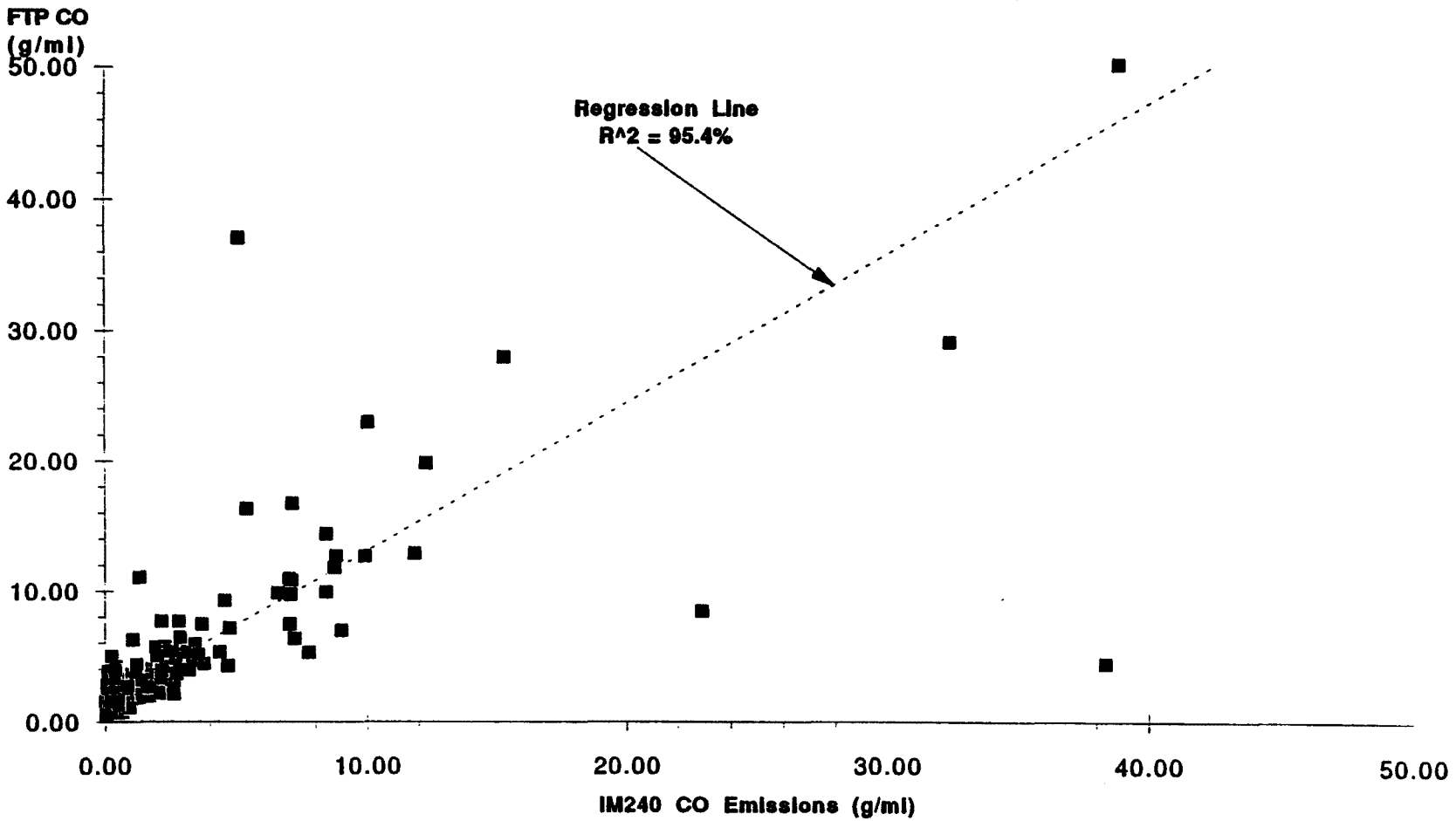
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.10242 | 0.0237 | 4.33 |
| **NOIM24** | 0.81782 | 0.0222 | 36.8 |

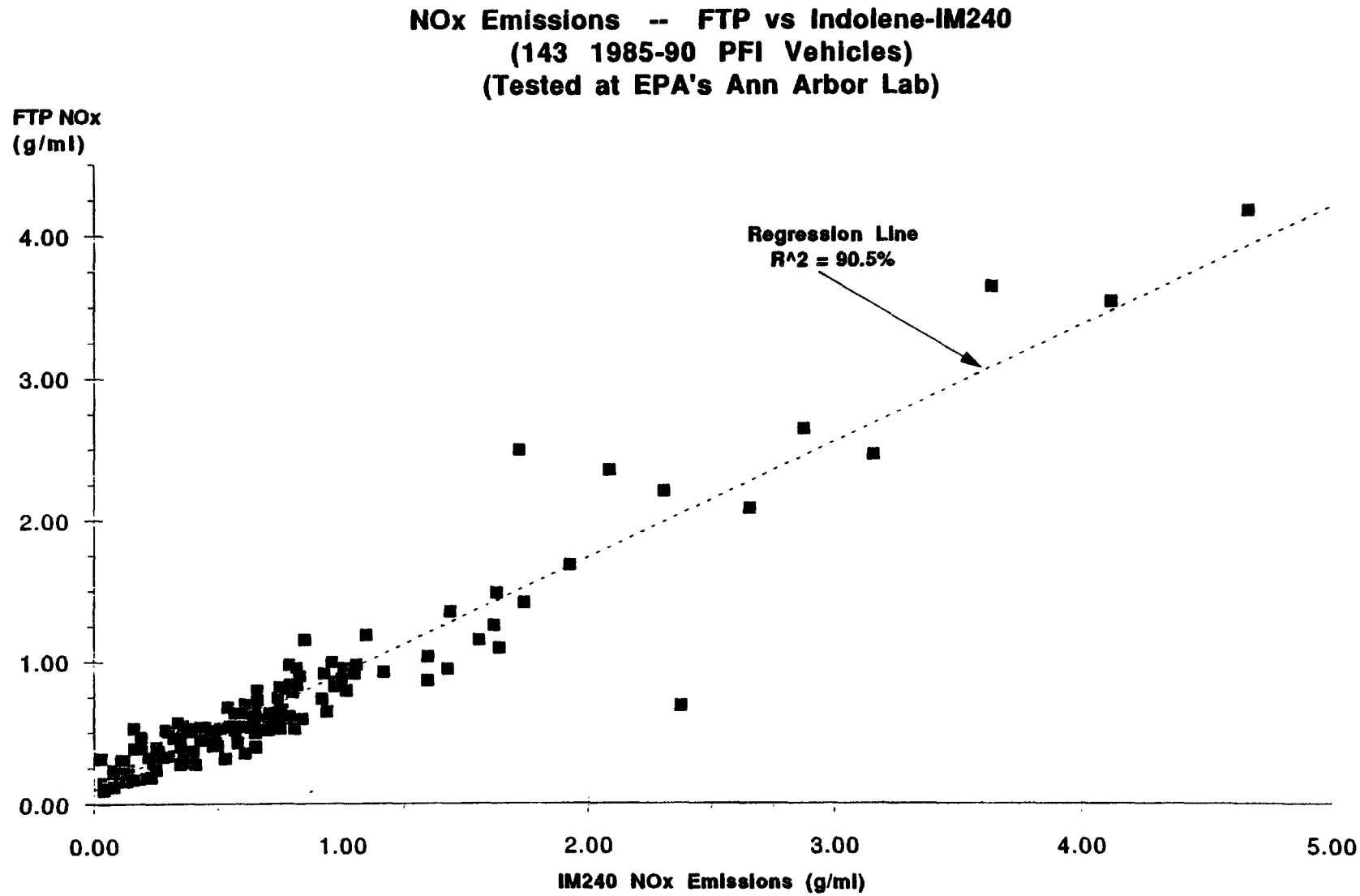

HC Emissions -- FTP vs Indolene-IM240
(143 1985-90 PFI Vehicles)
(Tested at EPA's Ann Arbor Lab)
FTP HC
(g/mi)
30.00
20.00
10.00
0.00
Regression Line
R^2 = 95.7%
0.00
5.00
10.00
15.00
IM240 HC Emissions (g/mi)


HC Emissions -- FTP vs Indolene-IM240
(143 1985-90 PFI Vehicles)
(Tested at EPA's Ann Arbor Lab)
Enlarged for Better Detail near Origin
FTP HC
(g/ml)
3.00
2.00
1.00
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
IM240 HC Emissions (g/ml)
Regression Line
R^2 = 95.7%

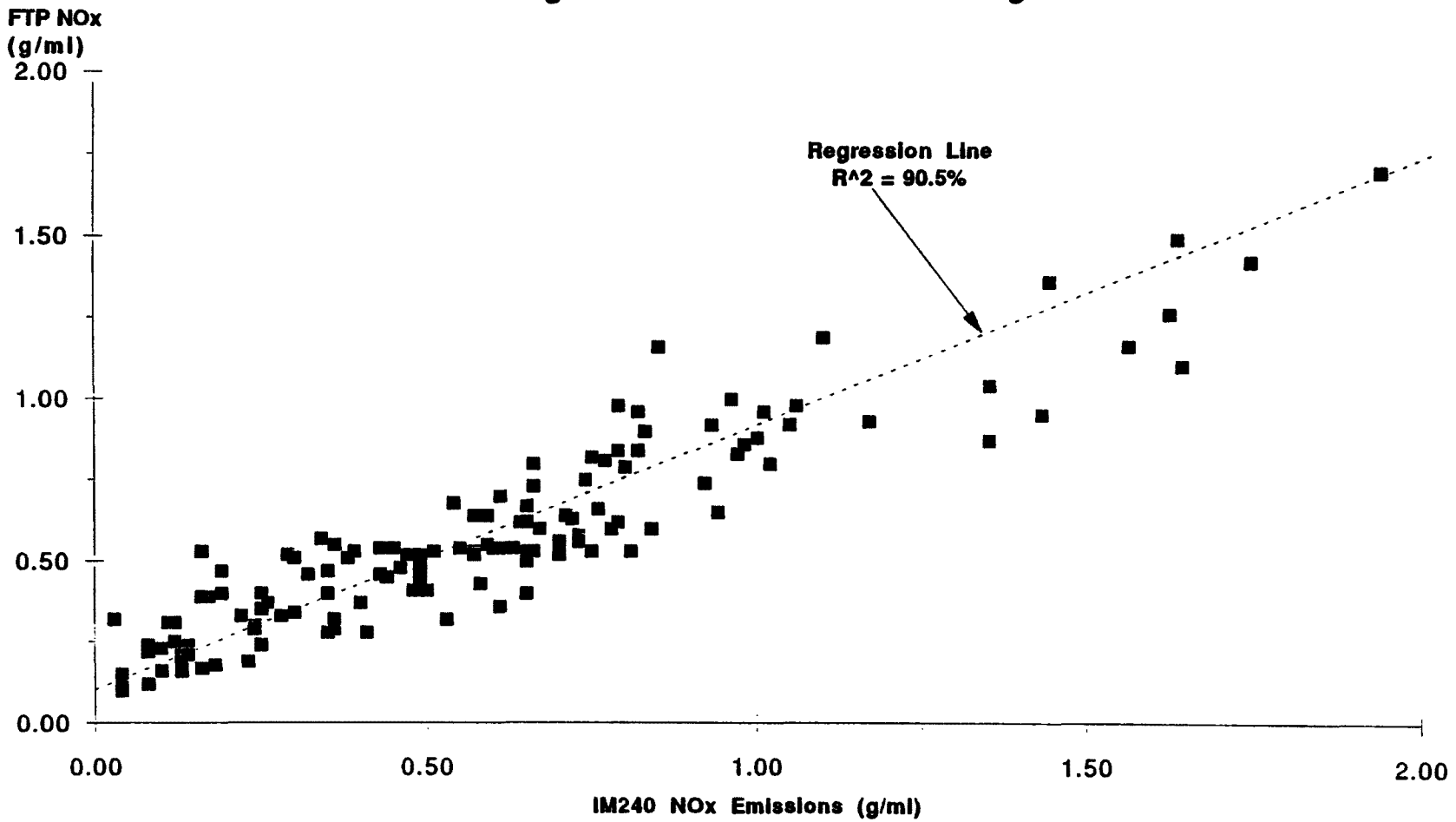

CO Emissions -- FTP vs Indolene-IM240
(143 1985-90 PFI Vehicles)
(Tested at EPA's Ann Arbor Lab)
FTP CO
(g/mi)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
Regression Line
R^2 = 95.4%
0.00
50.00
100.00
150.00
200.00
250.00
IM240 CO Emissions (g/mi)

**CO Emissions -- FTP vs Indolene-IM240**
**(143 1985-90 PFI Vehicles)**
**(Tested at EPA's Ann Arbor Lab)**
**Enlarged for Better Detail near Origin**




NOx Emissions -- FTP vs Indolene-IM240
(143 1985-90 PFI Vehicles)
(Tested at EPA's Ann Arbor Lab)
FTP NOx
(g/mi)
Regression Line
R^2 = 90.5%
4.00
3.00
2.00
1.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
IM240 NOx Emissions (g/mi)

**NOx Emissions -- FTP vs Indolene-IM240**
**(143 1985-90 PFI Vehicles)**
**(Tested at EPA's Ann Arbor Lab)**
**Enlarged for Better Detail near Origin**



## Description of Repair Regression Analysis

### Regression Analyses

The difference in emission levels before and after repairs for the FTP's and Lab IM240's run on Indolene fuel was calculated such that a positive difference would correspond to a decrease in emissions or an increase in fuel economy. The ΔFTP values (ΔHC, ΔCO, ΔNOx and ΔMPG) were regressed against the corresponding Indolene ΔIM240 values. The results and graphs of these regressions are included.

### Data Description

The data used in this analysis consisted of FTP and Indolene IM240 scores for tests performed before and after repairs. These results consisted of HC, CO, NOx, and fuel economy values. The database was restricted to 1983 and newer PFI and TBI vehicles which received repairs and whose as received FTP scores exceeded twice the FTP standard for either HC or CO. Also excluded from the analysis were vehicles which received repairs before the as received FTP and vehicles which had differences in dynamometer settings of greater than 15%. The resulting data set contained 41 TBI vehicles and 23 PFI vehicles. Summary Statistics for the variables used in the PFI analyses follow.

## Statistical Summaries for Variables Used in PFI Before and After Regression Analyses

Summary statistics for: ΔHC.IM240
NumNumeric = 23
Mean = 1.7848
Median = 0.59000
Midrange = 3.7950
Standard Deviation = 2.3719
Range = 8.2500
Minimum = -0.33000
Maximum = 7.9200

Summary statistics for: ΔHC.FTP
NumNumeric = 23
Mean = 2.4678
Median = 1.9700
Midrange = 4.2600
Standard Deviation = 2.9115
Range = 9.0800
Minimum = -0.28000
Maximum = 8.8000

Summary statistics for: ΔCO.IM240
NumNumeric = 23
Mean = 53.061
Median = 9.6200
Midrange = 119.73
Standard Deviation = 75.023
Range = 248.85
Minimum = -4.6900
Maximum = 244.16

Summary statistics for: ΔCO.FTP
NumNumeric = 23
Mean = 60.184
Median = 14.580
Midrange = 115.89
Standard Deviation = 74.656
Range = 239.46
Minimum = -3.8400
Maximum = 235.62

Summary statistics for: ΔNOX.IM240
NumNumeric = 23
Mean = -0.36174
Median = -0.23000
Midrange = -0.90000
Standard Deviation = 0.52710
Range = 2.3000
Minimum = -2.0500
Maximum = 0.25000

Summary statistics for: ΔNOX.FTP
NumNumeric = 23
Mean = -0.29522
Median = -0.15000
Midrange = -0.78000
Standard Deviation = 0.48197
Range = 2.2800
Minimum = -1.9200
Maximum = 0.36000

Summary statistics for: ΔMPG.IM240
NumNumeric = 23
Mean = 2.5904
Median = 1.5500
Midrange = 3.2800
Standard Deviation = 2.9593
Range = 10.780
Minimum = -2.1100
Maximum = 8.6700

Summary statistics for: ΔMPG.FTP
NumNumeric = 23
Mean = 2.5183
Median = 1.7100
Midrange = 5.3200
Standard Deviation = 3.5426
Range = 17.720
Minimum = -3.5400
Maximum = 14.180

**Regression Analyses for the Change in Emission Constituents Before and After Repairs of the PFI Vehicles for the FTP vs IM240-A**

Dependent variable is: **ΔHC.FTP**
R^2 = 90.8%
s = 0.9031 with 23 - 2 = 21 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 169.361 | 1 | 169 | 208 |
| Residual | 17.1275 | 21 | 0.815595 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.380093 | 0.2376 | 1.6 |
| **ΔHC.IM240** | 1.16974 | 0.0812 | 14.4 |

Dependent variable is: **ΔCO.FTP**
R^2 = 88.4%
s = 26.01 with 23 - 2 = 21 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 108409 | 1 | 100000 | 160 |
| Residual | 14207.5 | 21 | 676.547 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 10.5355 | 6.693 | 1.57 |
| **ΔCO.IM240** | 0.93568 | 0.0739 | 12.7 |

Dependent variable is: **ΔNOX.FTP**
R^2 = 71.2%
s = 0.2649 with 23 - 2 = 21 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 363679 | 1 | 3.6368 | 51.8 |
| Residual | 1.47378 | 21 | 0.07018 | |

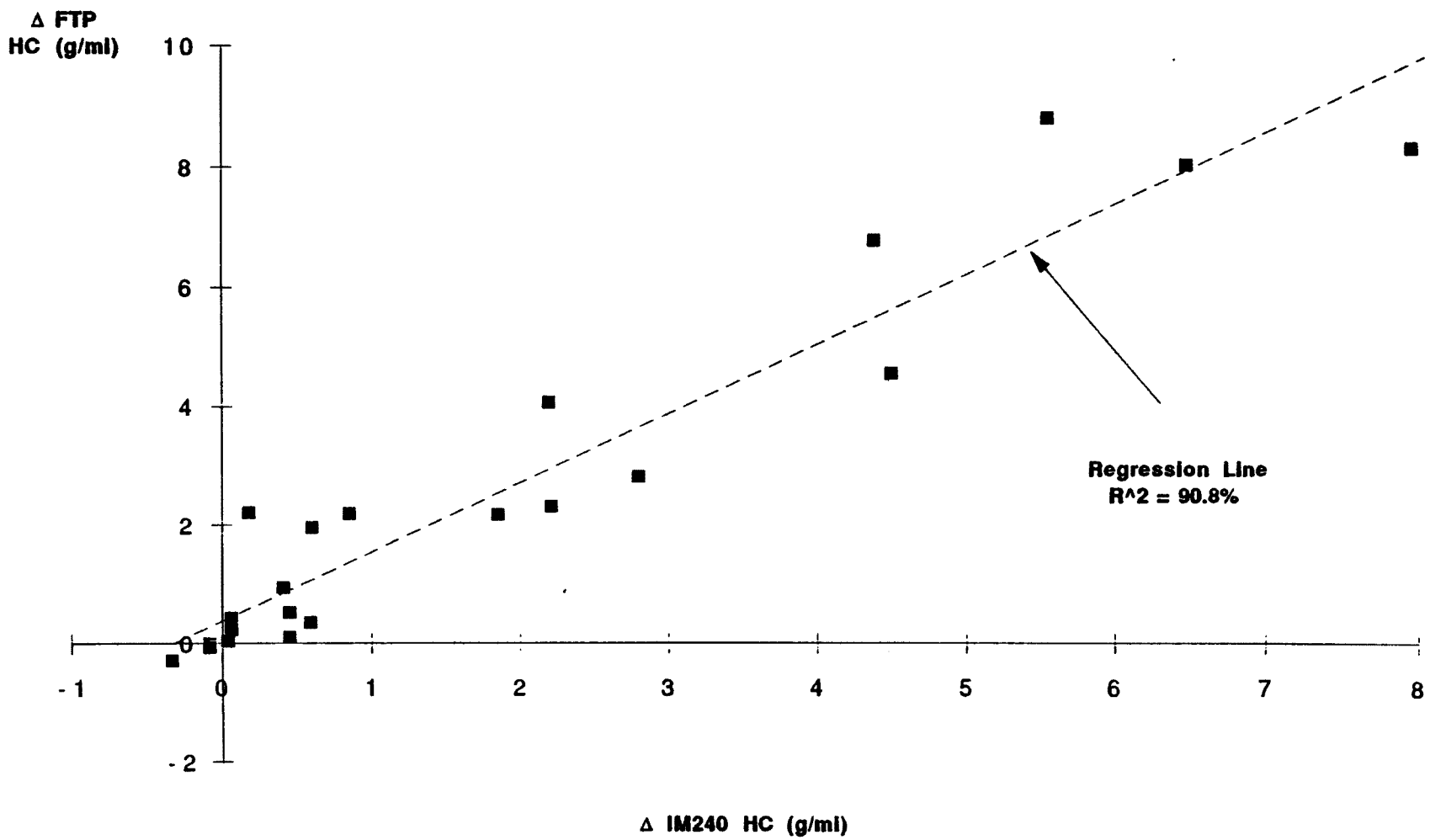
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | -0.016187 | 0.0675 | -0.24 |
| **ΔNOX.IM240** | 0.771357 | 0.1072 | 7.2 |

Dependent variable is: **ΔMPG.FTP**
R^2 = 36.7%
s = 2.885 with 23 - 2 = 21 degrees of freedom

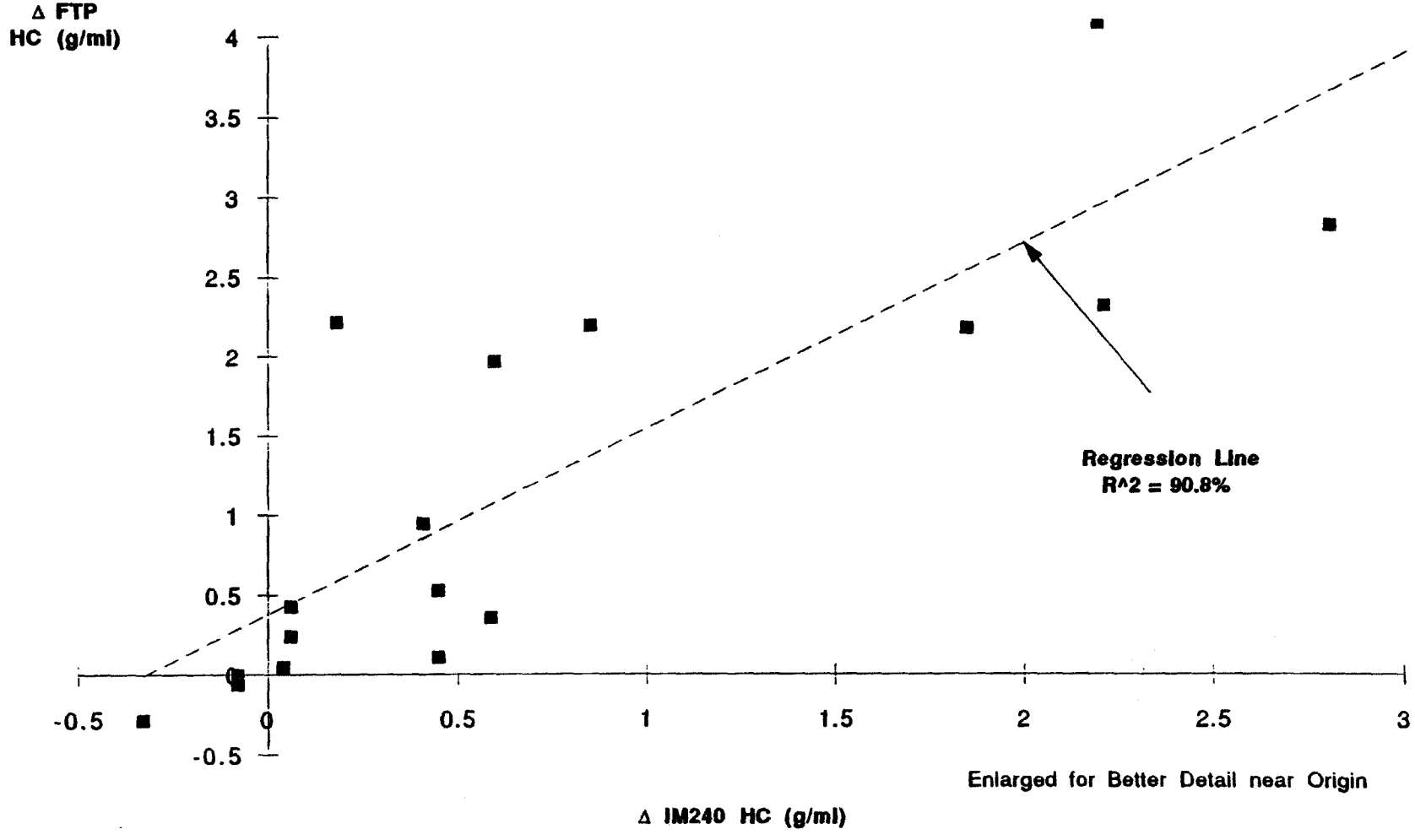
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 101.306 | 1 | 101 | 12.2 |
| Residual | 174.8 | 21 | 8.32381 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.639853 | 0.8074 | 0.793 |
| **ΔMPG.IM240** | 0.725132 | 0.2079 | 3.49 |

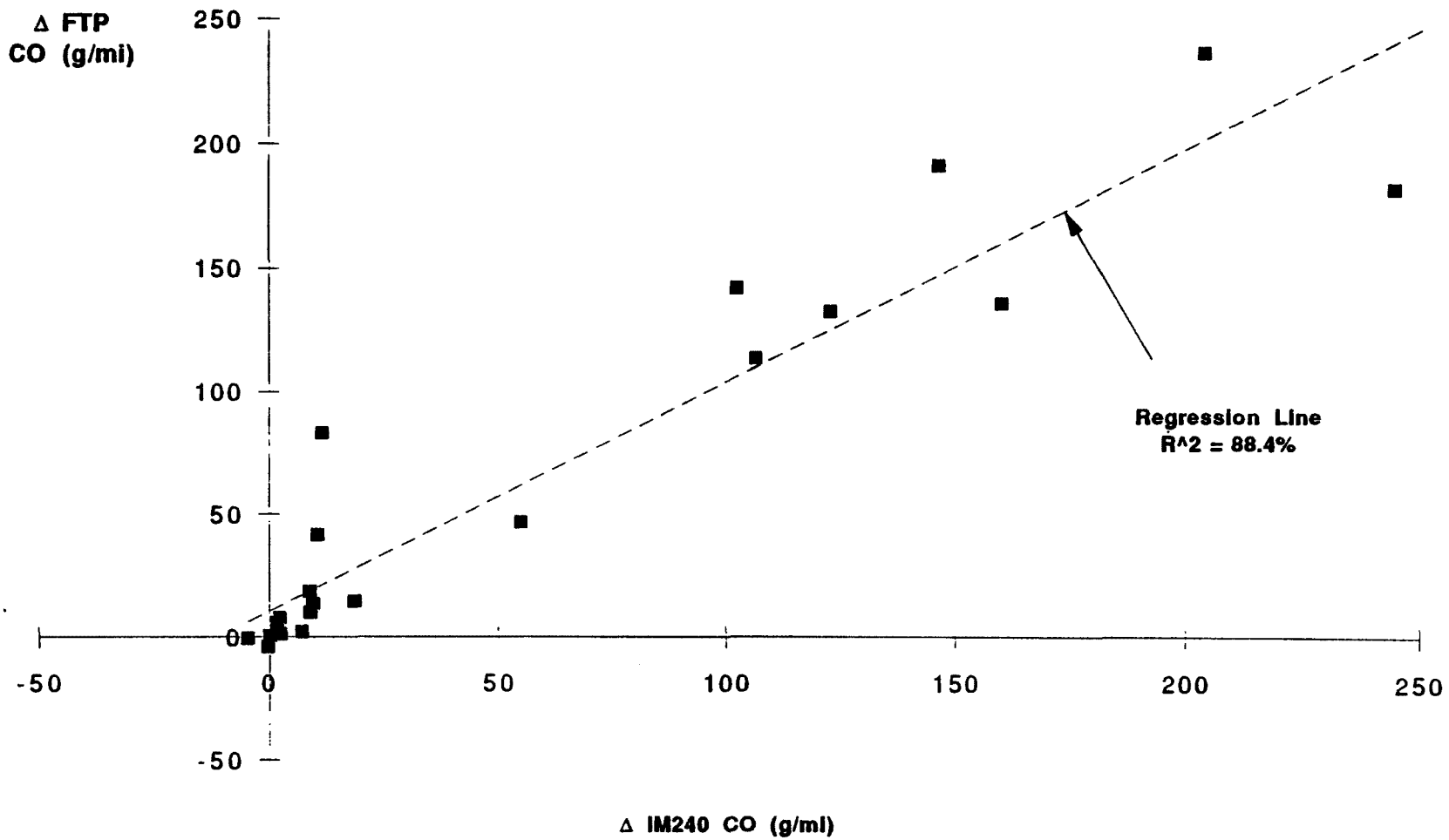
## HC Emissions -- ΔFTP vs ΔIndolene-IM240
## (23 1983 & Newer PFI Vehicles with Repairs and FTP ≥ 2*(FTP.Stnd))



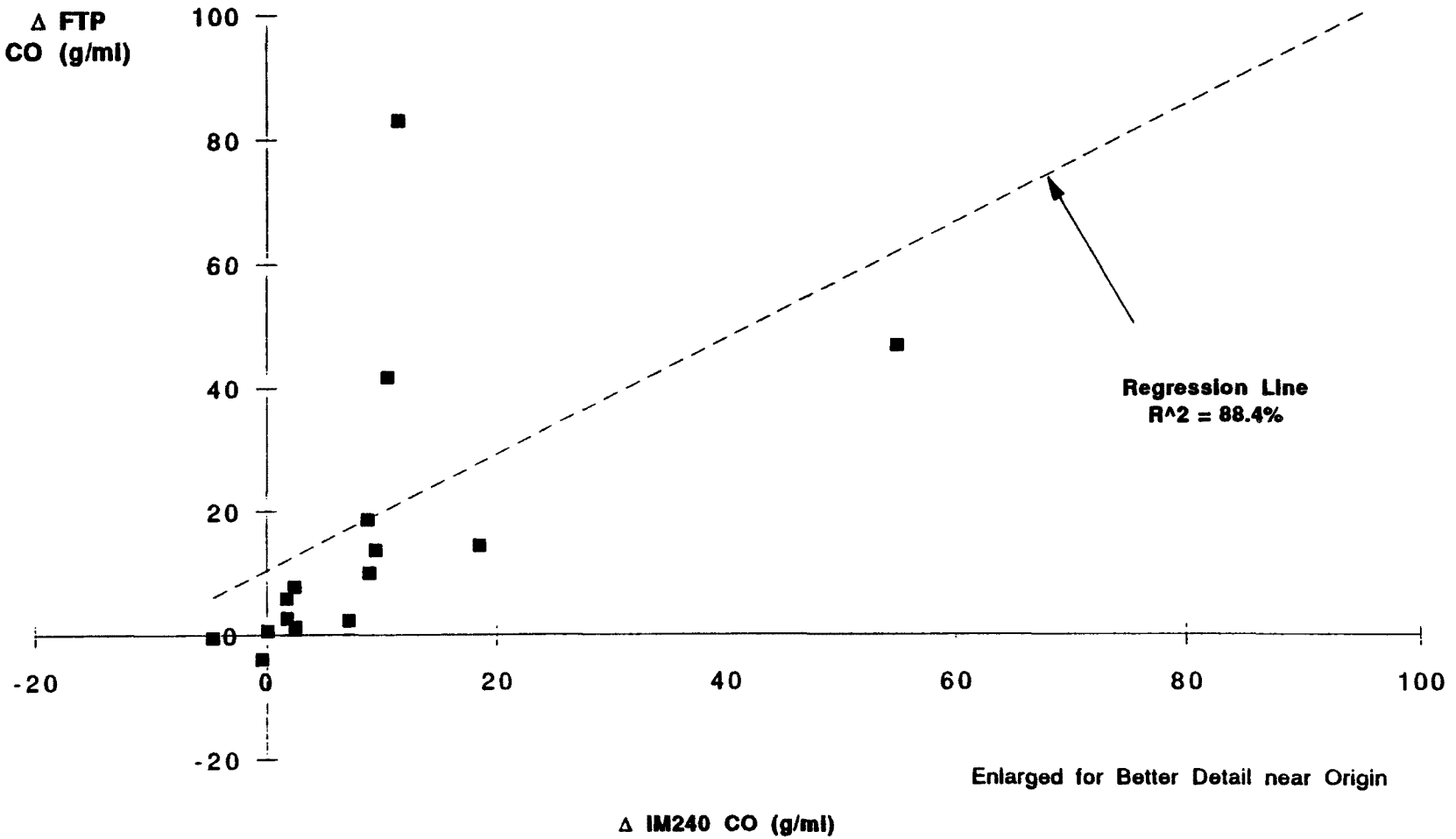
## HC Emissions -- ΔFTP vs ΔIndolene-IM240
## (23 1983 & Newer PFI Vehicles with Repairs and FTP ≥ 2*(FTP.Stnd))



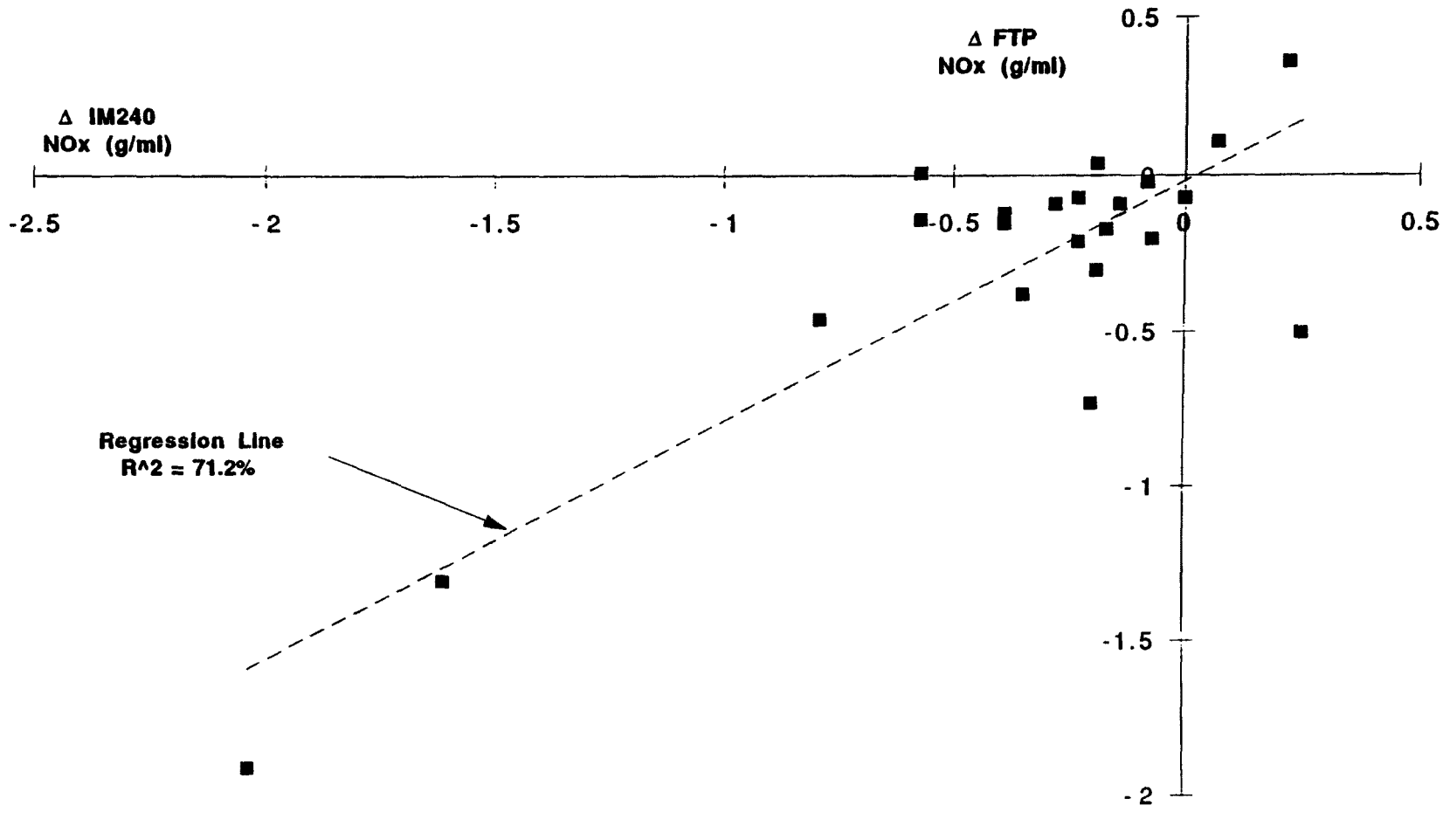
## CO Emissions -- ΔFTP vs ΔIndolene-IM240
## (23 1983 & Newer PFI Vehicles with Repairs and FTP ≥ 2*FTP.Stnd)



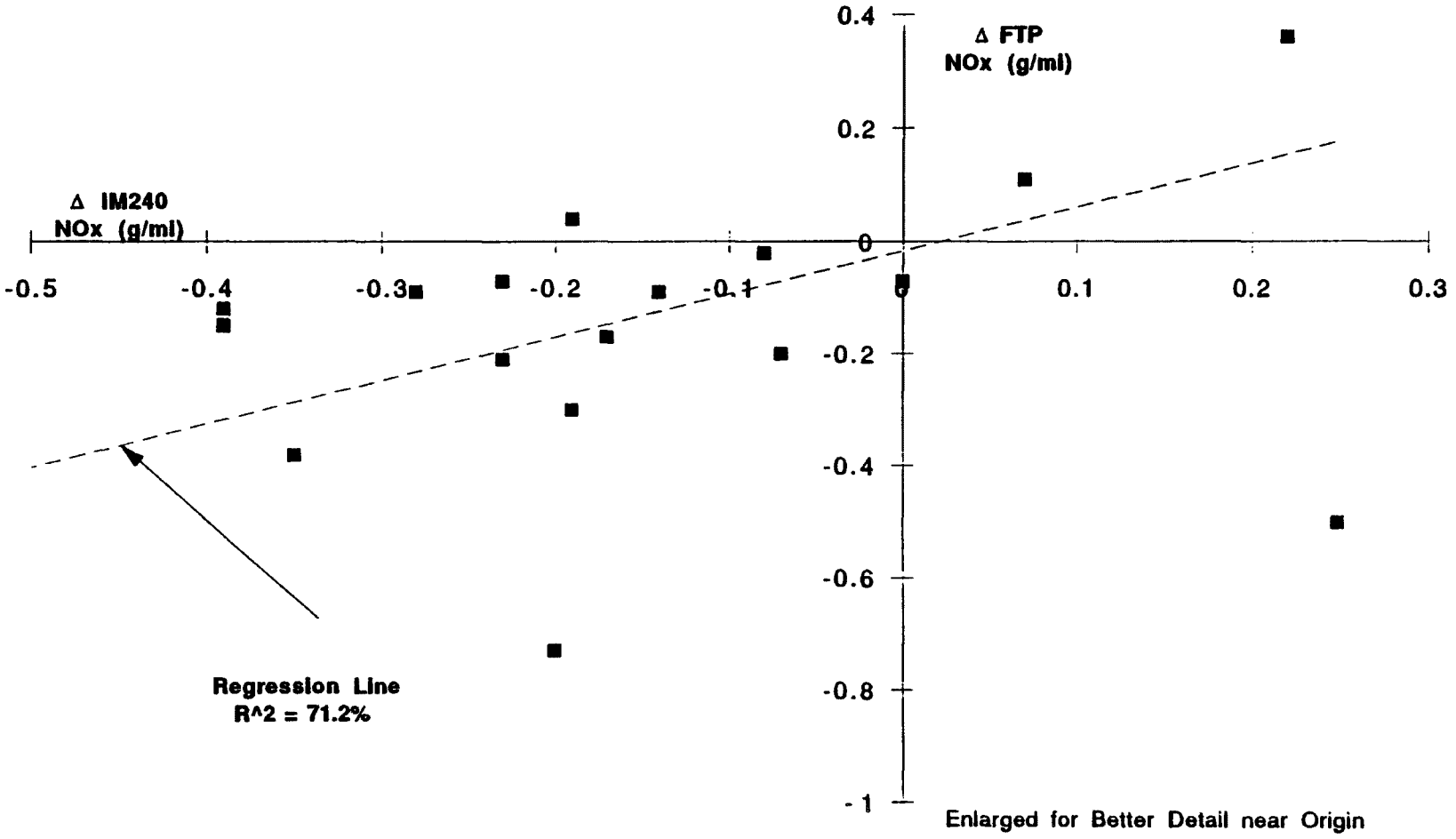
## CO Emissions -- ΔFTP vs ΔIndolene-IM240
## (23 1983 & Newer PFI Vehicles with Repairs and FTP ≥ 2*FTP.Stnd)



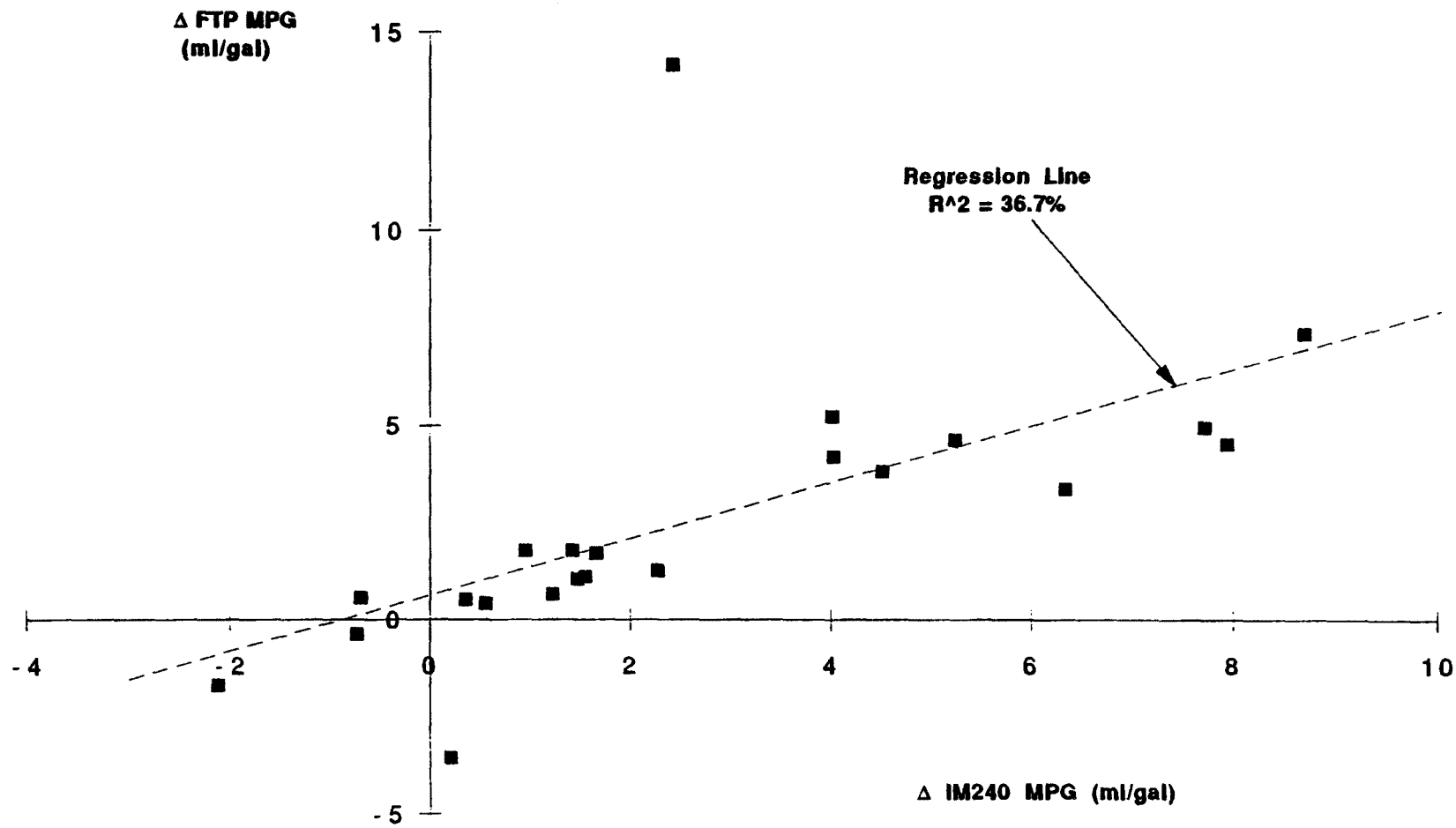
## NOx Emissions -- ΔFTP vs ΔIndolene-IM240
## (23 1983 & Newer PFI Vehicles with Repairs and FTP ≥ 2*FTP.Stnd)



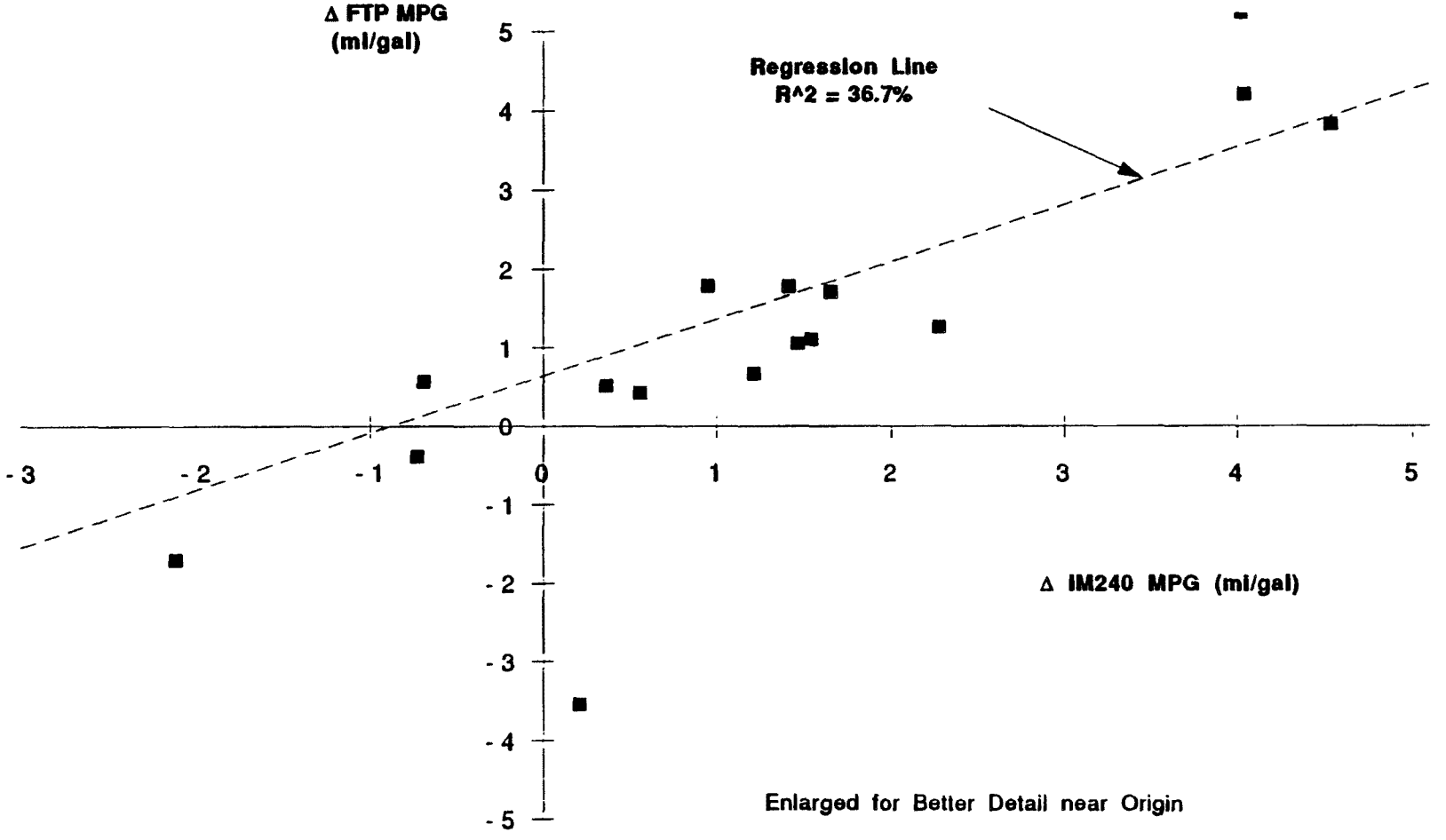
## NOx Emissions -- ΔFTP vs ΔIndolene-IM240
## (23 1983 & Newer PFI Vehicles with Repairs and FTP ≥ 2*FTP.Stnd)



## Fuel Economy -- ΔFTP vs ΔIndolene-IM240
## (23 1983 & Newer PFI Vehicles with Repairs and FTP ≥ 2*FTP.Stnd)



## Fuel Economy -- ΔFTP vs ΔIndolene-IM240
## (23 1983 & Newer PFI Vehicles with Repairs and FTP ≥ 2*FTP.Stnd)




Enlarged for Better Detail near Origin

**Regression Analyses - Throttle-Body Injected Vehicle Sample:**

As part of EPA's regression analysis, FTP results for HC and CO emissions were each regressed against the corresponding emission results on the Lane IM240, the second chance 2500/Idle Test, and the second chance Idle Test. Regressions were also performed comparing NOx results for the FTP and Lane IM240 (NOx emissions are not measured as part of either idle test and are therefore not included in this comparison). Lastly, FTP results for HC, CO, and NOx were each regressed against corresponding emissions from Lab IM240s run on Indolene fuel at the ATL lab in South Bend and at MVEL in Ann Arbor. This section provides the results of these regressions performed on a sample of throttle-body injected (TBI) vehicles recruited as part of the Hammond study.

EPA removed a total of twenty-two vehicles from its sample of TBI vehicles. Six were removed because of repairs performed after their I/M test but before their FTPs, all but two of which were exhaust leak repairs. Of the remaining two pre-FTP repaired vehicles, one received a new fuel pump and the other received an alternator and battery replacement. In addition to these six pre-FTP repair exclusions, sixteen TBI vehicles were removed from the analyses due to differences of 15% or greater between lane and lab dynamometer settings. The resulting database consisted of 108 TBI vehicles.

**Selecting One Score From the Second Chance 2500/Idle Test:**

To illustrate the correlation of FTP HC and CO results to the corresponding results on the second chance 2500/Idle Test, we had to select an HC score and CO score from the first chance or second chance test, and from the 2500 rpm mode or the idle mode. Concerning the first chance versus second chance results, we chose the better results relative to the HC/CO cutpoint being evaluated.

For the 2500 rpm versus idle modes, we chose the larger of the corresponding emissions measured. This approach is based on the assumption that the same cutpoints would be used on each of the modes. Hence, a vehicle would pass the two mode test if and only if the higher of its HC scores (whether Idle or 2500 rpm) met the HC cutpoint (with the same also following for the CO results).

**Graphing the Data:**

On each of the graphs comparing HC emissions, the three horizontal dotted lines are positioned at the boundaries separating:

- the normal emitters from the high emitters (0.82 g/mi),
- the high emitters from the very high emitters (1.64 g/mi), and
- the very high emitters from the super emitters (10.00 g/mi).

Similarly, on each of the graphs comparing CO emissions, the three horizontal dotted lines are positioned at the boundaries separating:

- the normal emitters from the high emitters (10.2 g/mi),
- the high emitters from the very high emitters (13.6 g/mi), and
- the very high emitters from the super emitters (150.0 g/mi).

## Regression Analyses of FTP HC versus HC Emissions Over: IM240, Idle Test, and 2500/Idle Test For TBI Vehicles

Dependent variable is: **HCFTP**
R^2 = 64.4%
s = 2.397 with 108 - 2 = 106 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 1102.31 | 1 | 1102 | 192 |
| Residual | 609.049 | 106 | 5.74575 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | -0.149912 | 0.261 | -0.574 |
| **HCIM24** | 1.45609 | 0.1051 | 13.9 |

Dependent variable is: **HCFTP**
R^2 = 8.4%
s = 3.845 with 108 - 2 = 106 degrees of freedom

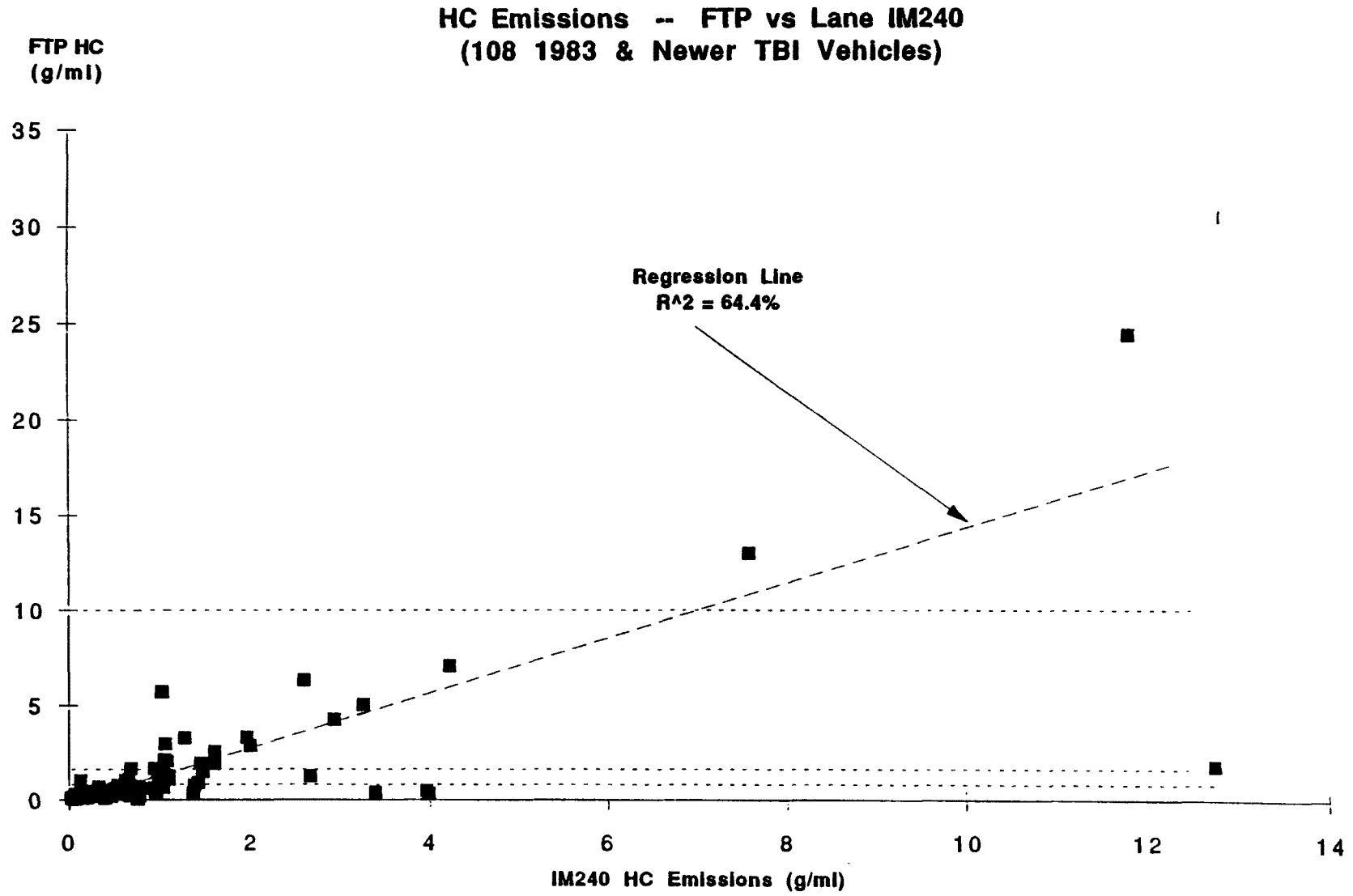
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 143.863 | 1 | 144 | 9.73 |
| Residual | 1567.5 | 106 | 14.7877 | |

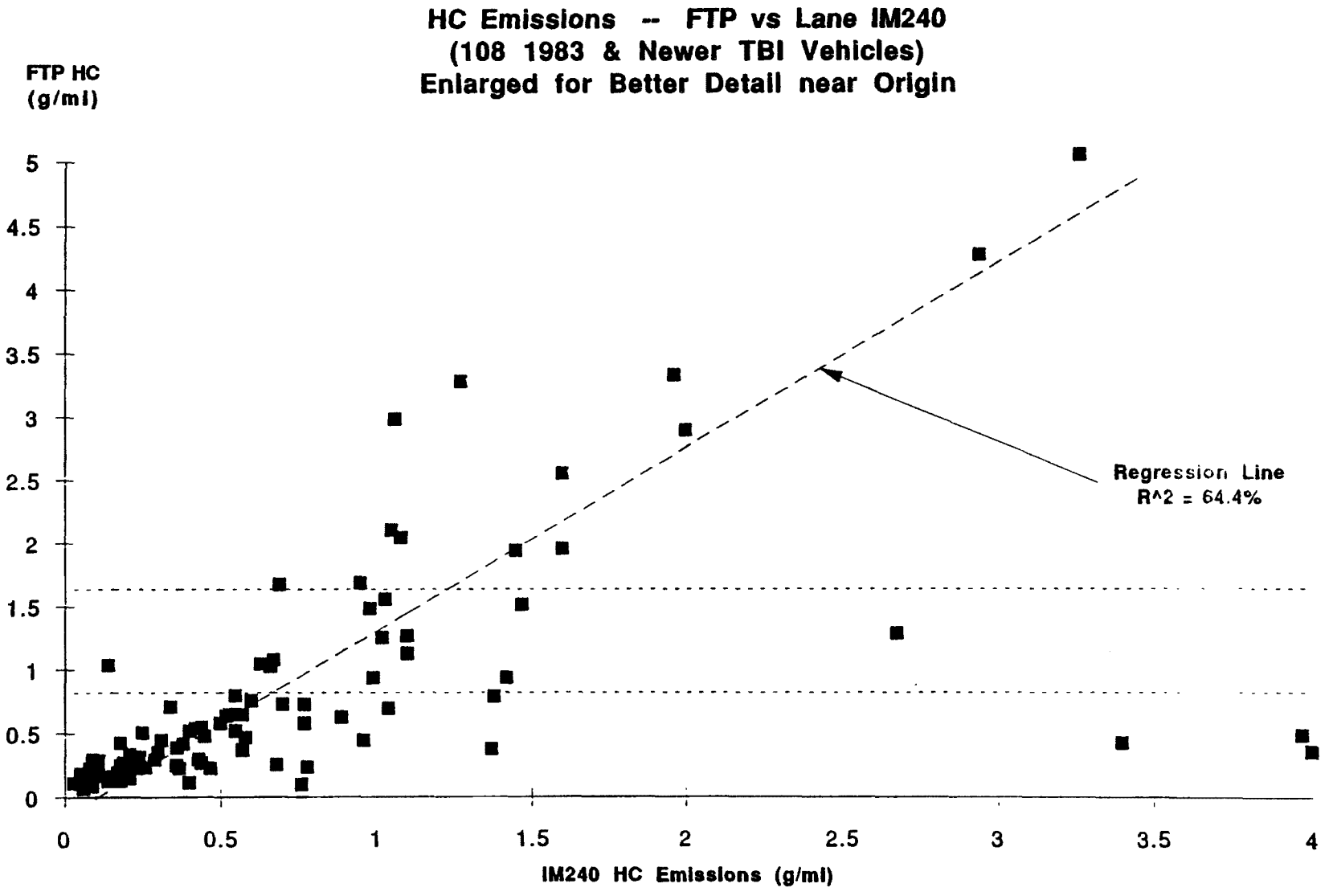
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.89518 | 0.4242 | 2.11 |
| **Higher(Idle ...** | 0.003197 | 0.001 | 3.12 |

Dependent variable is: **HCFTP**
R^2 = 14.0%
s = 3.727 with 108 - 2 = 106 degrees of freedom

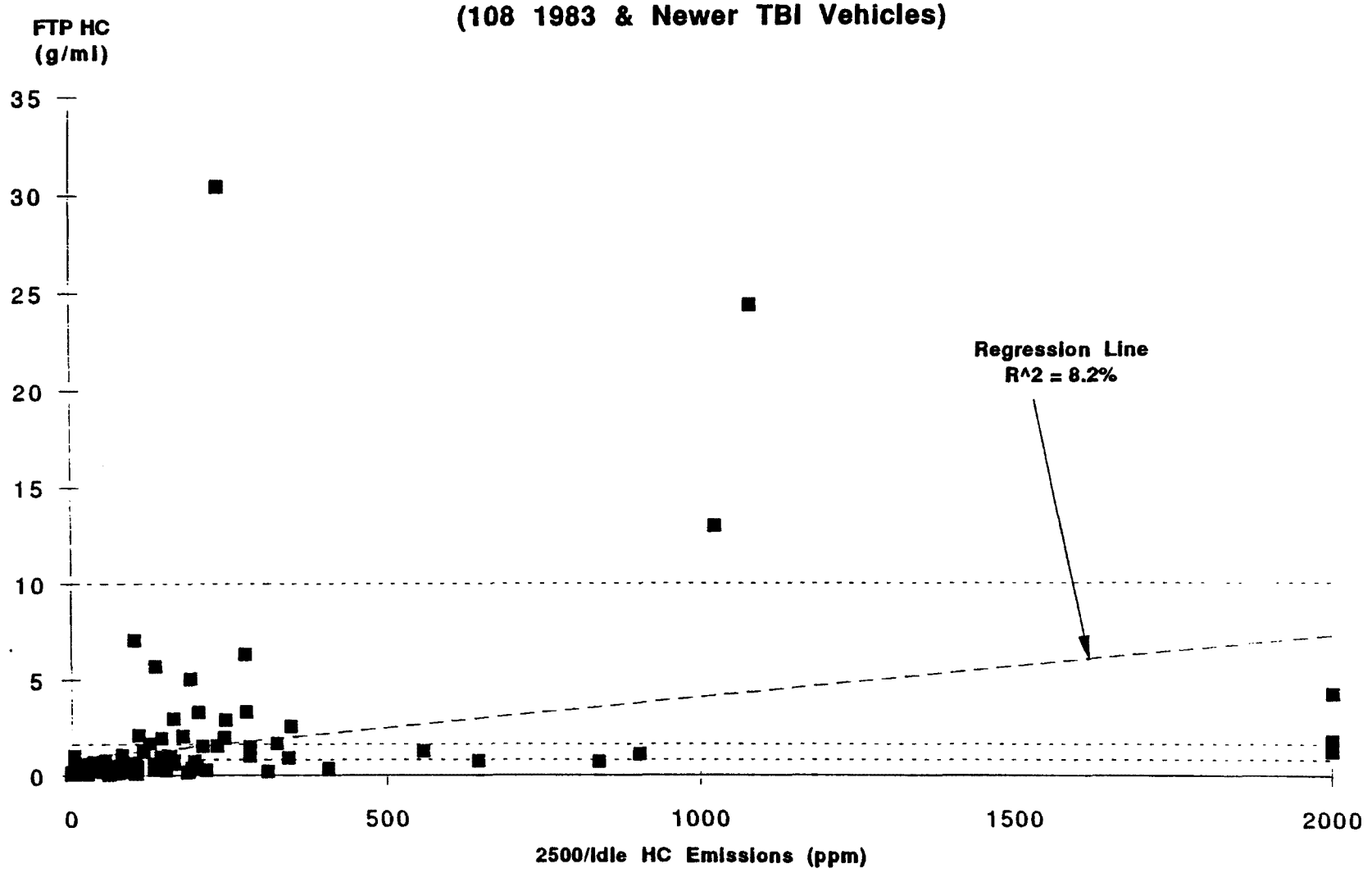
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 238.906 | 1 | 239 | 17.2 |
| Residual | 1472.46 | 106 | 13.8911 | |

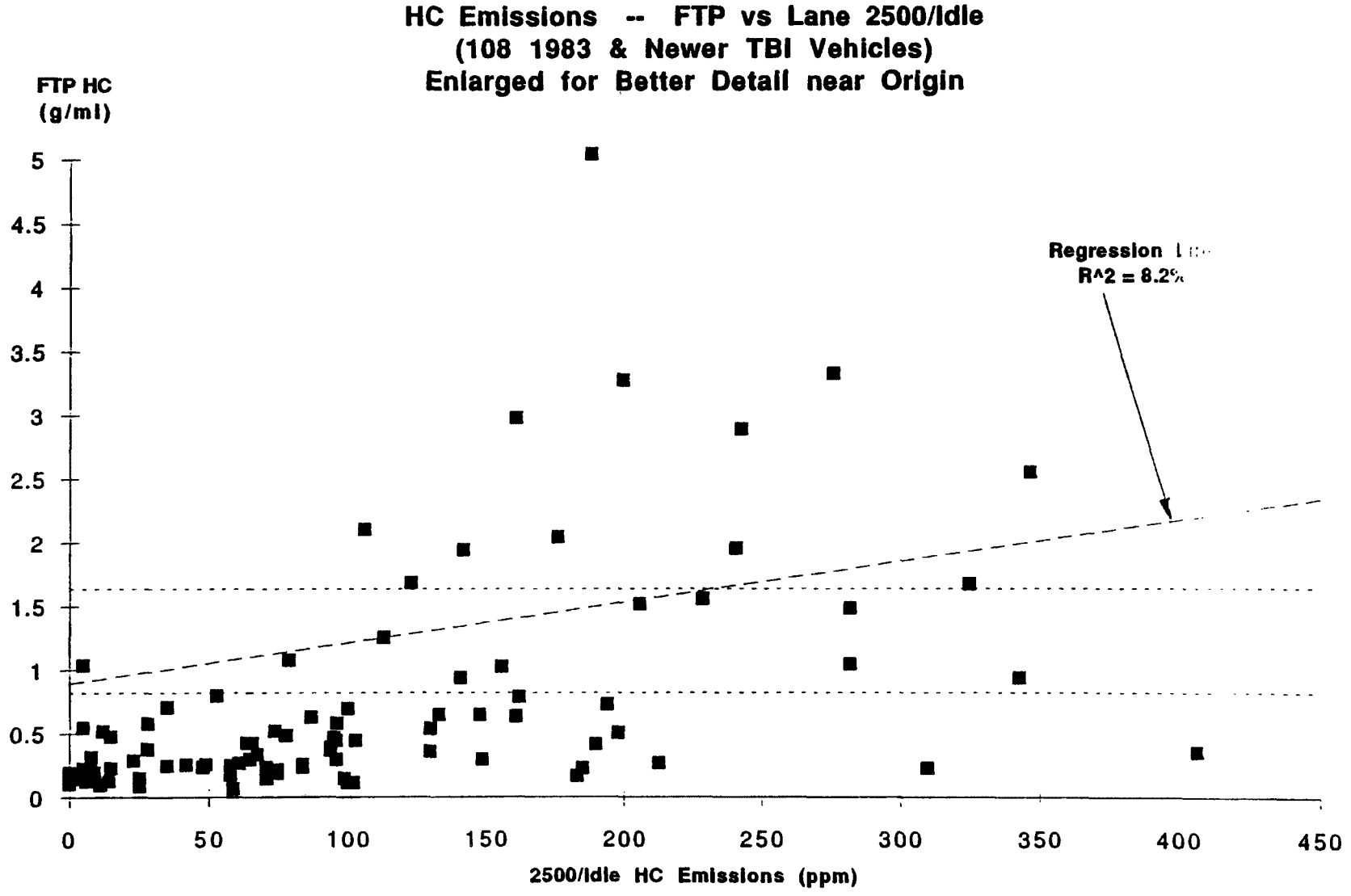
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.651022 | 0.418 | 1.56 |
| **Idle.HC** | 0.005218 | 0.0013 | 4.15 |


HC Emissions -- FTP vs Lane IM240
(108 1983 & Newer TBI Vehicles)
FTP HC
(g/ml)
35
30
25
20
15
10
5
0
Regression Line
R^2 = 64.4%
0
2
4
6
8
10
12
14
IM240 HC Emissions (g/ml)

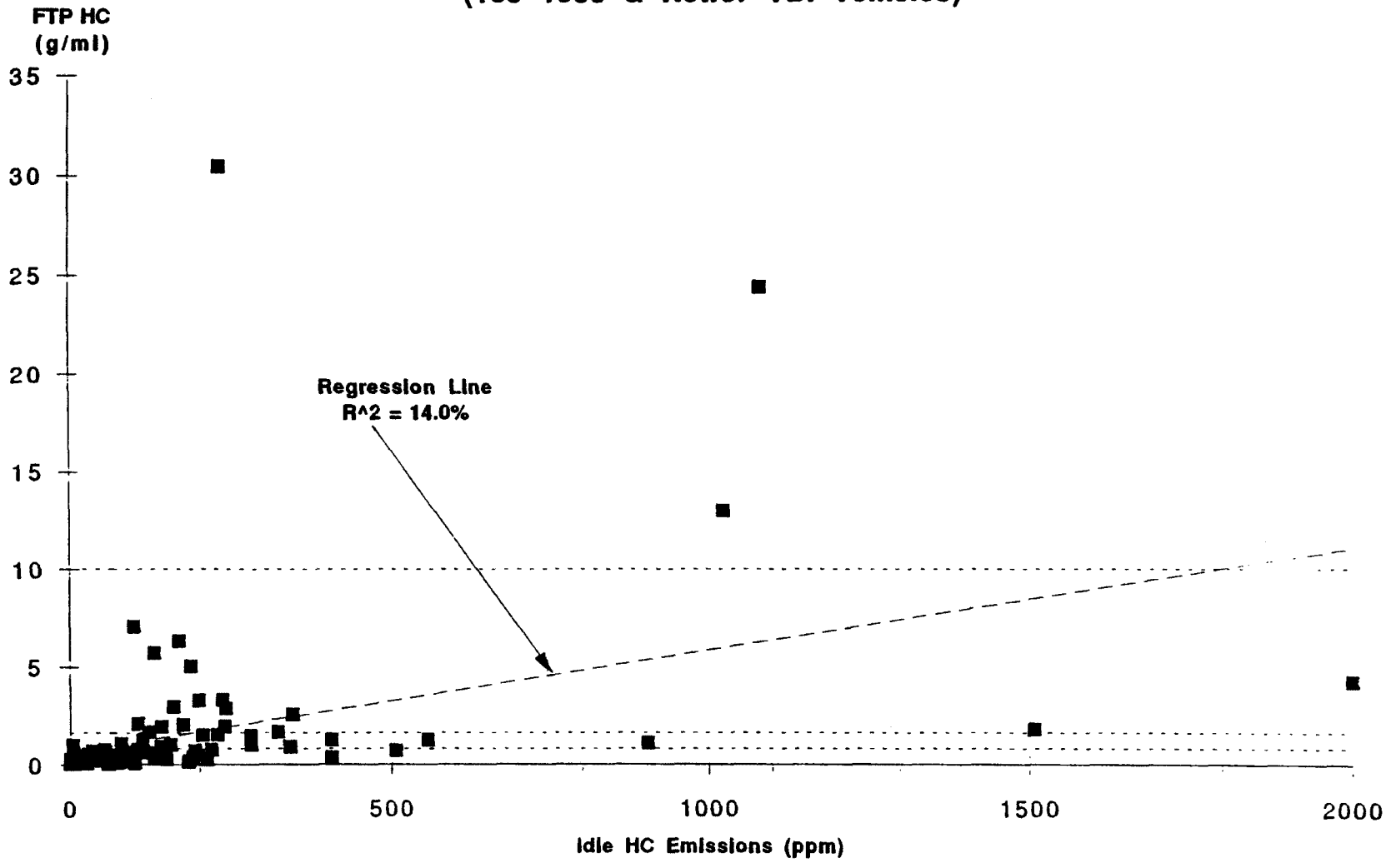

HC Emissions -- FTP vs Lane IM240
(108 1983 & Newer TBI Vehicles)
Enlarged for Better Detail near Origin
FTP HC
(g/mi)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
IM240 HC Emissions (g/mi)
Regression Line
R^2 = 64.4%

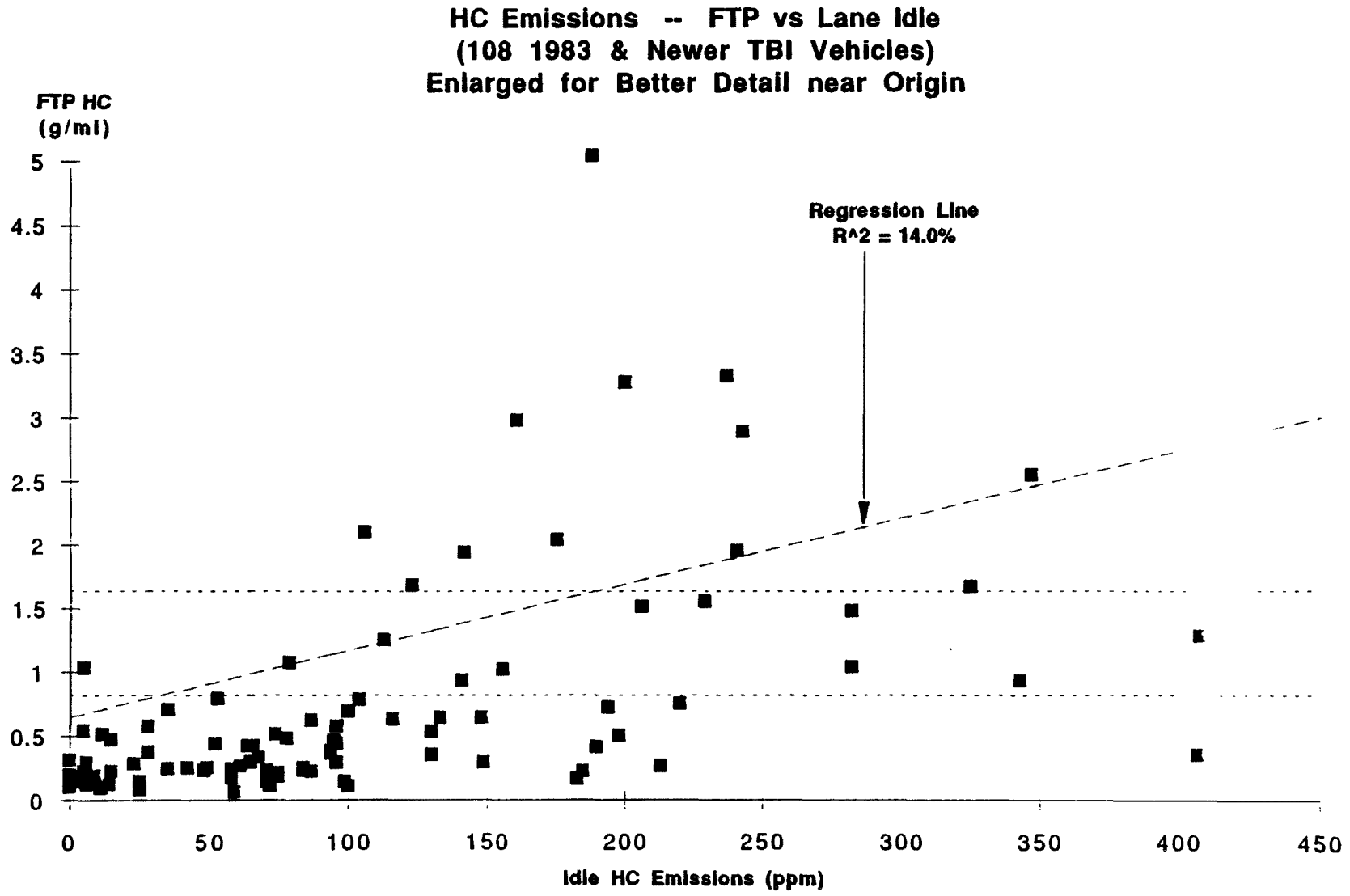
## HC Emissions -- FTP vs Lane 2500/Idle
## (108 1983 & Newer TBI Vehicles)




HC Emissions -- FTP vs Lane 2500/Idle
(108 1983 & Newer TBI Vehicles)
Enlarged for Better Detail near Origin
FTP HC
(g/ml)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Regression Line
R^2 = 8.2%
0
50
100
150
200
250
300
350
400
450
2500/Idle HC Emissions (ppm)

## HC Emissions -- FTP vs Lane Idle
## (108 1983 & Newer TBI Vehicles)




HC Emissions -- FTP vs Lane Idle
(108 1983 & Newer TBI Vehicles)
Enlarged for Better Detail near Origin
FTP HC
(g/mi)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Regression Line
R^2 = 14.0%
0
50
100
150
200
250
300
350
400
450
Idle HC Emissions (ppm)

## Regression Analyses of FTP CO versus CO Emissions Over: IM240, Idle Test, and 2500/Idle Test For TBI Vehicles

Dependent variable is: COFTP
R^2 = 79.9%
s = 20.97 with 108 - 2 = 106 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 185395 | 1 | 200000 | 421 |
| Residual | 46625.6 | 106 | 439.864 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | -3.46603 | 2.331 | -1.49 |
| COIM24 | 1.41279 | 0.0688 | 20.5 |

Dependent variable is: COFTP
R^2 = 46.9%
s = 34.10 with 108 - 2 = 106 degrees of freedom

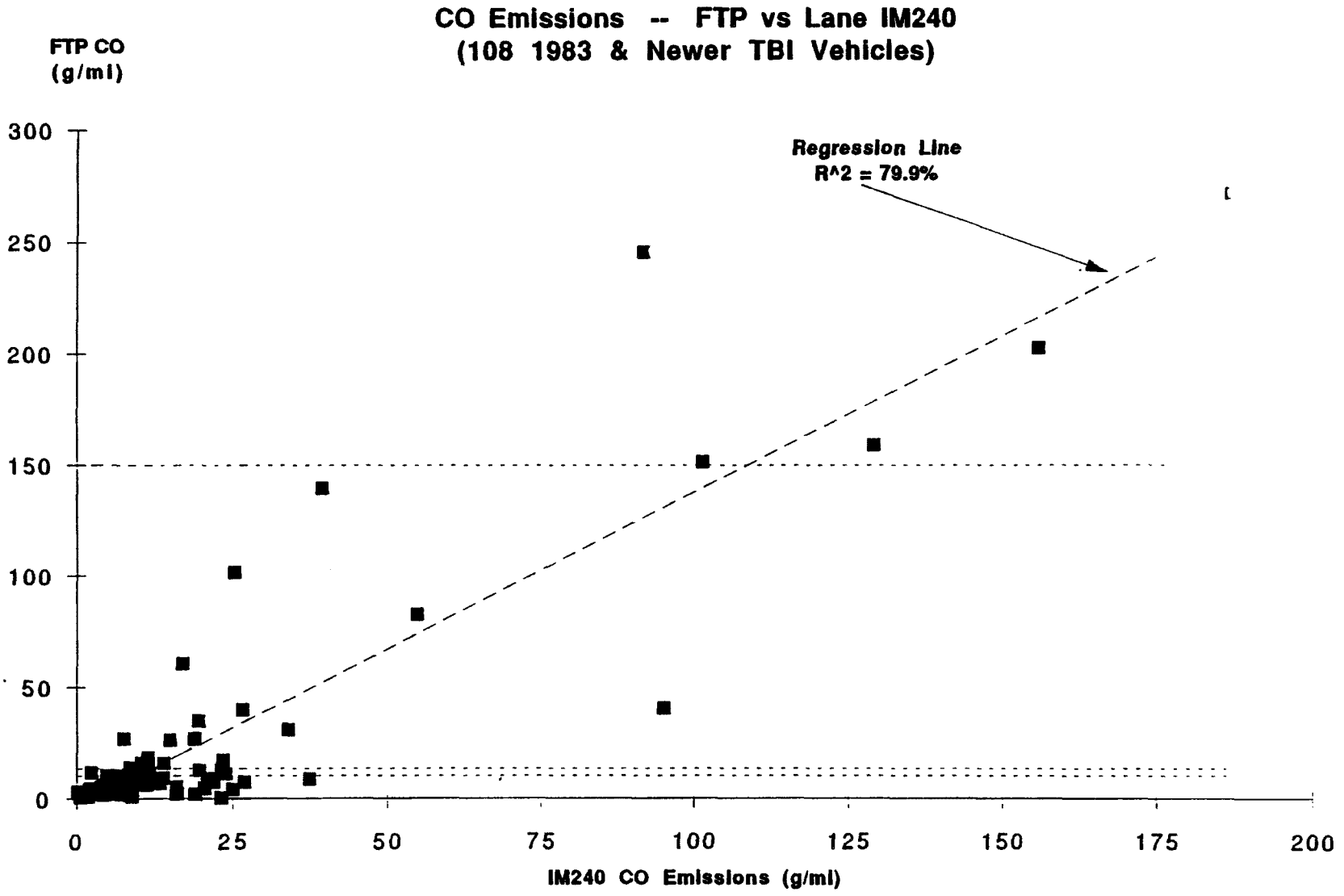
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 108761 | 1 | 100000 | 93.5 |
| Residual | 123260 | 106 | 1162.83 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 4.43526 | 3.677 | 1.21 |
| Higher(Idle ... | 15.0538 | 1.557 | 9.67 |

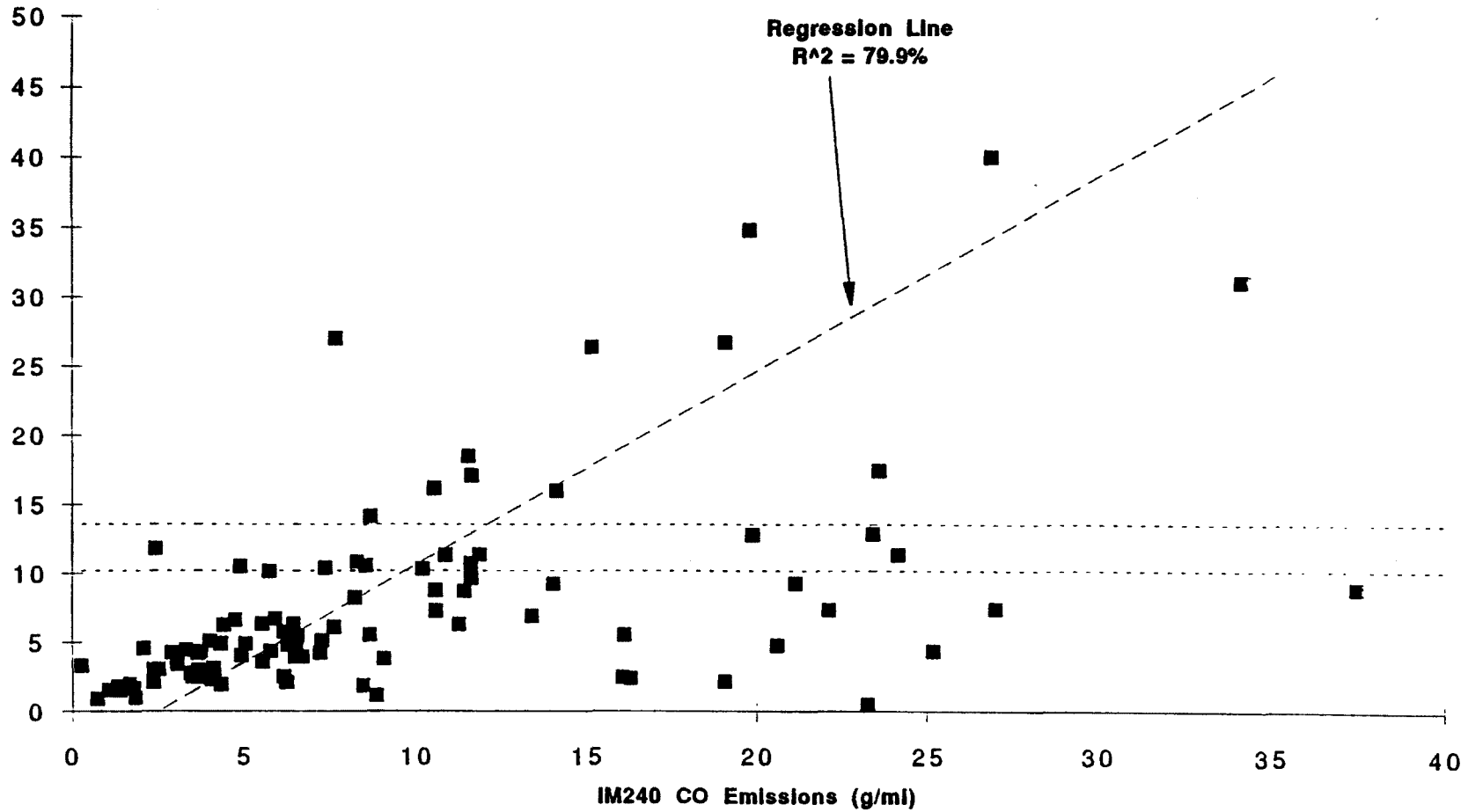
Dependent variable is: COFTP
R^2 = 51.1%
s = 32.73 with 108 - 2 = 106 degrees of freedom

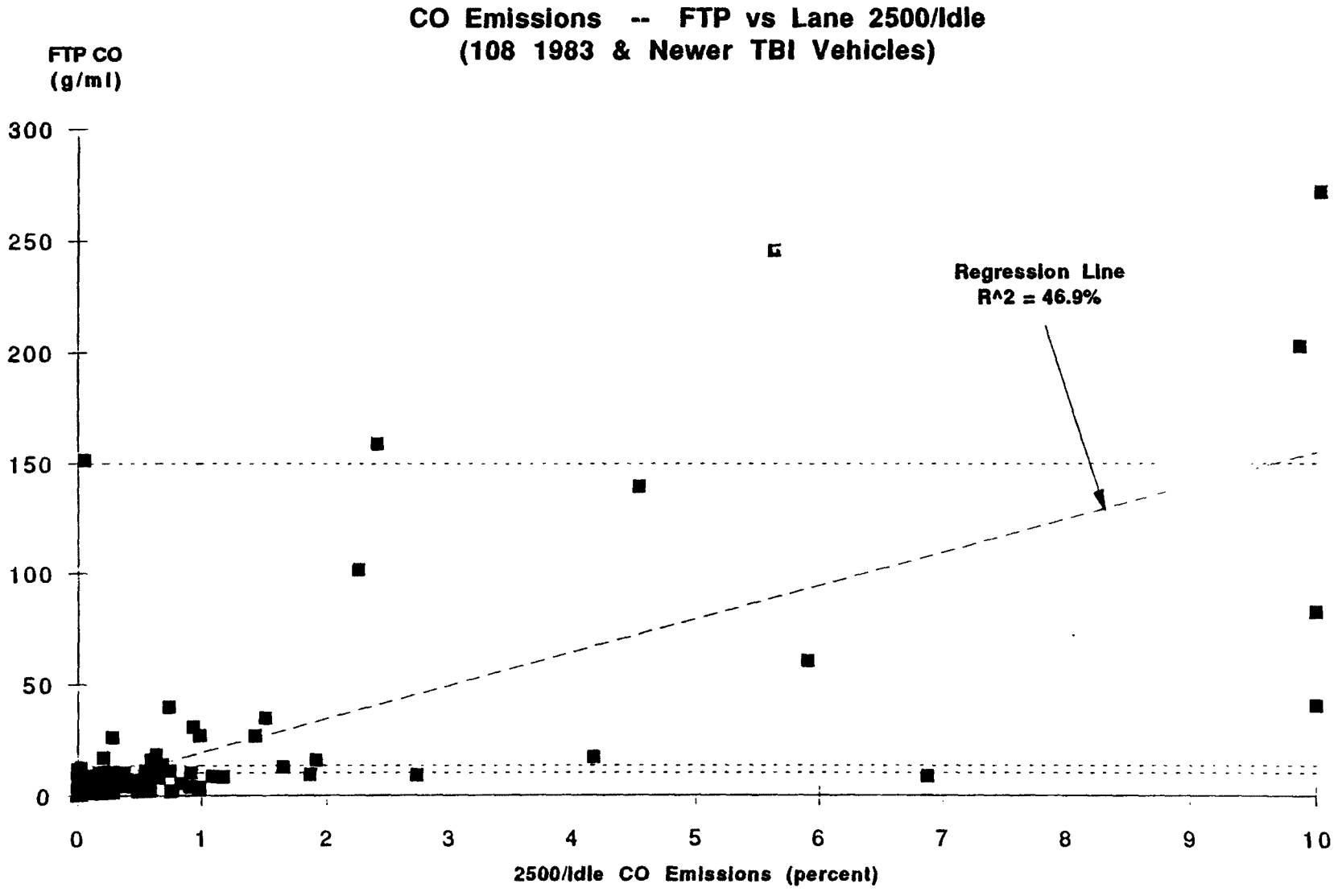
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 118502 | 1 | 100000 | 111 |
| Residual | 113519 | 106 | 1070.93 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 5.15188 | 3.47 | 1.48 |
| Idle.CO | 17.2888 | 1.644 | 10.5 |

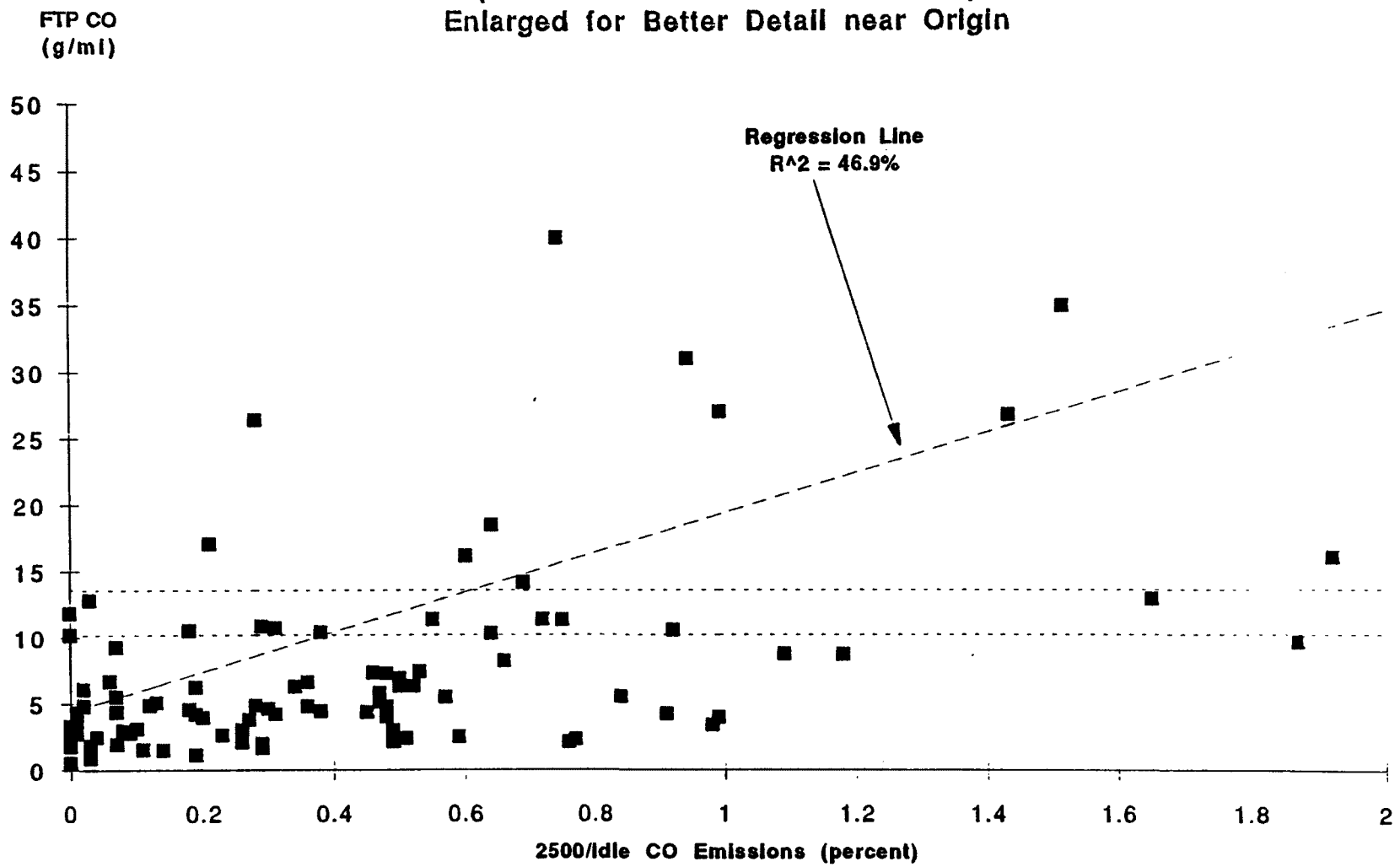

CO Emissions -- FTP vs Lane IM240
(108 1983 & Newer TBI Vehicles)
FTP CO
(g/mi)
Regression Line
R^2 = 79.9%
300
250
200
150
100
50
0
0
25
50
75
100
125
150
175
200
IM240 CO Emissions (g/mi)

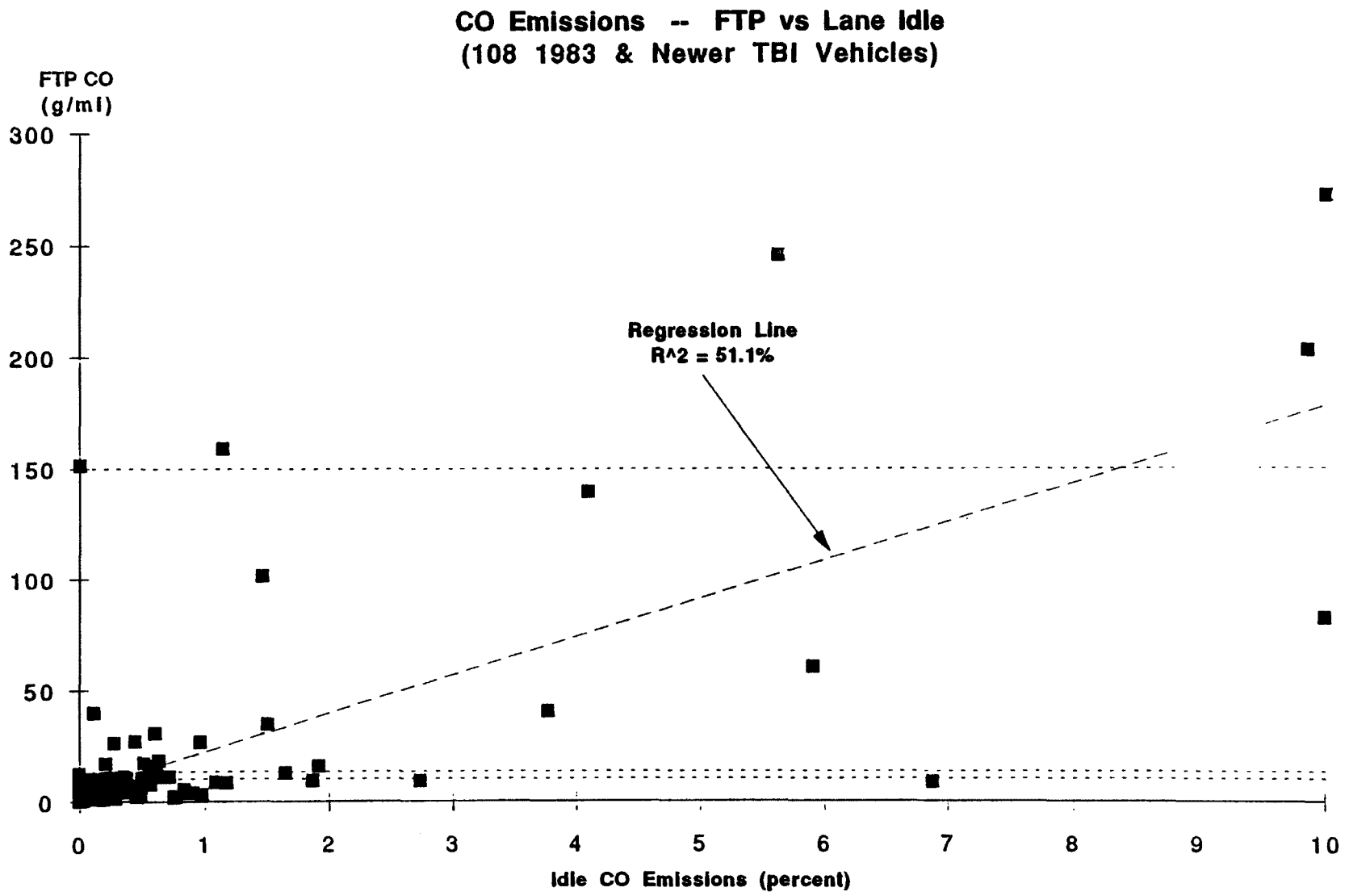
## CO Emissions -- FTP vs Lane IM240
## (108 1983 & Newer TBI Vehicles)
## Enlarged for Better Detail near Origin



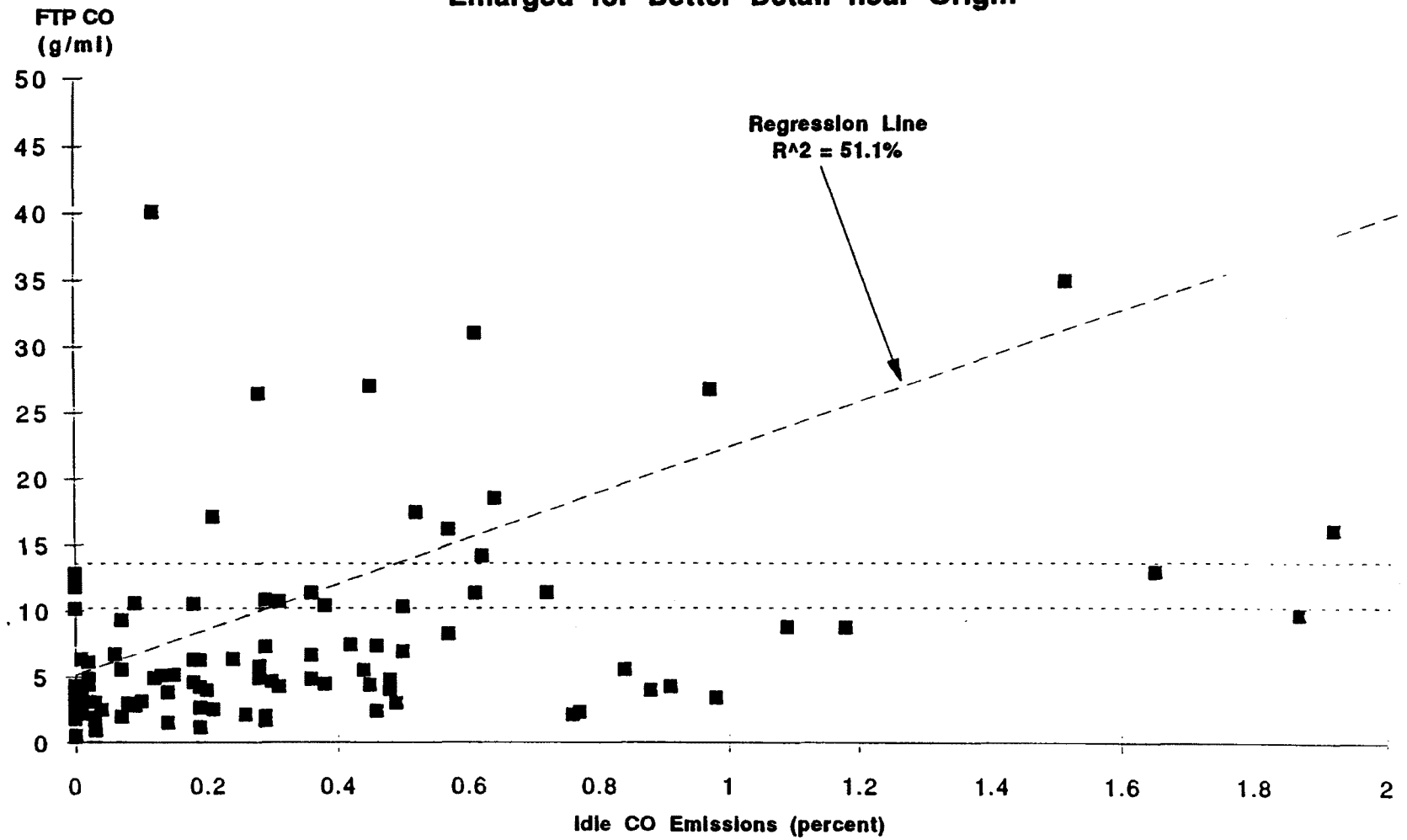

CO Emissions -- FTP vs Lane 2500/Idle
(108 1983 & Newer TBI Vehicles)
FTP CO
(g/ml)
300
250
200
150
100
50
0
Regression Line
R^2 = 46.9%
0
1
2
3
4
5
6
7
8
9
10
2500/Idle CO Emissions (percent)

## CO Emissions -- FTP vs Lane 2500/Idle
## (108 1983 & Newer TBI Vehicles)
## Enlarged for Better Detail near Origin




CO Emissions -- FTP vs Lane Idle
(108 1983 & Newer TBI Vehicles)
FTP CO
(g/ml)
300
250
200
150
100
50
0
Regression Line
R^2 = 51.1%
0
1
2
3
4
5
6
7
8
9
10
Idle CO Emissions (percent)

## CO Emissions -- FTP vs Lane Idle
## (108 1983 & Newer TBI Vehicles)
## Enlarged for Better Detail near Origin

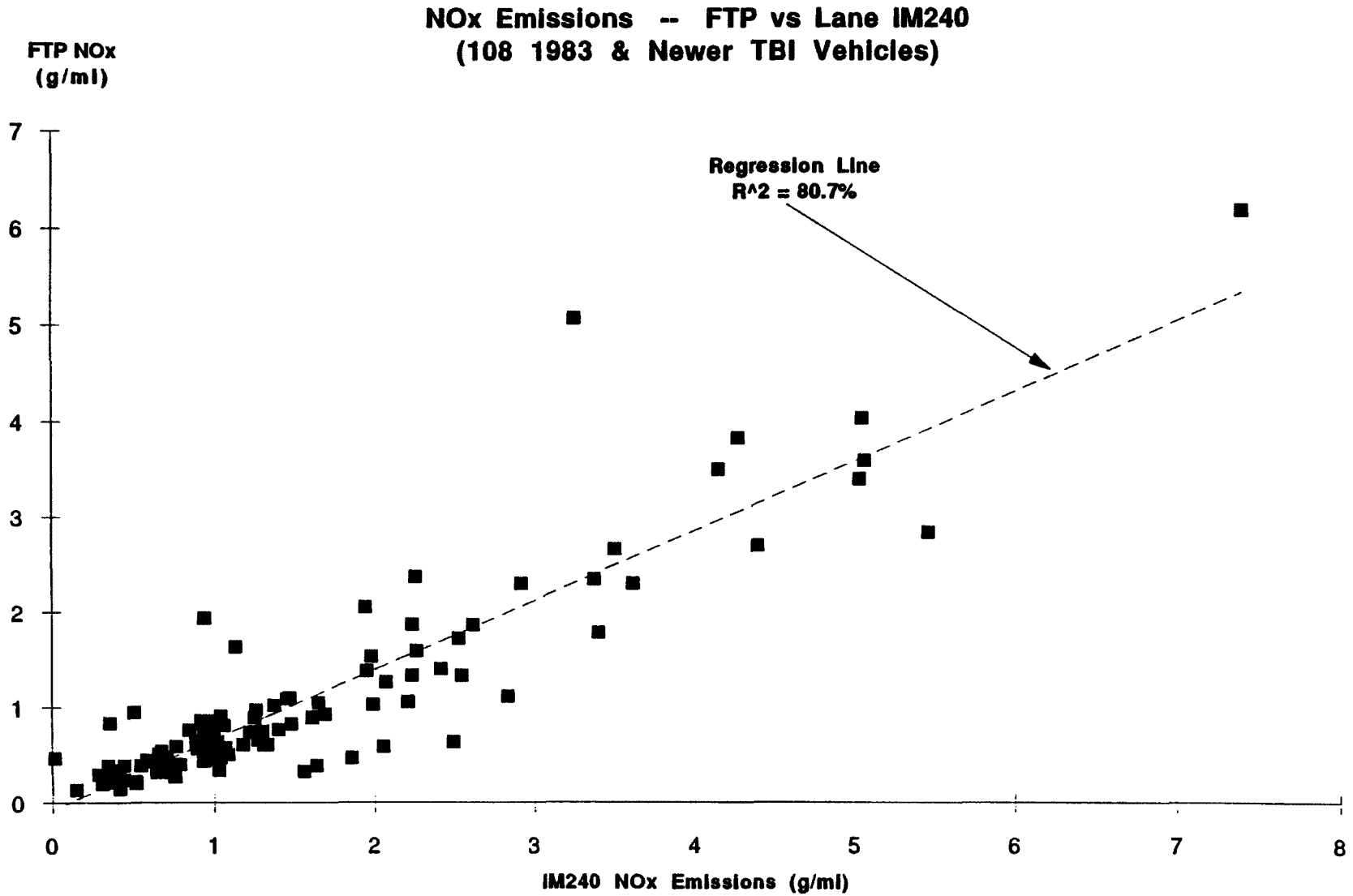


## Regression Analyses of FTP NOx versus IM240 NOx Emissions (Note: NOx is not Measured for the Idle Test)

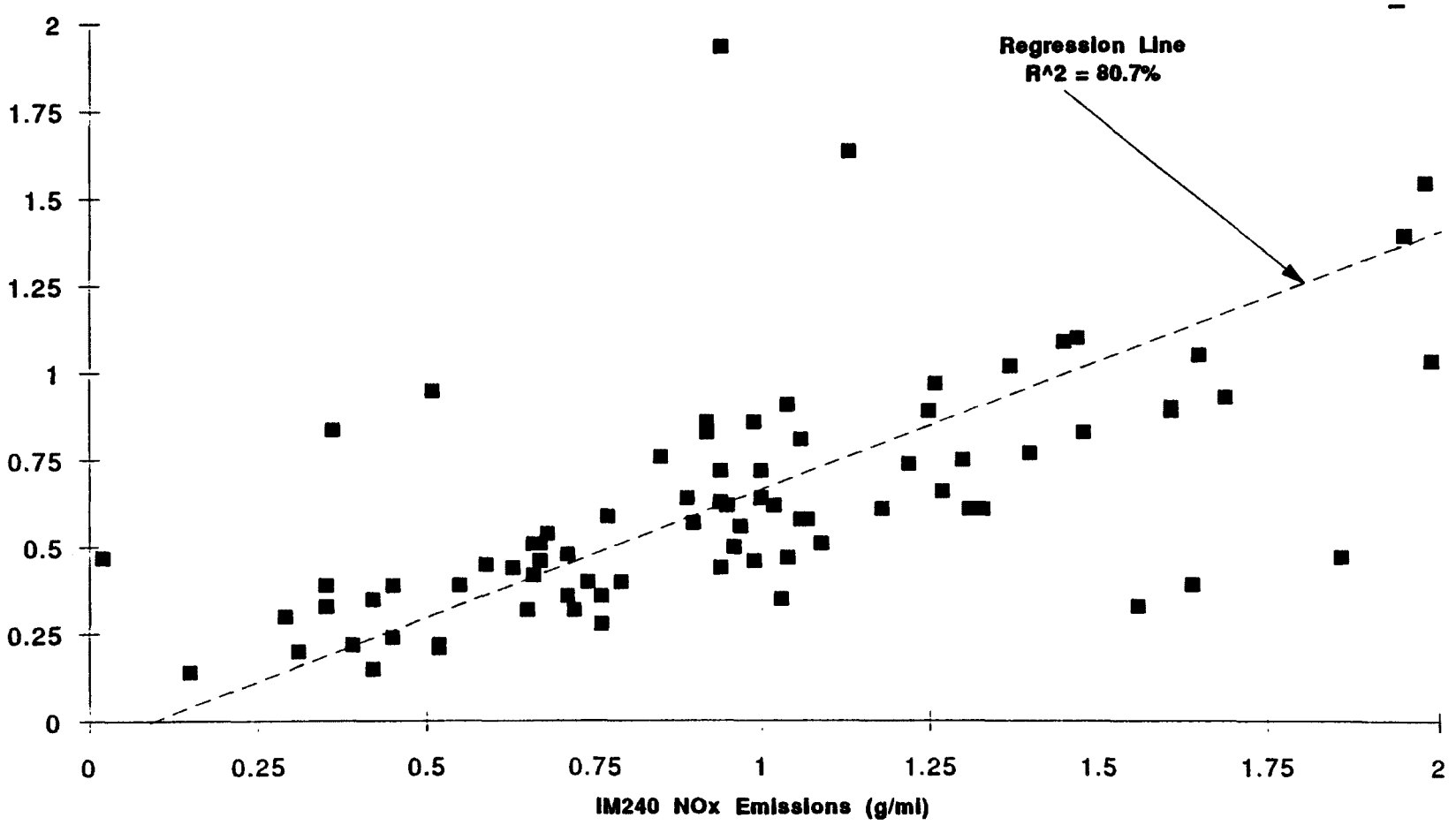
Dependent variable is: **NOFTP.TBI**
R^2 = 80.7%
s = 0.4677 with 108 - 2 = 106 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 96.941 | 1 | 96.94 | 443 |
| Residual | 23.1857 | 106 | 0.218733 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | -0.069973 | 0.071 | -0.985 |
| **NOIM24.TBI** | 0.734578 | 0.0349 | 21.1 |


NOx Emissions -- FTP vs Lane IM240
(108 1983 & Newer TBI Vehicles)
FTP NOx
(g/mi)
Regression Line
R^2 = 80.7%
0
1
2
3
4
5
6
7
8
IM240 NOx Emissions (g/mi)

## NOx Emissions -- FTP vs Lane IM240
## (108 1983 & Newer TBI Vehicles)
## Enlarged for Better Detail near Origin



# Vehicles Tested by ATL at Southbend, Indiana

## Regressions of FTP vs Indolene-IM240 for 91 1983 & Newer TBI Vehicles

Dependent variable is **HCFTP**
R^2 = 90.1%
s = 1.354 with 91 - 2 = 89 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 1491.43 | 1 | 1491 | 813 |
| Residual | 163.188 | 89 | 1.83357 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.002929 | 0.1537 | 0.019 |
| **HC.IM24.Indo...** | 1.66576 | 0.0584 | 28.5 |

Dependent variable is **COFTP**
R^2 = 90.3%
s = 15.12 with 91 - 2 = 89 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 190004 | 1 | 200000 | 831 |
| Residual | 20343.9 | 89 | 228.583 | |

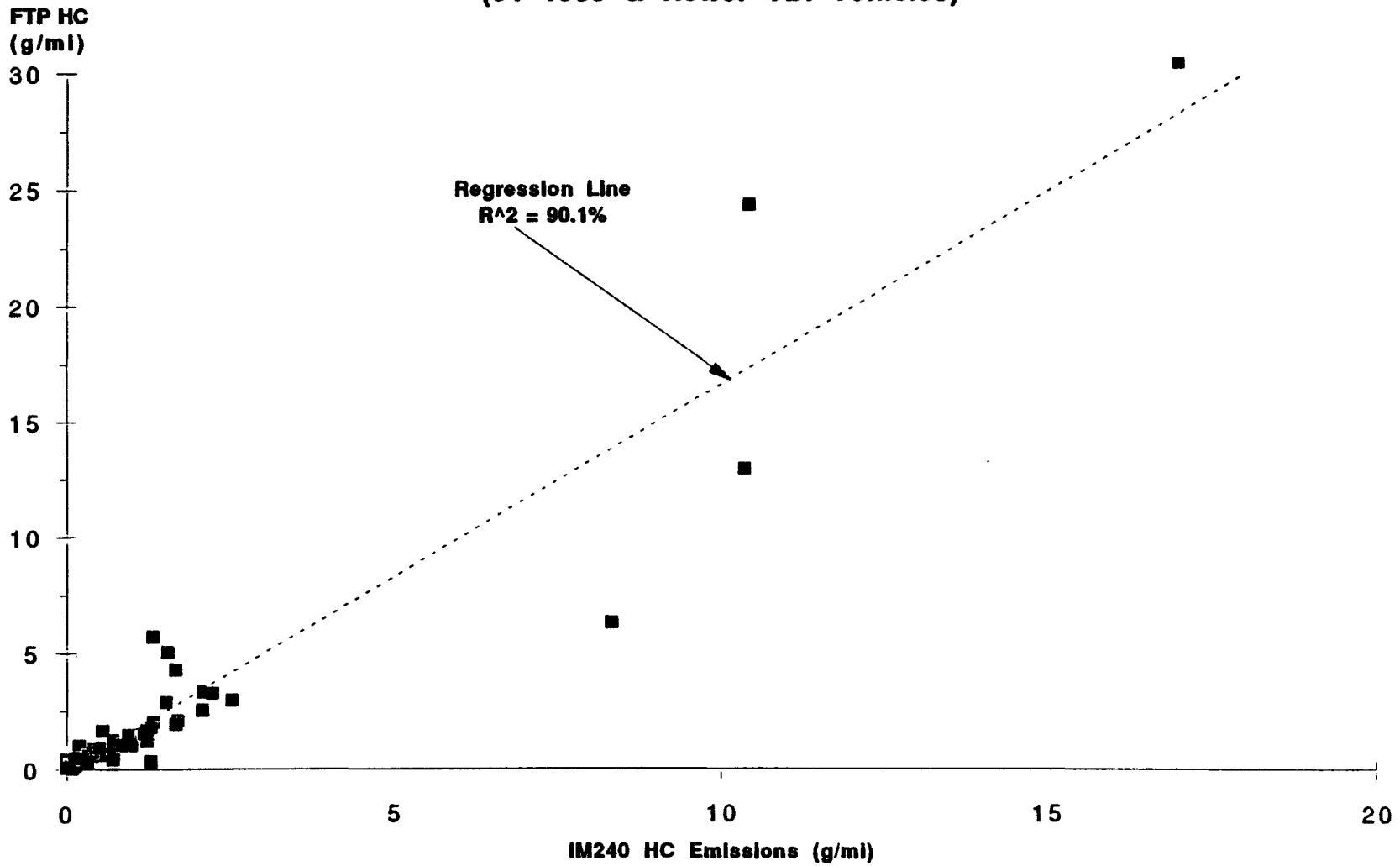
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | -0.174774 | 1.758 | -0.099 |
| **CO.IM24.Indo...** | 1.34497 | 0.0467 | 28.8 |

Dependent variable is **NOx.FTP**
R^2 = 92.6%
s = 0.2989 with 91 - 2 = 89 degrees of freedom

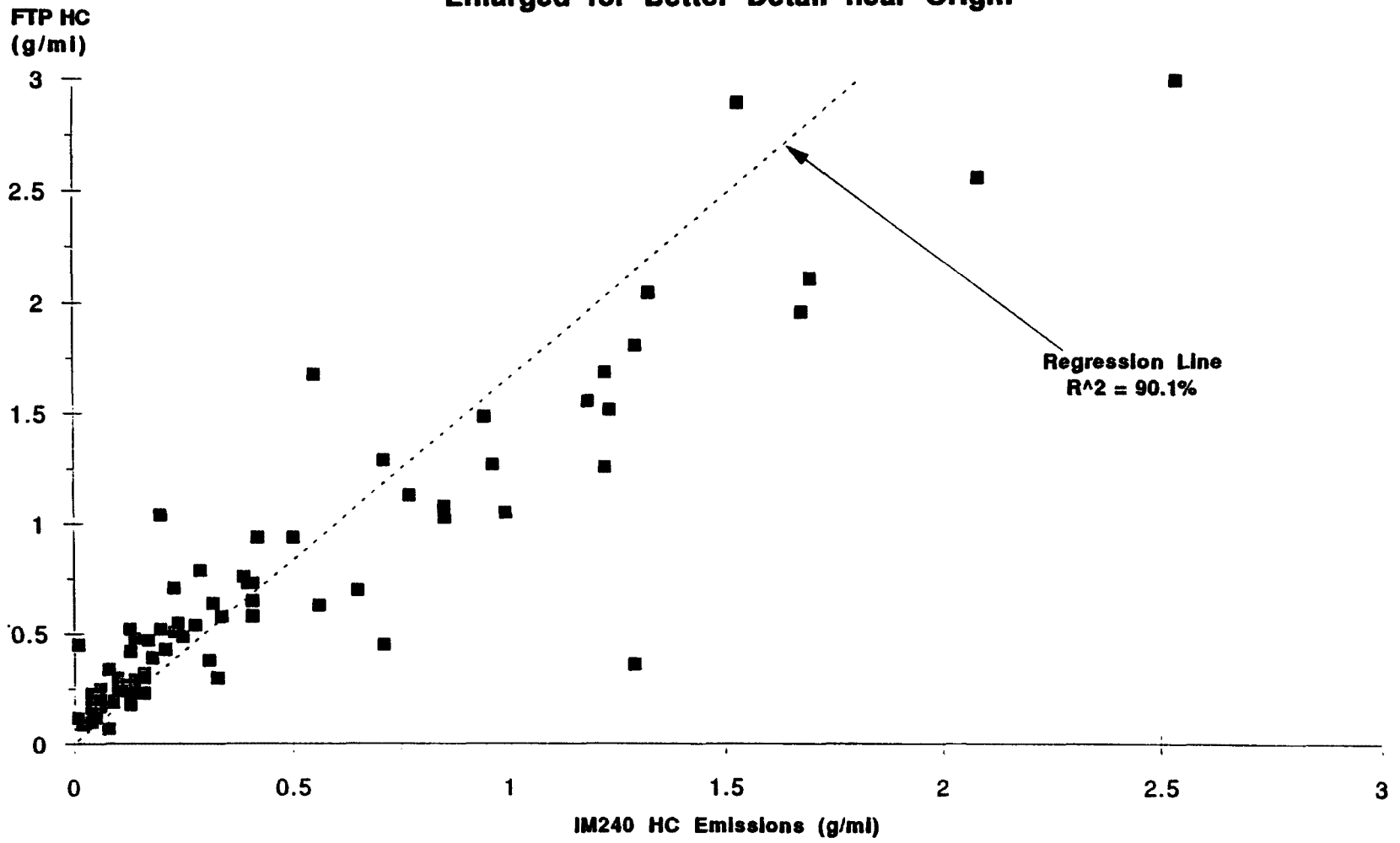
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 99.1838 | 1 | 99.18 | 1110 |
| Residual | 7.9495 | 89 | 0.08932 | |

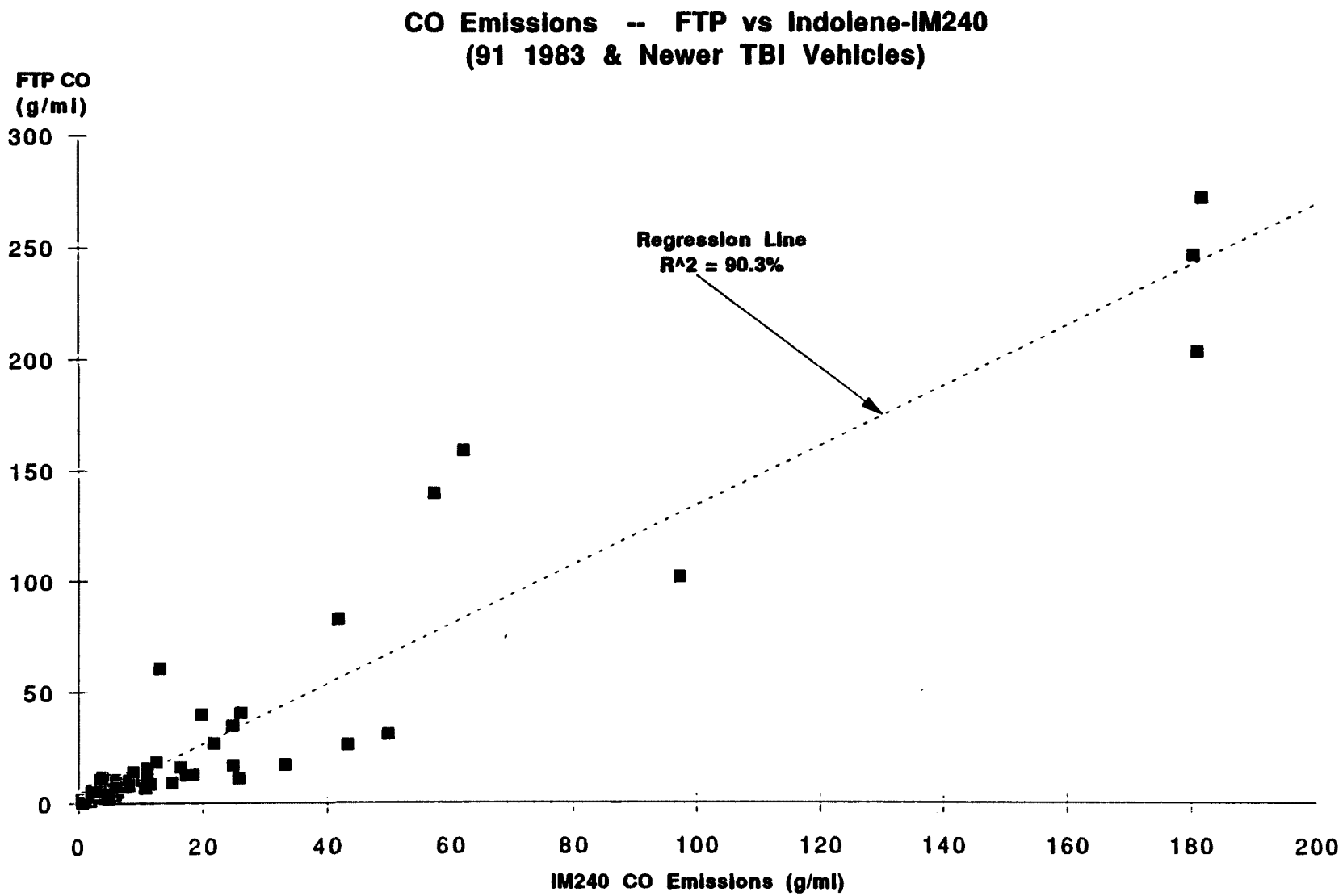
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.073869 | 0.0443 | 1.67 |
| **NOx.IM24.Ind...** | 0.845099 | 0.0254 | 33.3 |

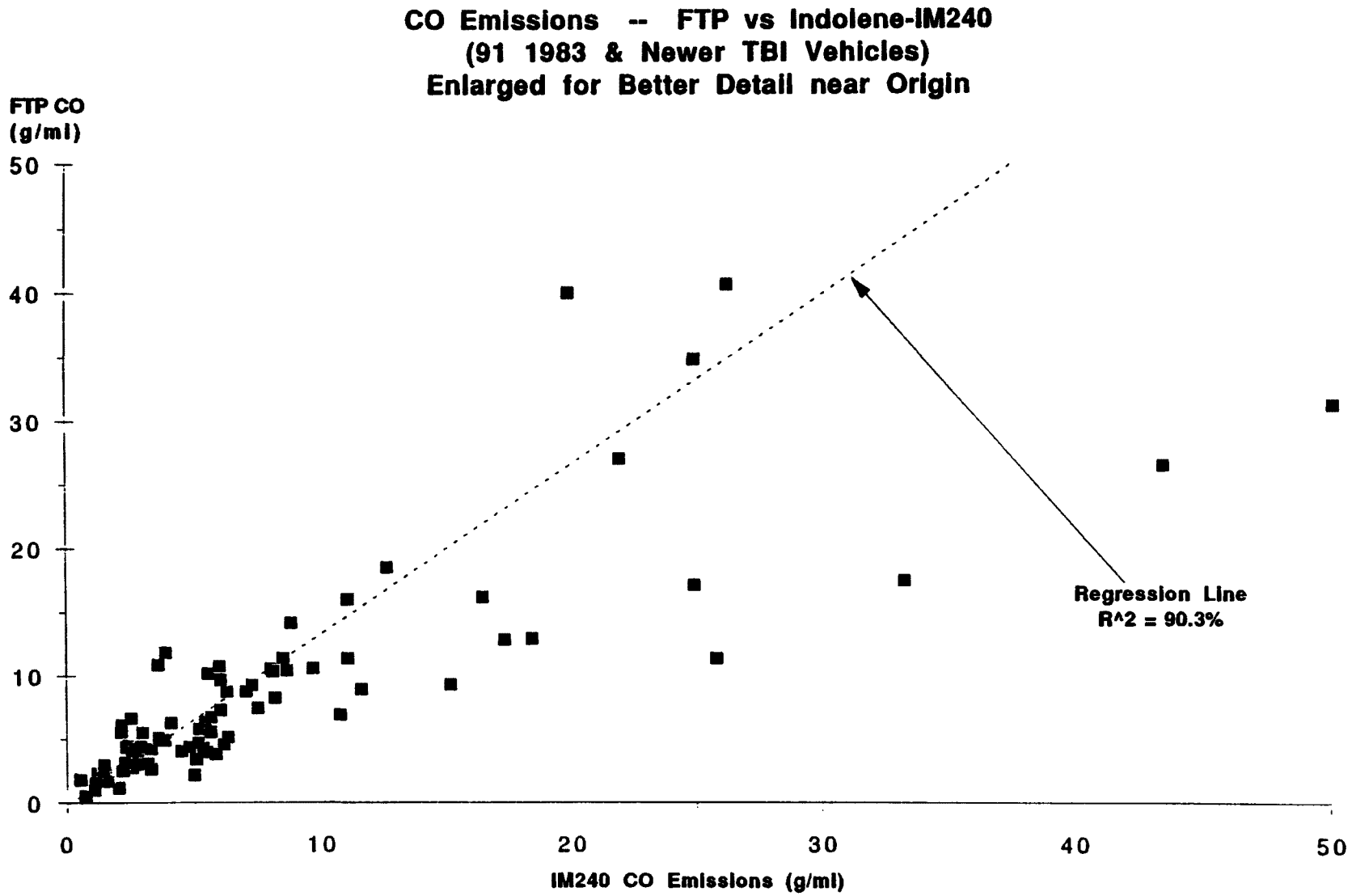
## HC Emissions -- FTP vs Indolene-IM240
## (91 1983 & Newer TBI Vehicles)

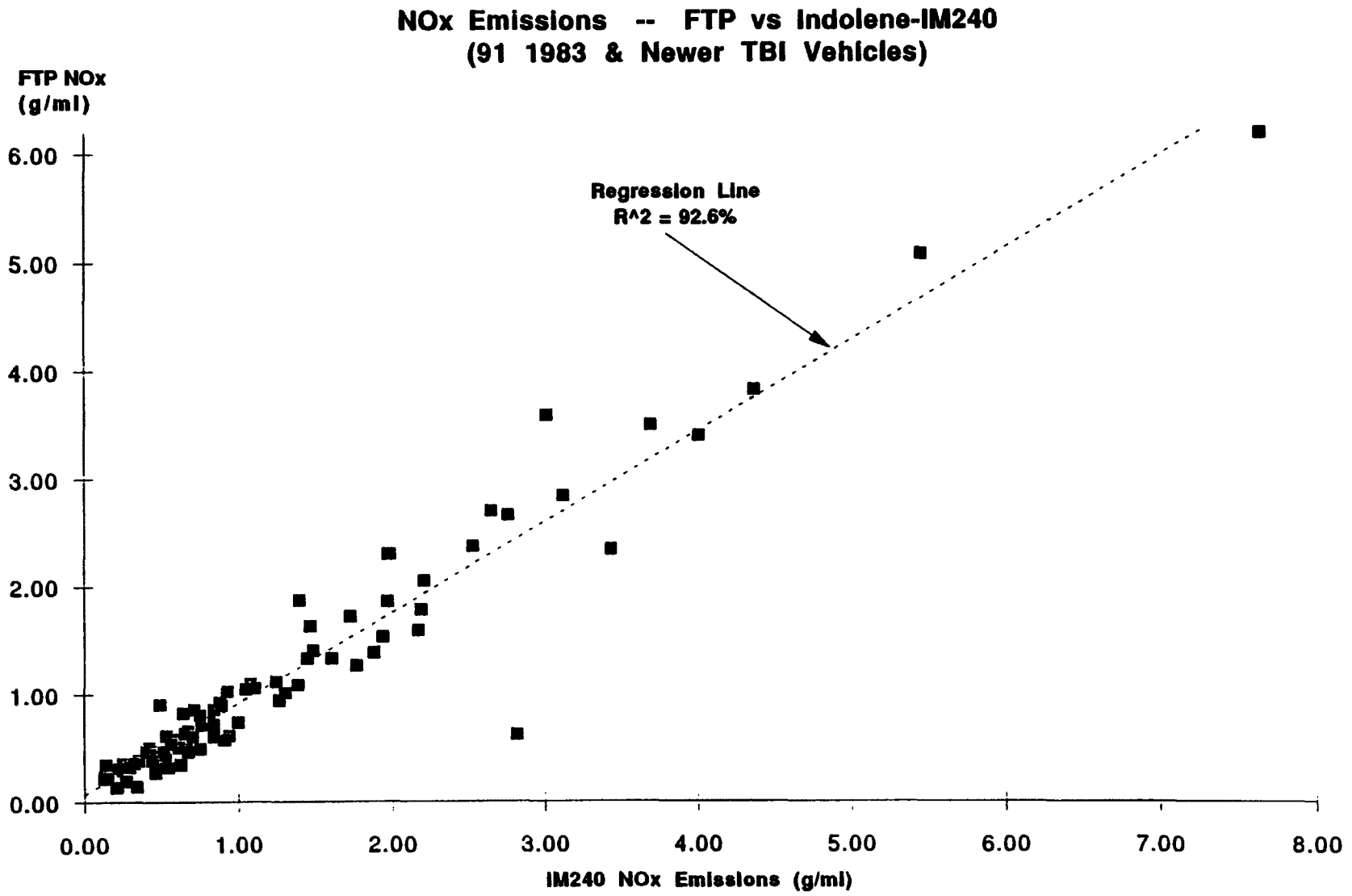


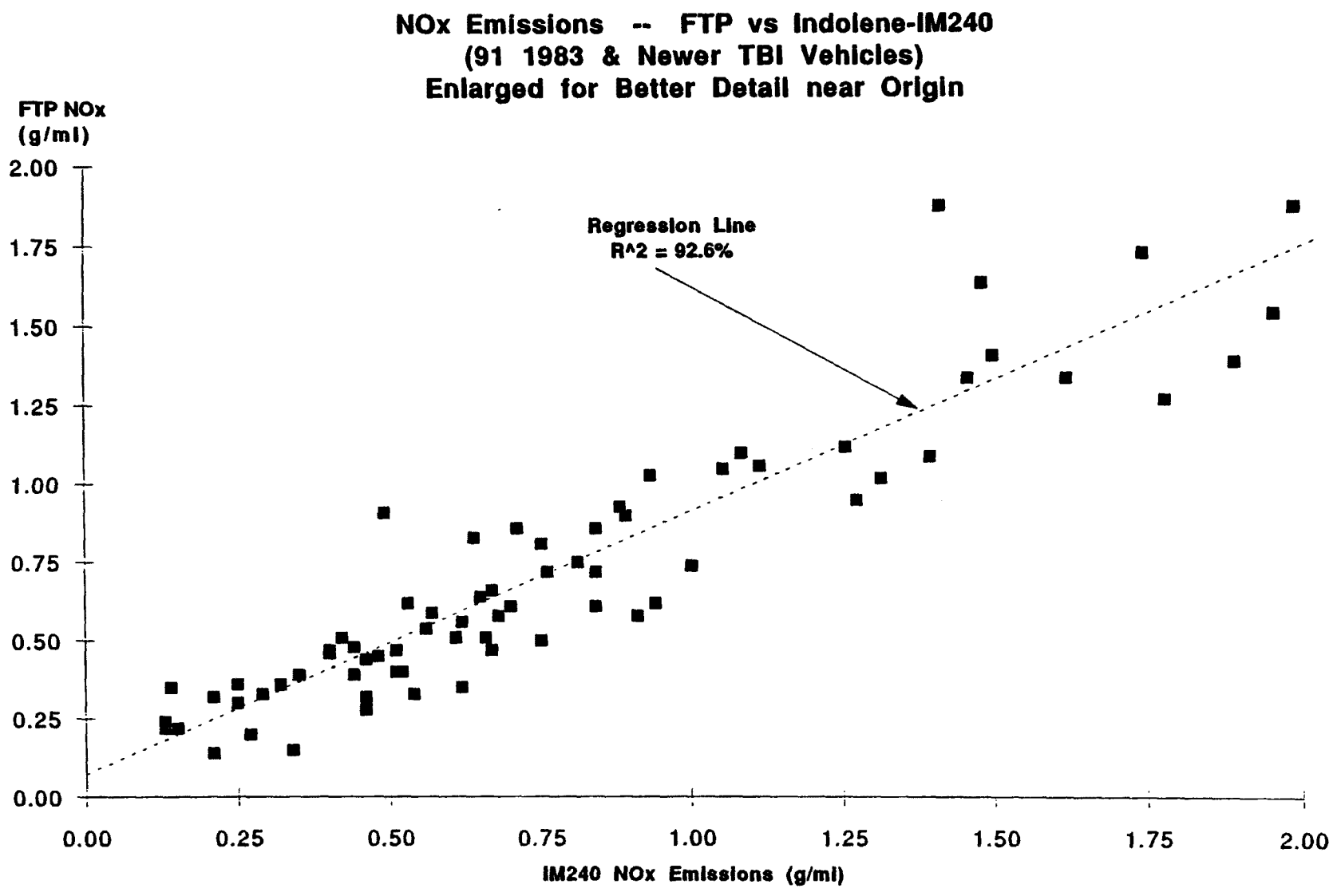
## HC Emissions -- FTP vs Indolene-IM240
## (91 1983 & Newer TBI Vehicles)
## Enlarged for Better Detail near Origin




CO Emissions -- FTP vs Indolene-IM240
(91 1983 & Newer TBI Vehicles)
FTP CO
(g/mi)
300
250
200
150
100
50
0
Regression Line
R^2 = 90.3%
0
20
40
60
80
100
120
140
160
180
200
IM240 CO Emissions (g/mi)


CO Emissions -- FTP vs Indolene-IM240
(91 1983 & Newer TBI Vehicles)
Enlarged for Better Detail near Origin
FTP CO
(g/mi)
50
40
30
20
10
0
0
10
20
30
40
50
IM240 CO Emissions (g/mi)
Regression Line
R^2 = 90.3%


NOx Emissions -- FTP vs Indolene-IM240
(91 1983 & Newer TBI Vehicles)
FTP NOx
(g/mi)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Regression Line
R^2 = 92.6%
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
IM240 NOx Emissions (g/mi)


NOx Emissions -- FTP vs Indolene-IM240
(91 1983 & Newer TBI Vehicles)
Enlarged for Better Detail near Origin
FTP NOx
(g/mi)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Regression Line
R^2 = 92.6%
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
IM240 NOx Emissions (g/mi)

# EF Vehicles Tested at EPA's MVEL

## Regressions of FTP vs Indolene IM240 for 62 1985-88 TBI Vehicles

Dependent variable is: **HC.FTP**
R^2 = 87.7%
s = 1.703 with 62 - 2 = 60 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 1241.84 | 1 | 1242 | 428 |
| Residual | 173.984 | 60 | 2.89973 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.146231 | 0.2279 | 0.642 |
| **HCIM24** | 1.71372 | 0.0828 | 20.7 |

Dependent variable is: **CO.FTP**
R^2 = 92.5%
s = 11.59 with 62 - 2 = 60 degrees of freedom

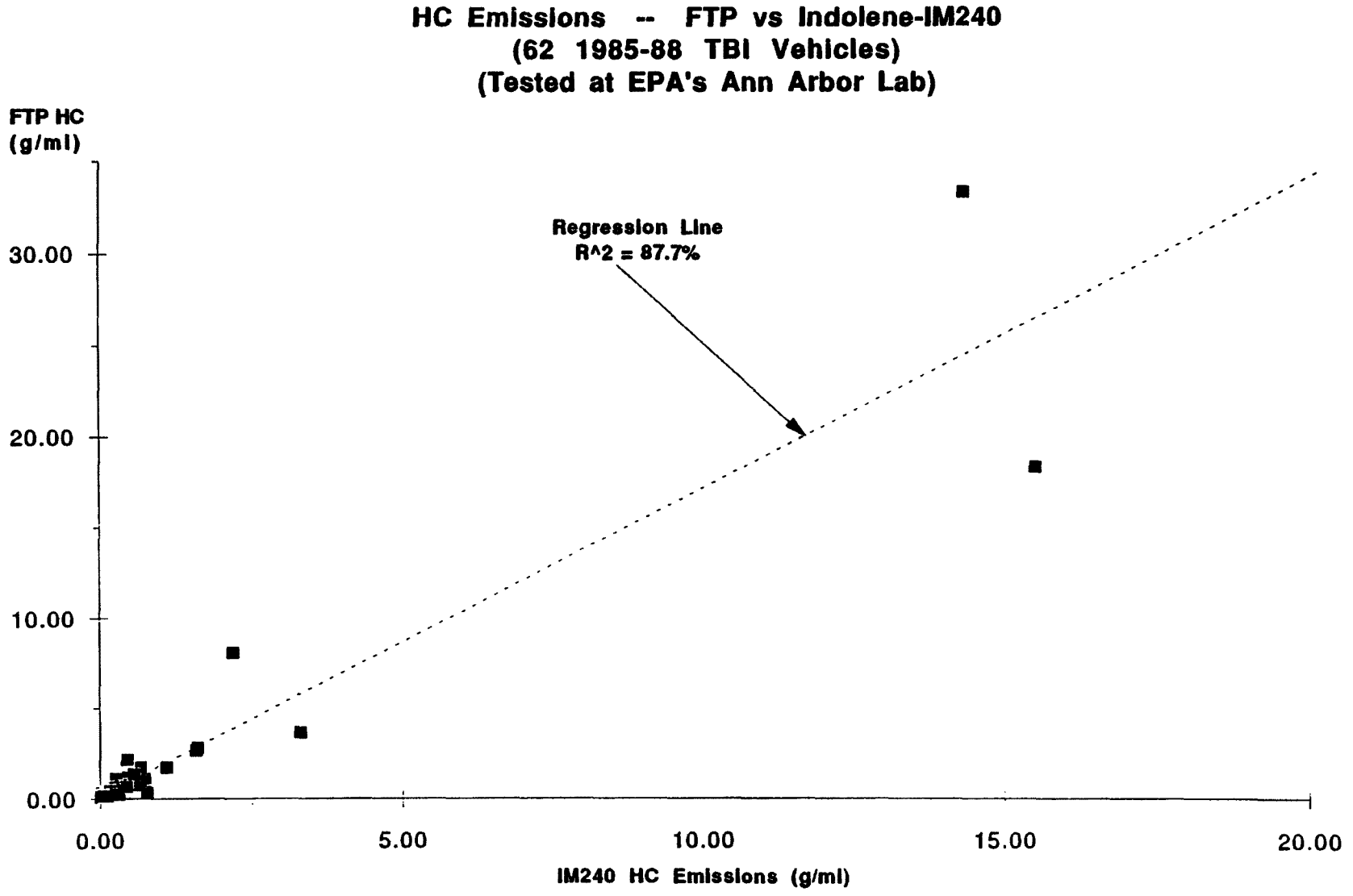
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 99522.9 | 1 | 99523 | 741 |
| Residual | 8056.07 | 60 | 134.268 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 2.56957 | 1.584 | 1.62 |
| **COIM24** | 1.10181 | 0.0405 | 27.2 |

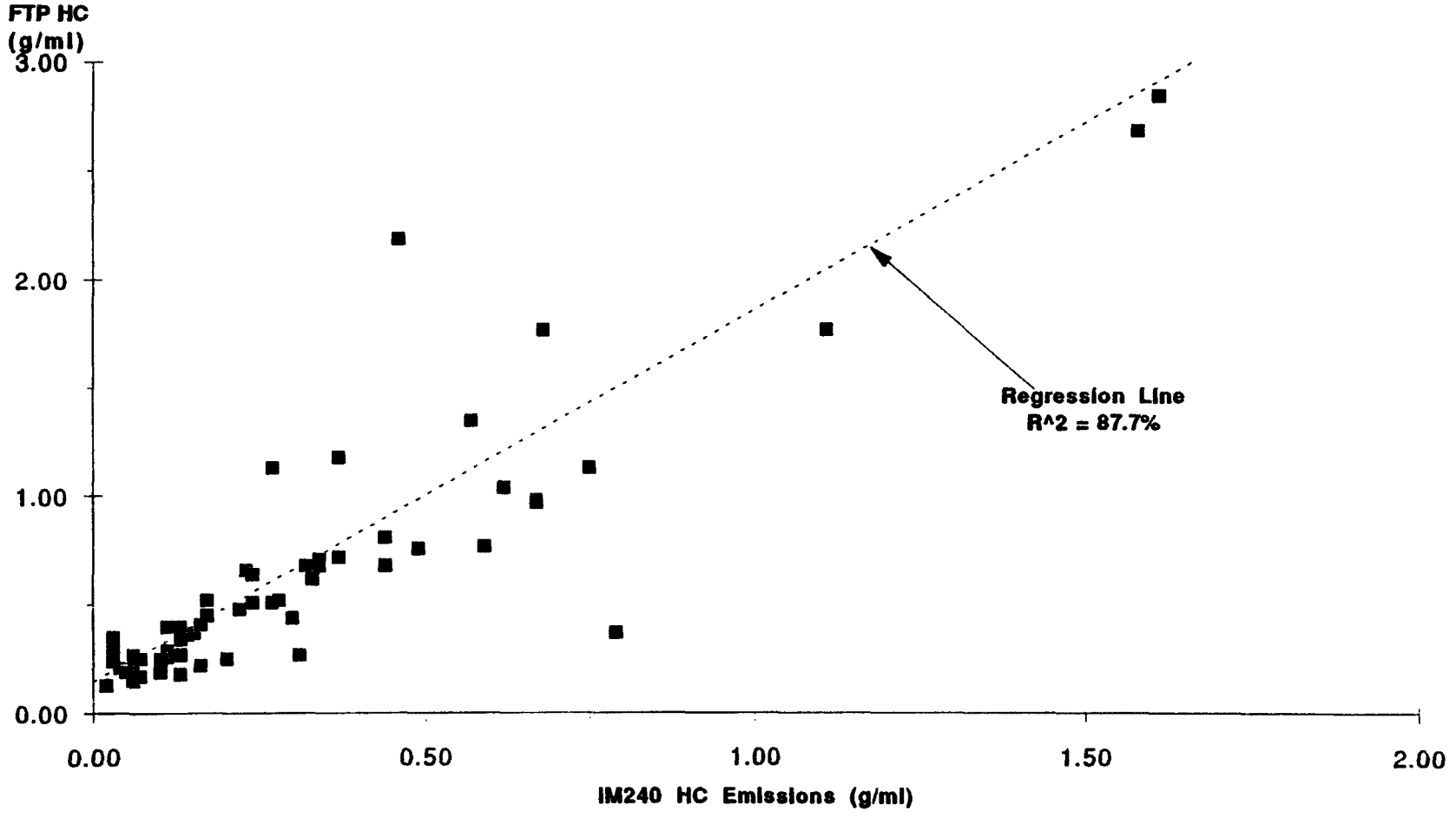
Dependent variable is: **NOx.FTP**
R^2 = 90.9%
s = 0.1594 with 62 - 2 = 60 degrees of freedom

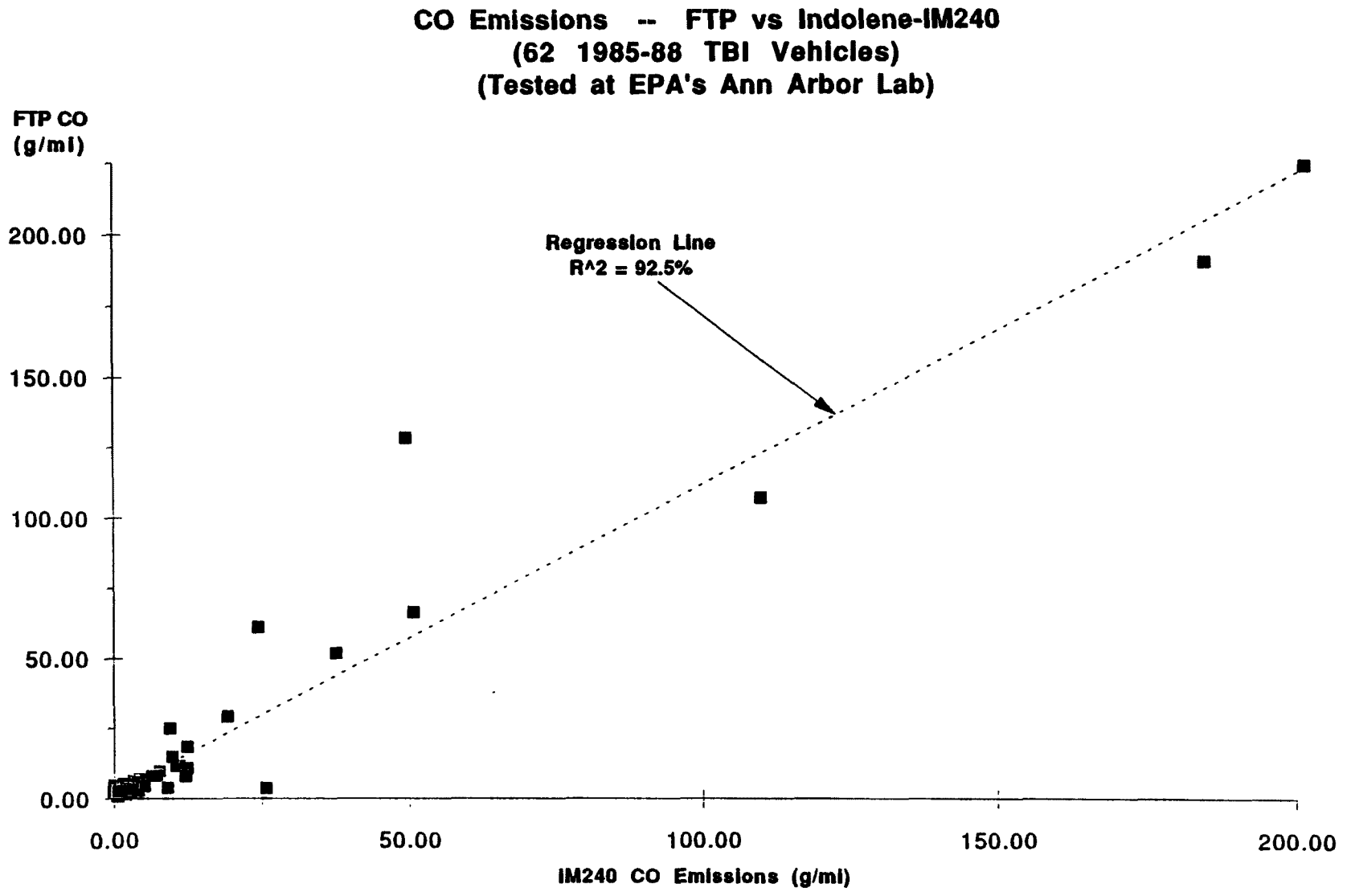
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 15.2107 | 1 | 15.21 | 599 |
| Residual | 1.52398 | 60 | 0.0254 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.067854 | 0.0323 | 2.1 |
| **NOIM24** | 0.780974 | 0.0319 | 24.5 |

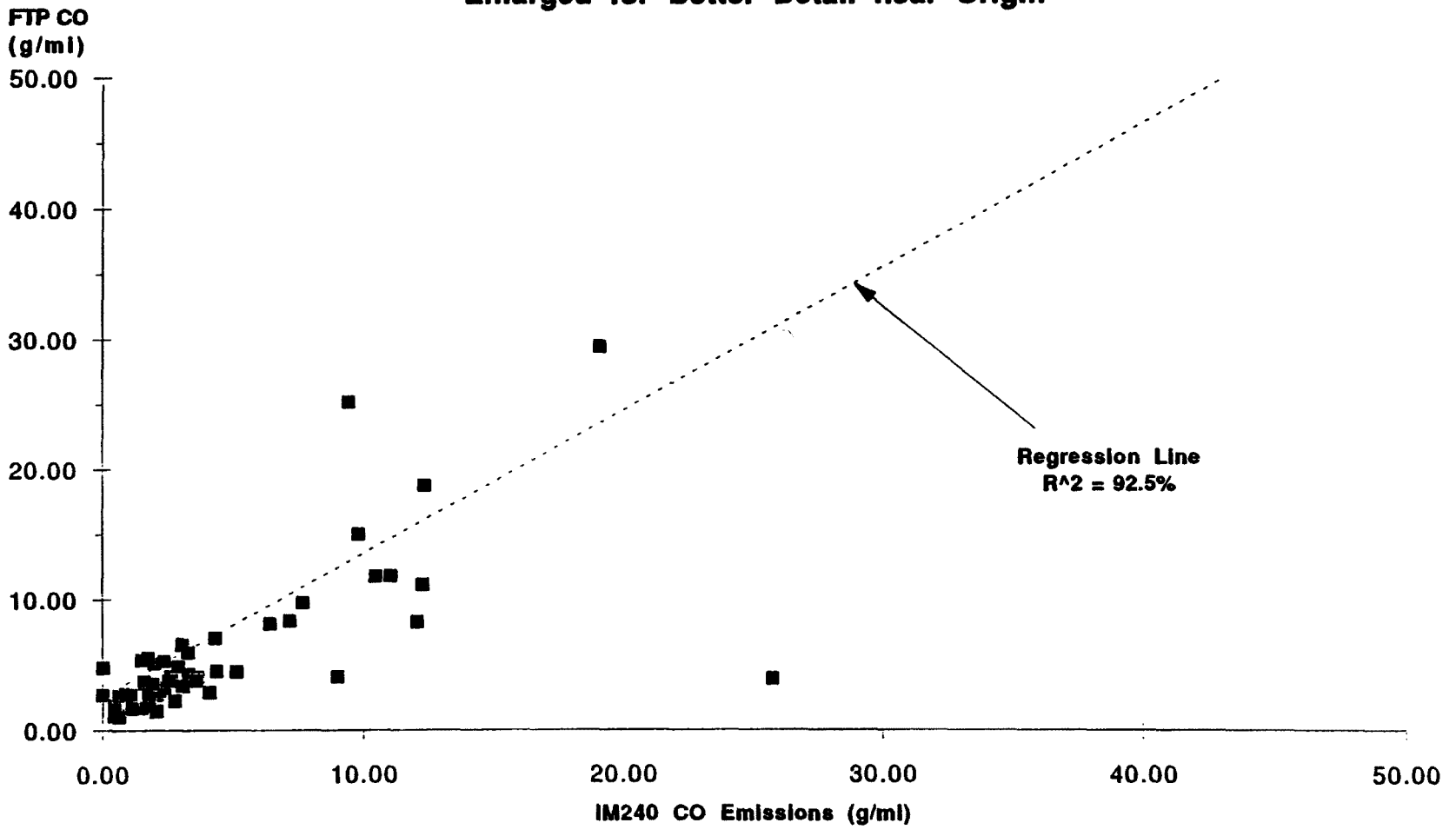

HC Emissions -- FTP vs Indolene-IM240
(62 1985-88 TBI Vehicles)
(Tested at EPA's Ann Arbor Lab)
FTP HC
(g/ml)
Regression Line
R^2 = 87.7%
30.00
20.00
10.00
0.00
0.00
5.00
10.00
15.00
20.00
IM240 HC Emissions (g/ml)

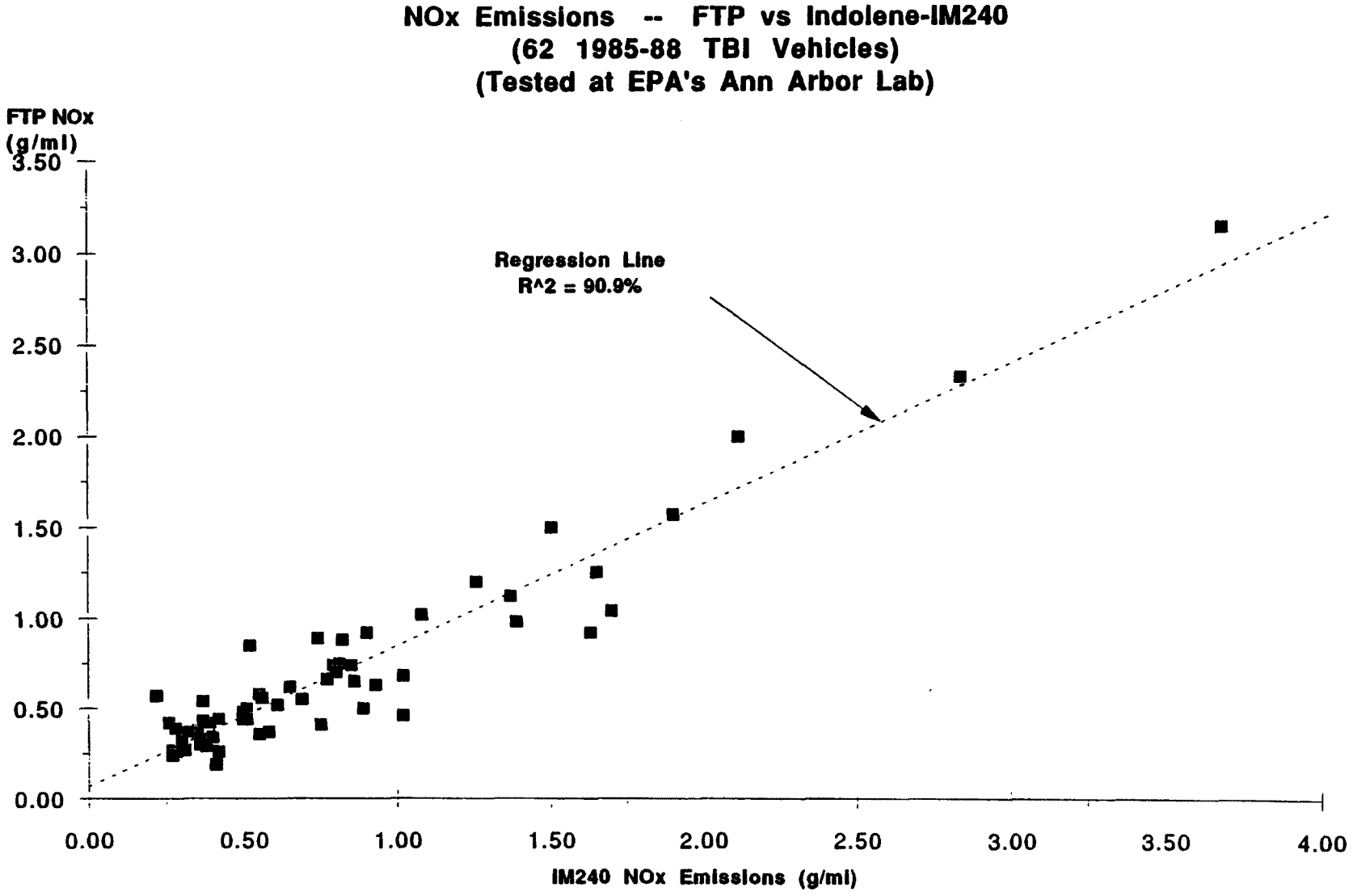
## HC Emissions -- FTP vs Indolene-IM240
## (62 1985-88 TBI Vehicles)
## (Tested at EPA's Ann Arbor Lab)
## Enlarged for Better Detail near Origin



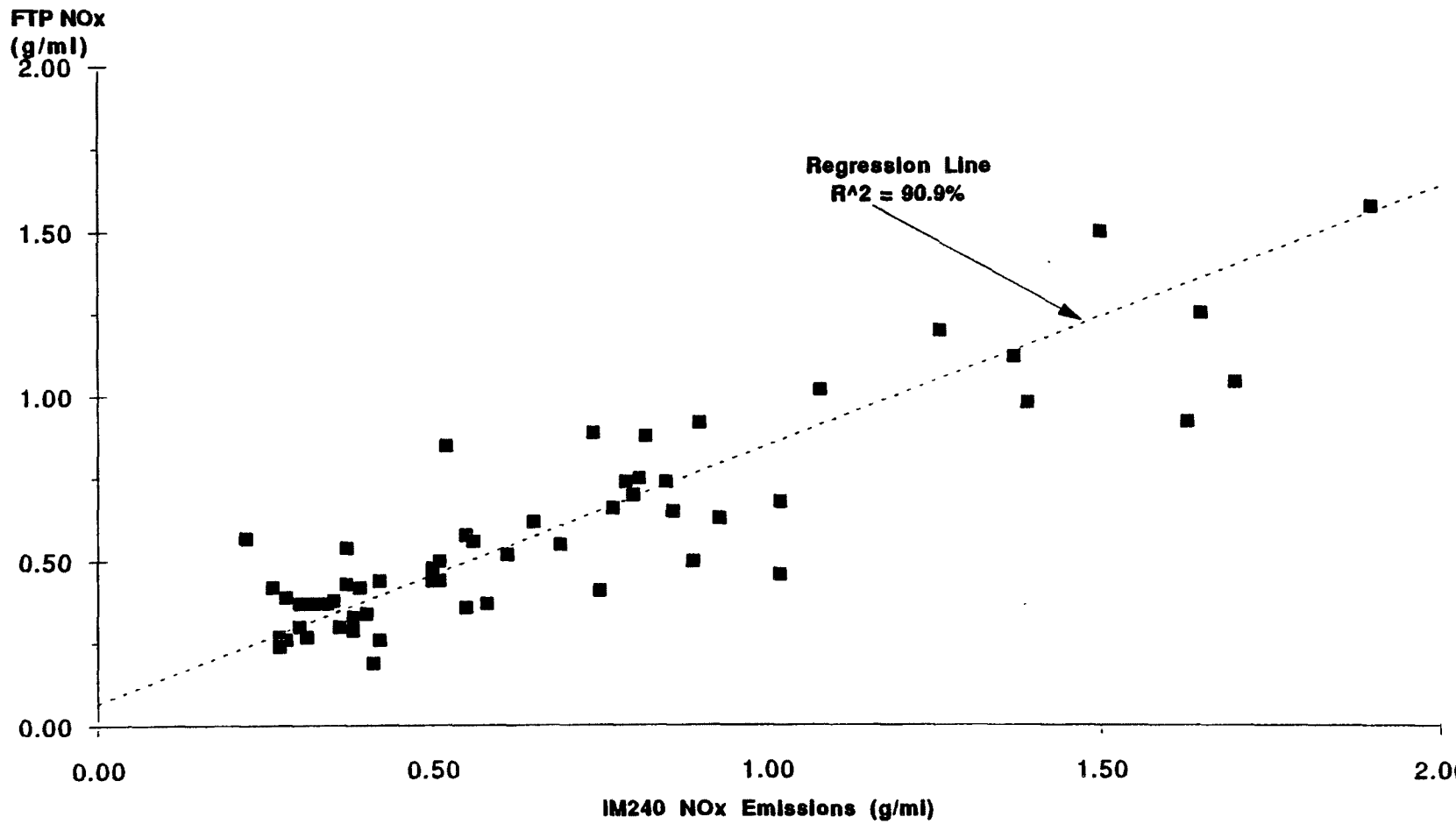

CO Emissions -- FTP vs Indolene-IM240
(62 1985-88 TBI Vehicles)
(Tested at EPA's Ann Arbor Lab)
FTP CO
(g/mi)
200.00
150.00
100.00
50.00
0.00
Regression Line
R^2 = 92.5%
0.00
50.00
100.00
150.00
200.00
IM240 CO Emissions (g/mi)

**CO Emissions -- FTP vs Indolene-IM240**
**(62 1985-88 TBI Vehicles)**
**(Tested at EPA's Ann Arbor Lab)**
**Enlarged for Better Detail near Origin**




NOx Emissions -- FTP vs Indolene-IM240
(62 1985-88 TBI Vehicles)
(Tested at EPA's Ann Arbor Lab)
FTP NOx
(g/mi)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Regression Line
R^2 = 90.9%
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
IM240 NOx Emissions (g/mi)

**NOx Emissions -- FTP vs Indolene-IM240**
**(62 1985-88 TBI Vehicles)**
**(Tested at EPA's Ann Arbor Lab)**
**Enlarged for Better Detail near Origin**



## Description of Repair Regression Analysis

### Regression Analyses

The difference in emission levels before and after repairs for the FTP's and Lab IM240's run on Indolene fuel was calculated such that a positive difference would correspond to a decrease in emissions or an increase in fuel economy. The ΔFTP values (ΔHC, ΔCO, ΔNOx and ΔMPG) were regressed against the corresponding Indolene ΔIM240 values. The results and graphs of these regressions are included.

### Data Description

The data used in this analysis consisted of FTP and Indolene IM240 scores for tests performed before and after repairs. These results consisted of HC, CO, NOx, and fuel economy values. The database was restricted to 1983 and newer PFI and TBI vehicles which received repairs and whose as received FTP scores exceeded twice the FTP standard for either HC or CO. Also excluded from the analysis were vehicles which received repairs before the as received FTP and vehicles which had differences in dynamometer settings of greater than 15%. The resulting data set contained 41 TBI vehicles and 23 PFI vehicles. Summary Statistics for the variables used in the TBI analyses follow.

## Statistical Summaries for Variables Used in TBI Before and After Regression Analyses

Summary statistics for: ΔHC.IM24
NumNumeric = 41
Mean = 1.3563
Median = 0.2200
Midrange = 7.8500
Standard Deviation = 3.4020
Range = 17.660
Minimum = -0.98000
Maximum = 16.680

Summary statistics for: ΔHC.FTP
NumNumeric = 41
Mean = 2.4634
Median = 0.3700
Midrange = 14.595
Standard Deviation = 6.0860
Range = 30.590
Minimum = -0.70000
Maximum = 29.890

Summary statistics for: ΔCO.IM24
NumNumeric = 41
Mean = 24.092
Median = 4.8800
Midrange = 84.310
Standard Deviation = 47.490
Range = 186.72
Minimum = -9.0500
Maximum = 177.67

Summary statistics for: ΔCO.FTP
NumNumeric = 41
Mean = 38.661
Median = 5.4500
Midrange = 128.11
Standard Deviation = 69.2007
Range = 265.65
Minimum = -4.7200
Maximum = 260.93

Summary statistics for: ΔNOx.IM24
NumNumeric = 41
Mean = 0.04683
Median = -0.07000
Midrange = 2.2850
Standard Deviation = 1.2167
Range = 8.3700
Minimum = -1.9000
Maximum = 6.4700

Summary statistics for: ΔNOx.FTP
NumNumeric = 41
Mean = -0.06439
Median = -0.06000
Midrange = 1.5800
Standard Deviation = 1.0174
Range = 6.8800
Minimum = -1.8600
Maximum = 5.0200

Summary statistics for: ΔMPG.IM24
NumNumeric = 41
Mean = 2.4132
Median = 1.4300
Midrange = 5.2600
Standard Deviation = 3.4721
Range = 15.420
Minimum = -2.4500
Maximum = 12.970

Summary statistics for: ΔMPG.FTP
NumNumeric = 41
Mean = 2.0820
Median = 0.97000
Midrange = 3.6850
Standard Deviation = 3.7642
Range = 21.810
Minimum = -7.2200
Maximum = 14.590

**Regression Analyses for the Change in Emission Constituents Before and After Repairs of the TBI Vehicles for the FTP vs IM240-A**

Dependent variable is: ΔHC.FTP
R^2 = 87.2%
s = 2.209 with 41 - 2 = 39 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 1291.3 | 1 | 1291 | 265 |
| Residual | 190.271 | 39 | 4.87875 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.198146 | 0.372 | 0.533 |
| ΔHC.IM24 | 1.67013 | 0.1027 | 16.3 |

Dependent variable is: ΔCO.FTP
R^2= 82.1%
s = 29.57 with 41 - 2 = 39 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 156368 | 1 | 200000 | 179 |
| Residual | 34110.7 | 39 | 874.633 | |

| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 6.94316 | 5.192 | 1.34 |
| ΔCO.IM240 | 1.31656 | 0.0985 | 13.4 |

Dependent variable is: ΔNOx.FTP
R^2 = 84.9%
s = 0.4008 with 41 - 2 = 39 degrees of freedom

| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 35.1435 | 1 | 35.14 | 219 |
| Residual | 6.26452 | 39 | 0.160629 | |

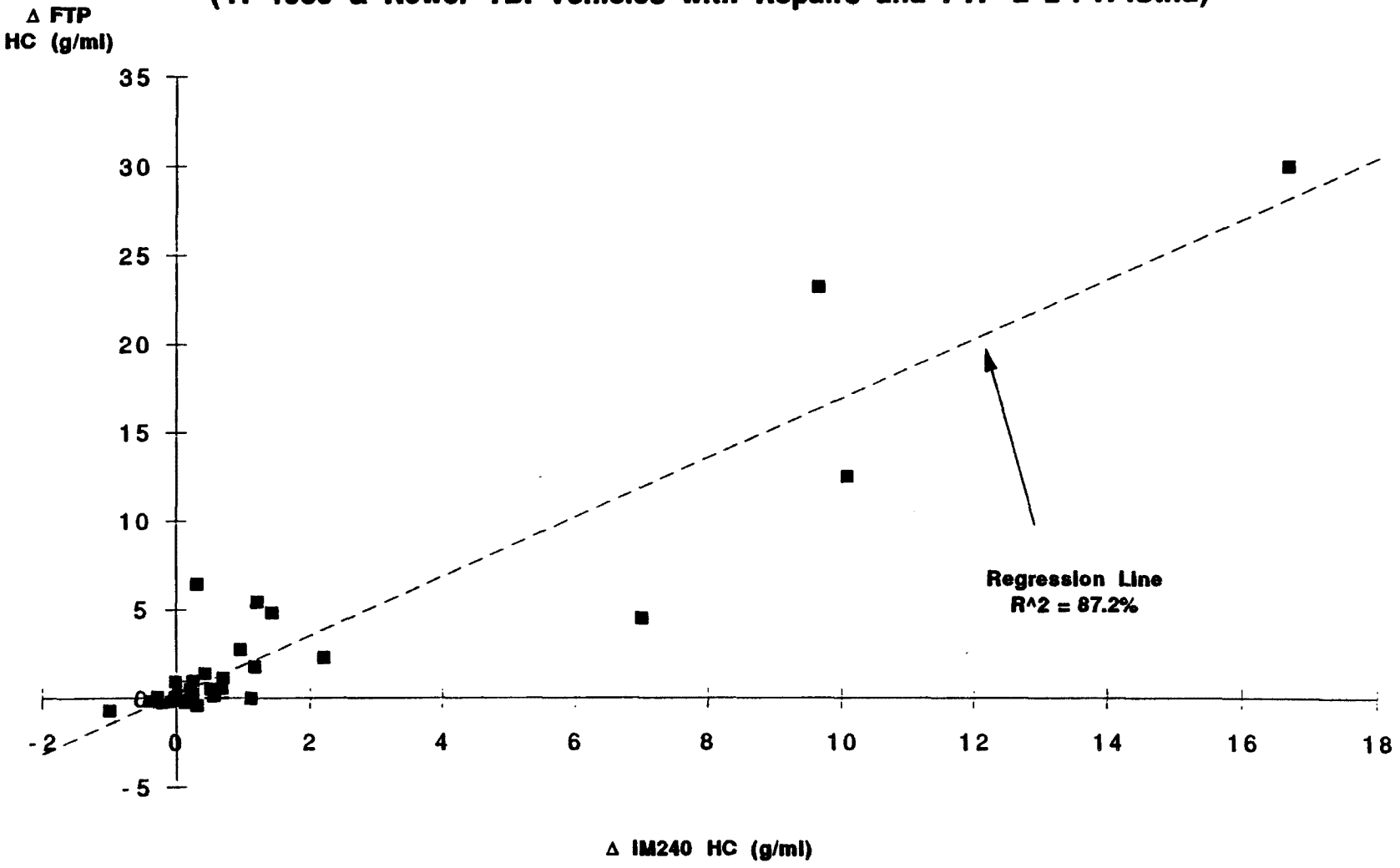
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | -0.100466 | 0.0626 | -1.6 |
| ΔNOx.IM240 | 0.770364 | 0.0521 | 14.8 |

Dependent variable is: ΔMPG.FTP
R^2 = 58.3%
s = 2.489 with 41 - 2 = 39 degrees of freedom

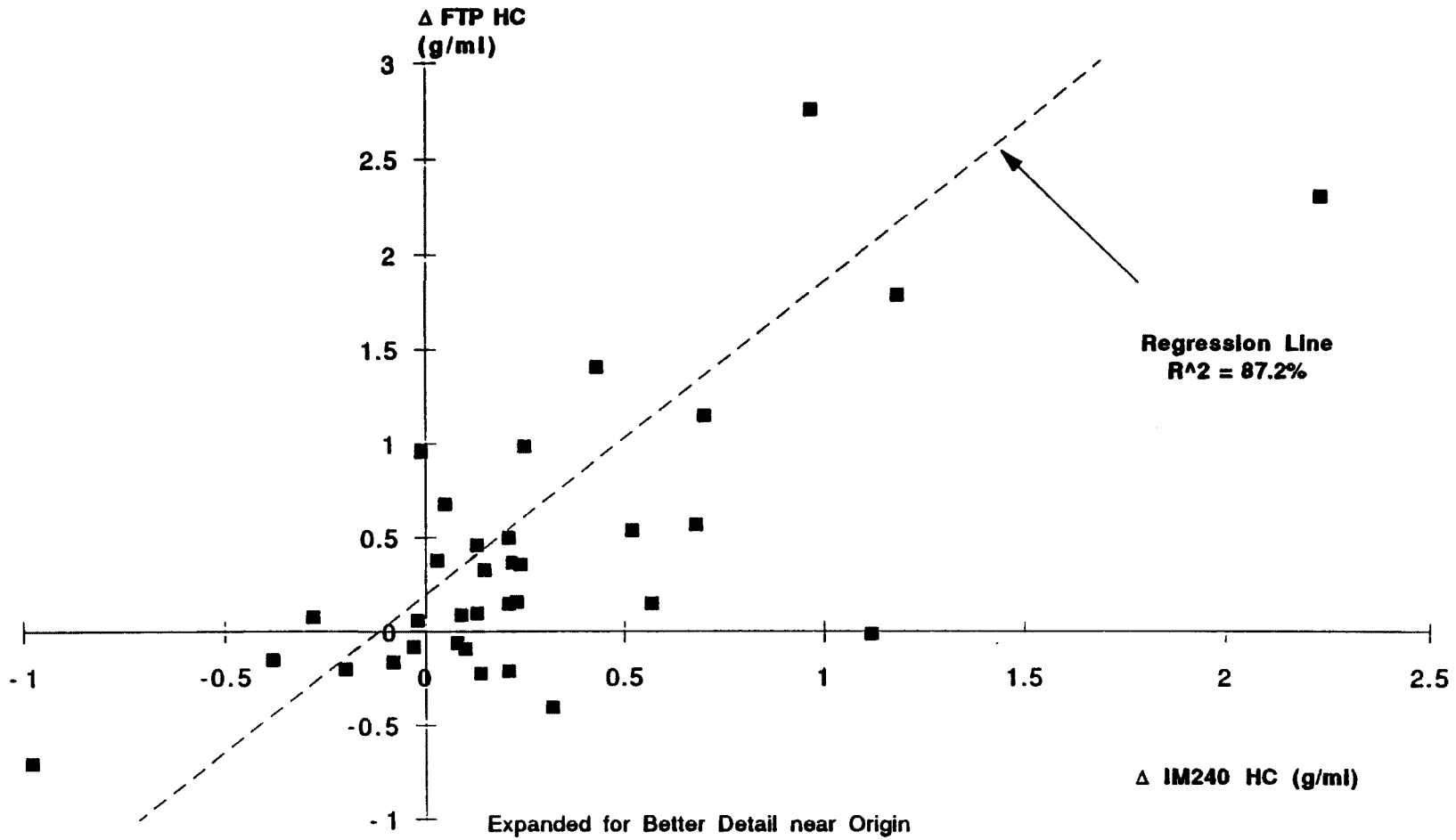
| Source | Sum of Squares | df | Mean Square | F-ratio |
|---|---|---|---|---|
| Regression | 325.213 | 1 | 325 | 52.5 |
| Residual | 241.558 | 39 | 6.19379 | |

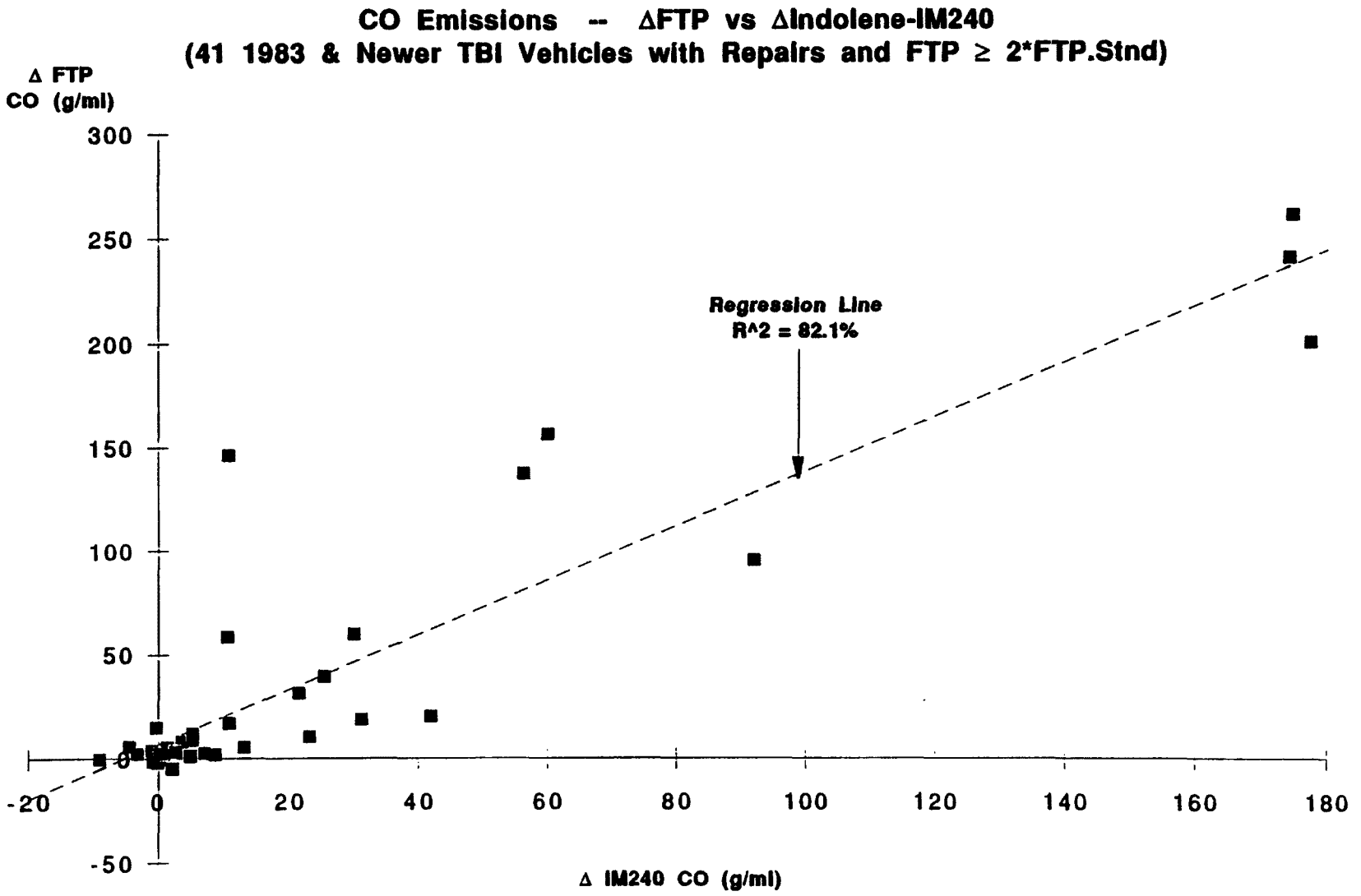
| Variable | Coefficient | s.e. of Coeff | t-ratio |
|---|---|---|---|
| Constant | 0.100224 | 0.4753 | 0.158 |
| ΔMPG.IM240 | 0.821213 | 0.1133 | 7.25 |

## HC Emissions -- ΔFTP vs ΔIndolene-IM240
## (41 1983 & Newer TBI Vehicles with Repairs and FTP ≥ 2*FTP.Stnd)

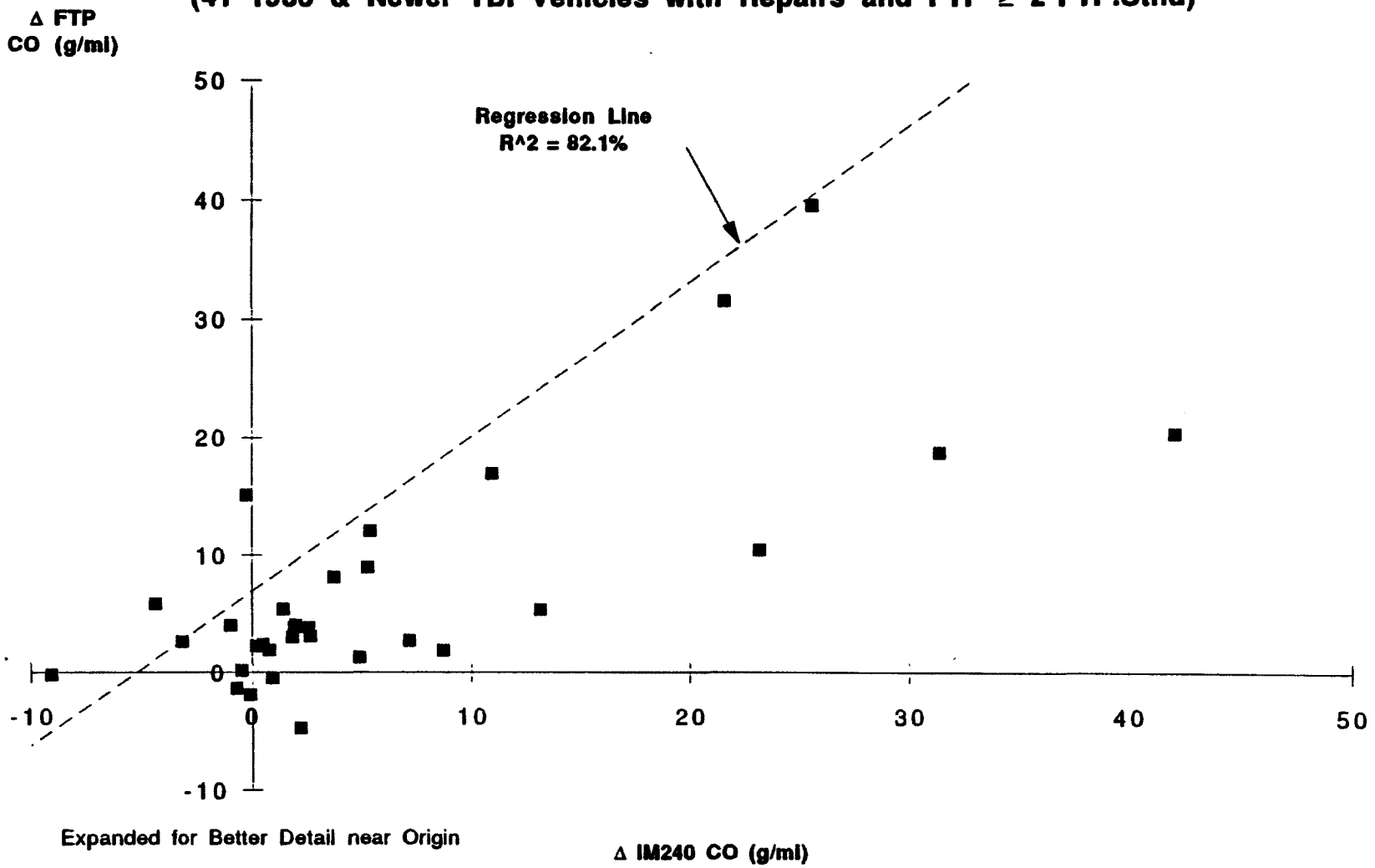


## HC Emissions -- ΔFTP vs ΔIndolene-IM240
## (41 1983 & Newer TBI Vehicles with Repairs and FTP ≥ 2*FTP.Stnd)

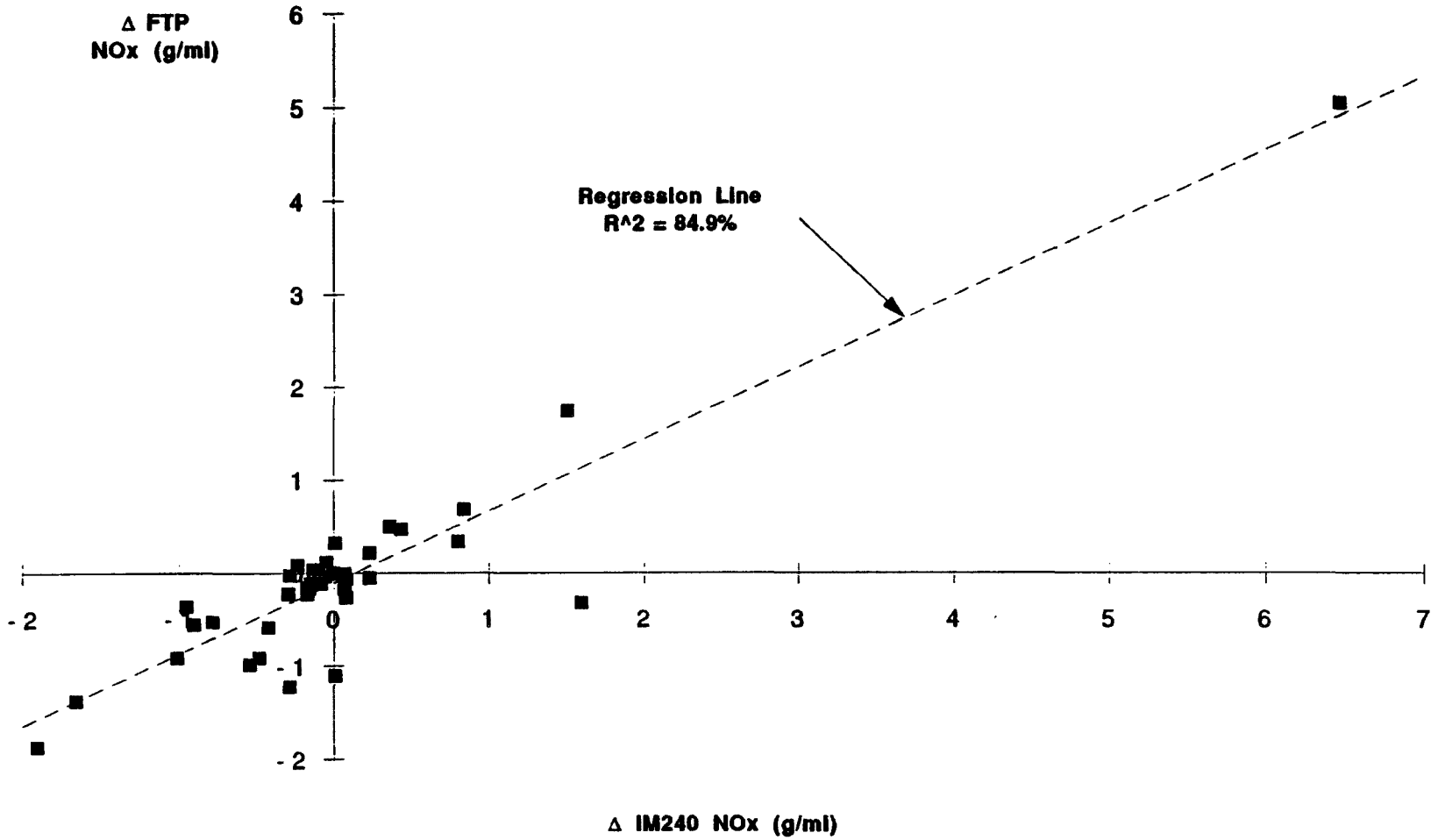



CO Emissions -- ΔFTP vs ΔIndolene-IM240
(41 1983 & Newer TBI Vehicles with Repairs and FTP ≥ 2*FTP.Stnd)
Δ FTP
CO (g/ml)
300
250
200
150
100
50
0
-50
-20
0
20
40
60
80
100
120
140
160
180
Regression Line
R^2 = 82.1%
Δ IM240 CO (g/ml)

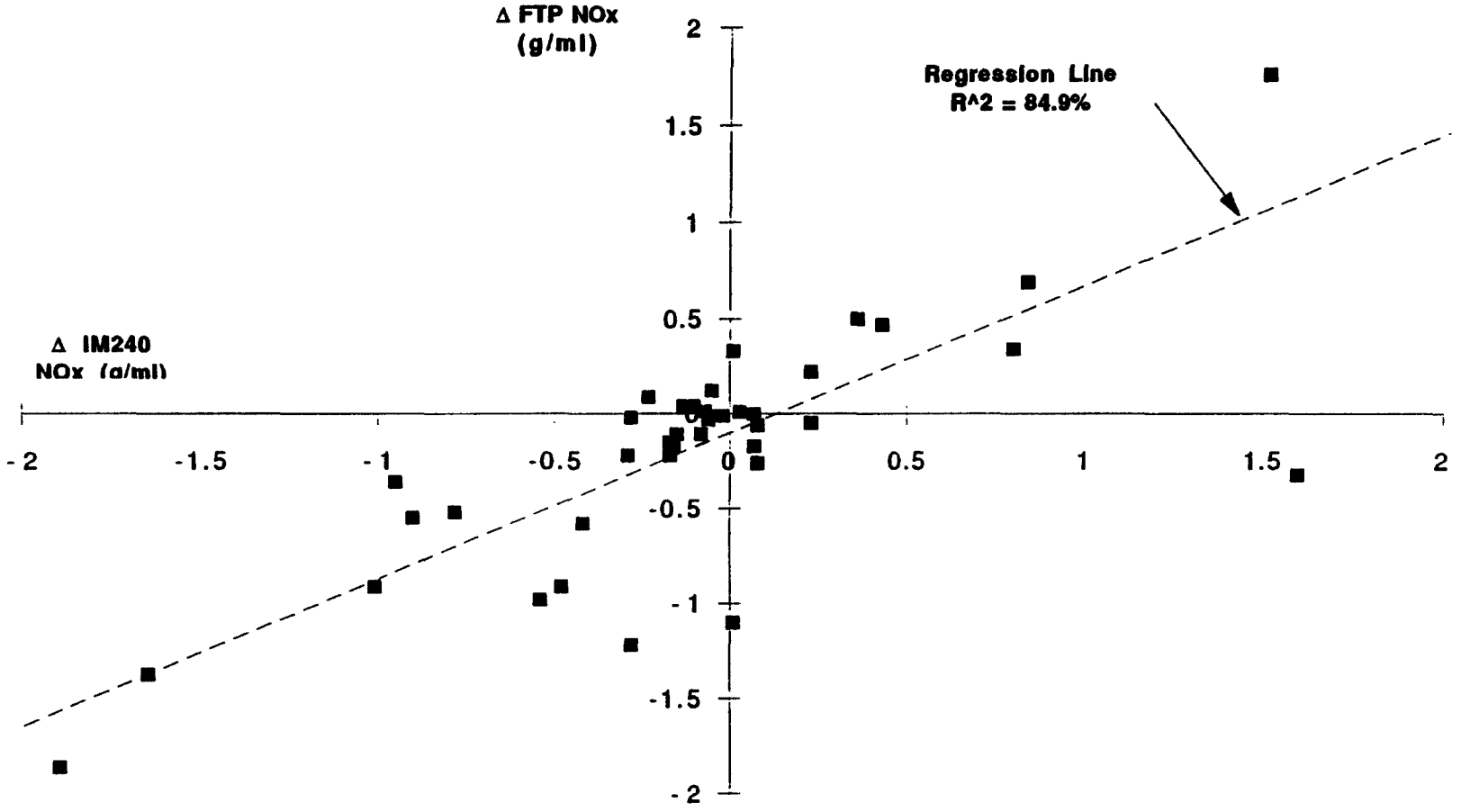
## CO Emissions -- ΔFTP vs ΔIndolene-IM240
## (41 1983 & Newer TBI Vehicles with Repairs and FTP ≥ 2*FTP.Stnd)



## NOx Emissions -- ΔFTP vs ΔIndolene-IM240
## (41 1983 & Newer TBI Vehicles with Repairs and FTP ≥ FTP.stnd)

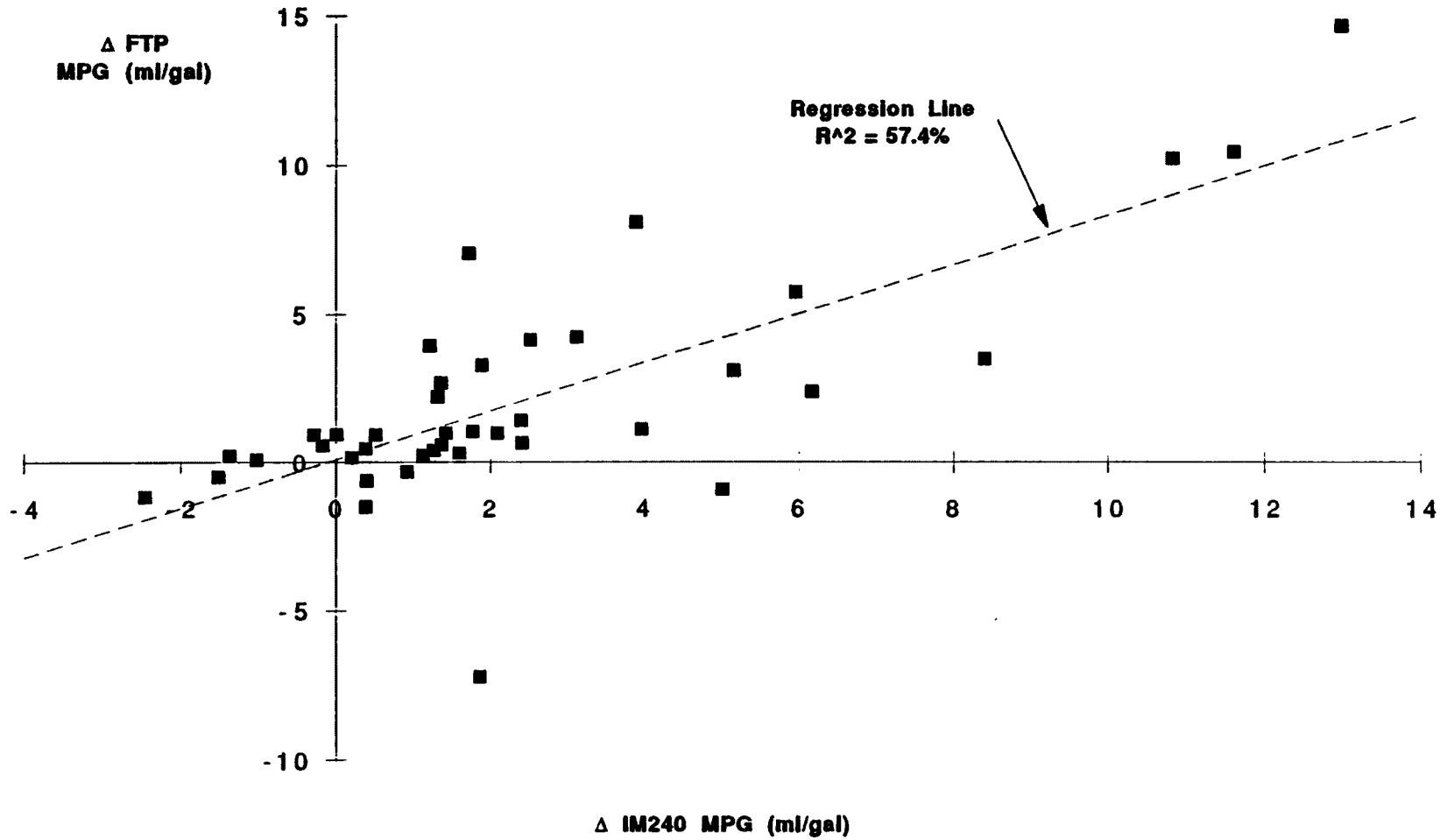


## NOx Emissions -- ΔFTP vs ΔIndolene-IM240
## (41 1983 & Newer TBI Vehicles with Repairs and FTP ≥ FTP.stnd)

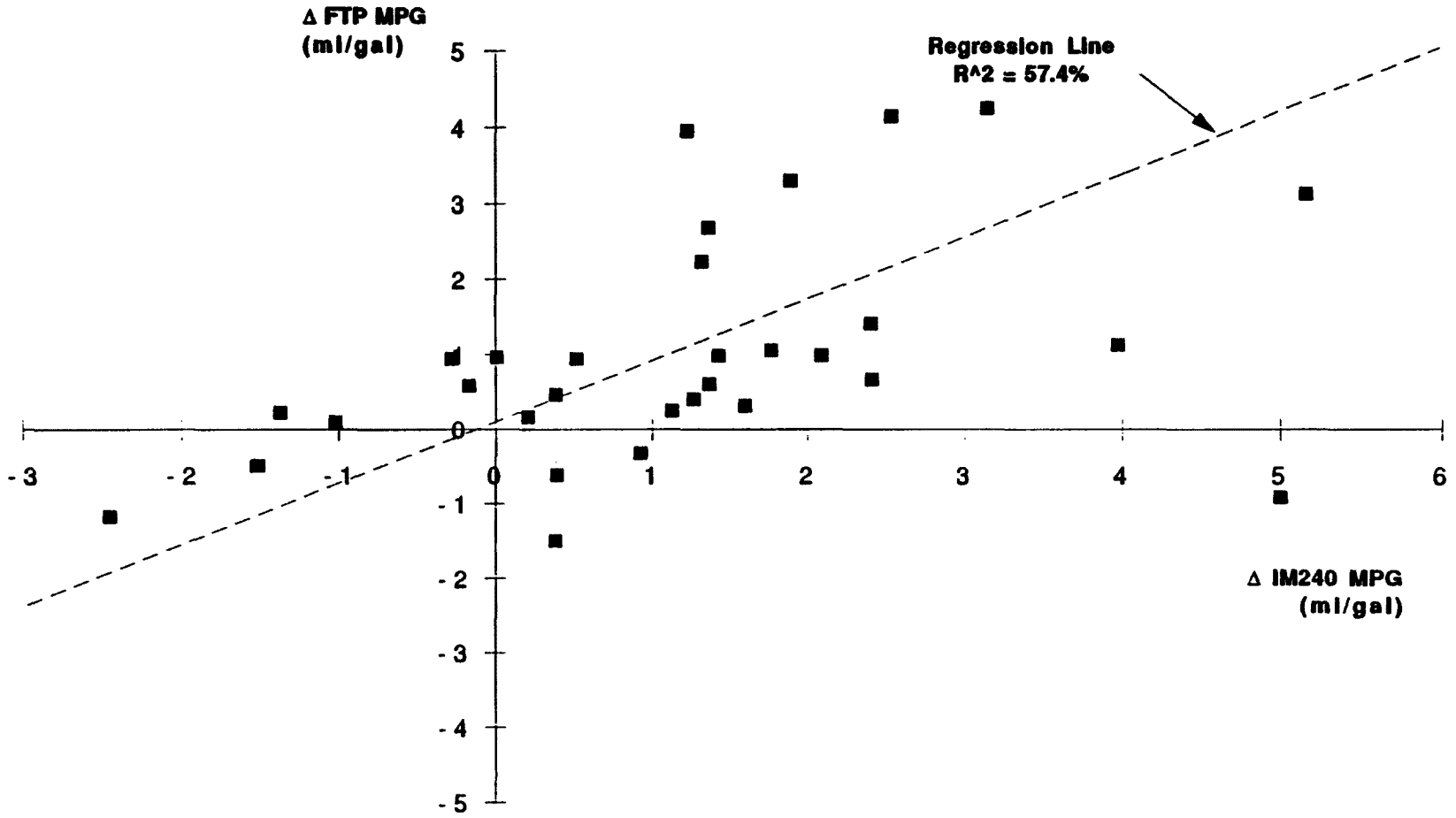



Expanded for Better Detail near Origin

## Fuel Economy -- ΔFTP vs ΔIndolene-IM240
## (41 1983 & Newer TBI Vehicles with Repairs and FTP ≥ 2*FTP.Stnd)



## Fuel Economy -- ΔFTP vs ΔIndolene-IM240
## (41 1983 & Newer TBI Vehicles with Repairs and FTP ≥ 2*FTP.Stnd)




Expanded for Better Detail near Origin

# APPENDIX F

## MOBILE4.1 TECHNOLOGY DISTRIBUTION AND EMISSION GROUP RATES AND EMISSION LEVELS

## MOBILE4.1
## Technology Distribution for Gasoline Passenger Cars

| Model Year | CLLP 3way Carb | CLLP 3way MPFI | CLLP 3way TBI | Oplp 3way Carb | Oplp 3way MPFI | Oplp 3way TBI | CLLP Ox3way Carb | CLLP Ox3way MPFI | CLLP Ox3way TBI | Oplp Ox3way Carb | Oplp Ox3way MPFI | Oplp Ox3way TBI | Oplp Oxid | Oplp None | All | GM FI | % GM FI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | 1571360 | 413972 | 0 | 48896 | 0 | 0 | 2731528 | 1434 | 201346 | 932653 | 284 | 0 | 943390 | 38 | 6844901 | 133369 | 1.9% |
| 1982 | 1040449 | 403436 | 435887 | 54160 | 0 | 0 | 2265172 | 0 | 258479 | 1181258 | 0 | 0 | 889494 | 10 | 6528339 | 636022 | 9.7% |
| 1983 | 151414 | 591266 | 794934 | 0 | 0 | 0 | 3211332 | 15517 | 471542 | 870343 | 409 | 0 | 817824 | 0 | 6924581 | 831142 | 12.0% |
| 1984 | 761159 | 938060 | 1414498 | 25877 | 0 | 0 | 4140952 | 40669 | 1091249 | 488429 | 0 | 0 | 0 | 0 | 8900893 | 1444036 | 16.2% |
| 1985 | 966873 | 2182617 | 432479 | 25478 | 0 | 0 | 2085078 | 116557 | 1125292 | 547055 | 0 | 0 | 0 | 0 | 7481429 | 1644484 | 22.0% |
| 1986 | 594368 | 2607047 | 1058186 | 50 | 0 | 150047 | 1936299 | 504156 | 1041046 | 40209 | 0 | 0 | 0 | 0 | 7931408 | 2087185 | 26.3% |
| 1987 | 415441 | 2239841 | 1397261 | 16821 | 64 | 41918 | 1188253 | 156340 | 942058 | 48809 | 650 | 0 | 0 | 0 | 6447456 | 1673716 | 26.0% |
| 1988 | 277445 | 2998983 | 2206819 | 0 | 65 | 0 | 404916 | 322283 | 542380 | 0 | 0 | 0 | 0 | 0 | 6752891 | 2420729 | 35.8% |
| 1989 | 613700 | 4652439 | 2034135 | 0 | 90 | 0 | 449631 | 431553 | 308598 | 25000 | 0 | 0 | 0 | 0 | 8515146 | 3018191 | 35.4% |
| 1990 | 10800 | 5177046 | 1395418 | 0 | 0 | 0 | 122142 | 311612 | 186117 | 7000 | 0 | 0 | 0 | 0 | 7210135 | 2522963 | 35.0% |
| 1991 | 9000 | 6419242 | 1570776 | 0 | 0 | 0 | 15690 | 176552 | 103342 | 0 | 0 | 0 | 0 | 0 | 8294602 | 3639046 | 43.9% |

| Model Year | CLLP 3way Carb | CLLP 3way MPFI | CLLP 3way TBI | Oplp 3way Carb | Oplp 3way MPFI | Oplp 3way TBI | CLLP Ox3way Carb | CLLP Ox3way MPFI | CLLP Ox3way TBI | Oplp Ox3way Carb | Oplp Ox3way MPFI | Oplp Ox3way TBI | Oplp Oxid | Oplp None |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981 | 23.0% | 6.0% | 0.0% | 0.7% | 0.0% | 0.0% | 39.9% | 0.0% | 2.9% | 13.6% | 0.0% | 0.0% | 13.8% | 0.0% |
| 1982 | 15.9% | 6.2% | 6.7% | 0.8% | 0.0% | 0.0% | 34.7% | 0.0% | 4.0% | 18.1% | 0.0% | 0.0% | 13.6% | 0.0% |
| 1983 | 2.2% | 8.5% | 11.5% | 0.0% | 0.0% | 0.0% | 46.4% | 0.2% | 6.8% | 12.6% | 0.0% | 0.0% | 11.8% | 0.0% |
| 1984 | 8.6% | 10.5% | 15.9% | 0.3% | 0.0% | 0.0% | 46.5% | 0.5% | 12.3% | 5.5% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1985 | 12.9% | 29.2% | 5.8% | 0.3% | 0.0% | 0.0% | 27.9% | 1.6% | 15.0% | 7.3% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1986 | 7.5% | 32.9% | 13.3% | 0.0% | 0.0% | 1.9% | 24.4% | 6.4% | 13.1% | 0.5% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1987 | 6.4% | 34.7% | 21.7% | 0.3% | 0.0% | 0.7% | 18.4% | 2.4% | 14.6% | 0.8% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1988 | 4.1% | 44.4% | 32.7% | 0.0% | 0.0% | 0.0% | 6.0% | 4.8% | 8.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1989 | 7.2% | 54.6% | 23.9% | 0.0% | 0.0% | 0.0% | 5.3% | 5.1% | 3.6% | 0.3% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1990 | 0.1% | 71.8% | 19.4% | 0.0% | 0.0% | 0.0% | 1.7% | 4.3% | 2.6% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% |
| 1991 | 0.1% | 77.4% | 18.9% | 0.0% | 0.0% | 0.0% | 0.2% | 2.1% | 1.2% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |

| Model Year | CLLP Carb | CLLP MPFI | CLLP TBI | Oplp Any |
|---|---|---|---|---|
| 1981 | 62.9% | 6.1% | 2.9% | 28.1% |
| 1982 | 50.6% | 6.2% | 10.6% | 32.5% |
| 1983 | 48.6% | 8.8% | 18.3% | 24.4% |
| 1984 | 55.1% | 11.0% | 28.2% | 5.8% |
| 1985 | 40.8% | 30.7% | 20.8% | 7.7% |
| 1986 | 31.9% | 39.2% | 26.5% | 2.4% |
| 1987 | 24.9% | 37.2% | 36.3% | 1.7% |
| 1988 | 10.1% | 49.2% | 40.7% | 0.0% |
| 1989 | 12.5% | 59.7% | 27.5% | 0.3% |
| 1990 | 1.8% | 76.1% | 21.9% | 0.1% |
| 1991 | 0.3% | 79.5% | 20.2% | 0.0% |

| Model Year | Any Carb | Any MPFI | Any TBI |
|---|---|---|---|
| 1981 | 91.0% | 6.1% | 2.9% |
| 1982 | 83.2% | 6.2% | 10.6% |
| 1983 | 72.9% | 8.8% | 18.3% |
| 1984 | 60.9% | 11.0% | 28.2% |
| 1985 | 48.4% | 30.7% | 20.8% |
| 1986 | 32.4% | 39.2% | 28.4% |
| 1987 | 25.9% | 37.2% | 36.9% |
| 1988 | 10.1% | 49.2% | 40.7% |
| 1989 | 12.8% | 59.7% | 27.5% |
| 1990 | 1.9% | 76.1% | 21.9% |
| 1991 | 0.3% | 79.5% | 20.2% |

| Model Year | Any 3way | Any Ox3way | Any Oxid |
|---|---|---|---|
| 1981 | 29.7% | 56.5% | 13.8% |
| 1982 | 29.6% | 56.8% | 13.6% |
| 1983 | 22.2% | 66.0% | 11.8% |
| 1984 | 35.3% | 64.7% | 0.0% |
| 1985 | 48.2% | 51.8% | 0.0% |
| 1986 | 55.6% | 44.4% | 0.0% |
| 1987 | 63.8% | 36.2% | 0.0% |
| 1988 | 81.2% | 18.8% | 0.0% |
| 1989 | 85.7% | 14.3% | 0.0% |
| 1990 | 91.3% | 8.7% | 0.0% |
| 1991 | 96.4% | 3.6% | 0.0% |

All vehicle counts taken from CAFE estimates, except 1989 and newer model years, which are from General Label predictions.

# MOBILE4.1

## Emitter Group Emission Levels*

| Model Year Group | Emission Level Group | Technology Group | HC ZML | HC DET | HC Emissions at 50,000 Miles | HC Emissions at 100,000 Miles | CO ZML | CO DET | CO Emissions at 50,000 Miles | CO Emissions at 100,000 Miles | NOx ZML | NOx DET | NOx Emissions at 50,000 Miles | NOx Emissions at 100,000 Miles |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1981-82 | Normal | MPFI | 0.188 | 0.0450 | 0.413 | 0.638 | 1.548 | 0.5807 | 4.452 | 7.355 | 0.380 | 0.1280 | 1.020 | 1.660 |
| 1981-82 | Normal | TBI | 0.279 | 0.0161 | 0.360 | 0.440 | 3.422 | 0.2520 | 4.682 | 5.942 | 0.545 | 0.1414 | 1.252 | 1.959 |
| 1981-82 | Normal | Carb | 0.288 | 0.0253 | 0.415 | 0.541 | 3.067 | 0.3281 | 4.708 | 6.348 | 0.678 | 0.0696 | 1.026 | 1.374 |
| 1981-82 | Normal | Oplp | 0.306 | 0.0230 | 0.421 | 0.536 | 3.368 | 0.2877 | 4.807 | 6.245 | 0.649 | 0.0440 | 0.869 | 1.089 |
| 1983-85 | Normal | MPFI | 0.269 | 0.0115 | 0.327 | 0.384 | 2.598 | 0.1554 | 3.375 | 4.152 | 0.689 | 0.0185 | 0.782 | 0.874 |
| 1983-85 | Normal | TBI | 0.242 | 0.0134 | 0.309 | 0.376 | 2.953 | 0.1572 | 3.739 | 4.525 | 0.585 | 0.0470 | 0.820 | 1.055 |
| 1983-85 | Normal | Carb | 0.222 | 0.0199 | 0.322 | 0.421 | 2.209 | 0.2282 | 3.350 | 4.491 | 0.692 | 0.0558 | 0.971 | 1.250 |
| 1983-85 | Normal | Oplp | 0.334 | 0.0248 | 0.458 | 0.582 | 4.093 | 0.2093 | 5.140 | 6.186 | 0.524 | 0.0540 | 0.794 | 1.064 |
| 1986+ | Normal | MPFI | 0.269 | 0.0115 | 0.327 | 0.384 | 2.598 | 0.1554 | 3.375 | 4.152 | 0.539 | 0.0185 | 0.632 | 0.724 |
| 1986+ | Normal | TBI | 0.242 | 0.0134 | 0.309 | 0.376 | 2.953 | 0.1572 | 3.739 | 4.525 | 0.316 | 0.0470 | 0.551 | 0.786 |
| 1986+ | Normal | Carb | 0.222 | 0.0199 | 0.322 | 0.421 | 2.209 | 0.2282 | 3.350 | 4.491 | 0.478 | 0.0558 | 0.757 | 1.036 |
| 1986+ | Normal | Oplp | 0.334 | 0.0248 | 0.458 | 0.582 | 4.093 | 0.2093 | 5.140 | 6.186 | 0.524 | 0.0540 | 0.794 | 1.064 |
| 1981-82 | High | MPFI | 0.374 | 0.0450 | 0.599 | 0.824 | 3.879 | 0.5807 | 6.783 | 9.686 | | | | |
| 1981-82 | High | TBI | 0.758 | 0.0161 | 0.839 | 0.919 | 6.843 | 0.2520 | 8.103 | 9.363 | | | | |
| 1981-82 | High | Carb | 0.781 | 0.0253 | 0.908 | 1.034 | 8.496 | 0.3281 | 10.137 | 11.777 | | | | |
| 1981-82 | High | Oplp | 0.757 | 0.0230 | 0.872 | 0.987 | 8.142 | 0.2877 | 9.581 | 11.019 | | | | |
| 1983+ | High | MPFI | 0.997 | 0.0115 | 1.055 | 1.112 | 7.602 | 0.1554 | 8.379 | 9.156 | | | | |
| 1983+ | High | TBI | 0.762 | 0.0134 | 0.829 | 0.896 | 8.620 | 0.1572 | 9.606 | 10.392 | | | | |
| 1983+ | High | Carb | 0.703 | 0.0199 | 0.803 | 0.902 | 8.577 | 0.2282 | 9.718 | 10.859 | | | | |
| 1983+ | High | Oplp | 0.840 | 0.0248 | 0.964 | 1.088 | 8.386 | 0.2093 | 9.433 | 10.479 | | | | |
| 1981-82 | Very High | MPFI | 0.606 | 0.0450 | 0.831 | 1.056 | 18.049 | 0.5807 | 20.953 | 23.856 | | | | |
| 1981-82 | Very High | TBI | 1.163 | 0.0161 | 1.244 | 1.324 | 22.059 | 0.2520 | 23.319 | 24.579 | | | | |
| 1981-82 | Very High | Carb | 1.950 | 0.0253 | 2.077 | 2.203 | 33.396 | 0.3281 | 35.037 | 36.677 | | | | |
| 1981-82 | Very High | Oplp | 1.589 | 0.0230 | 1.704 | 1.819 | 27.650 | 0.2877 | 29.089 | 30.527 | | | | |
| 1983+ | Very High | MPFI | 2.019 | 0.0115 | 2.077 | 2.134 | 22.301 | 0.1554 | 23.078 | 23.855 | | | | |
| 1983+ | Very High | TBI | 2.242 | 0.0134 | 2.309 | 2.376 | 44.416 | 0.1572 | 45.202 | 45.988 | | | | |
| 1983+ | Very High | Carb | 2.002 | 0.0199 | 2.102 | 2.201 | 36.130 | 0.2282 | 37.271 | 38.412 | | | | |
| 1983+ | Very High | Oplp | 1.352 | 0.0248 | 1.476 | 1.600 | 34.021 | 0.2093 | 35.068 | 36.114 | | | | |
| 1981-82 | Super | MPFI | 15.259 | N/A | 15.259 | 15.259 | 173.840 | N/A | 173.840 | 173.840 | | | | |
| 1981-82 | Super | TBI | 15.259 | N/A | 15.259 | 15.259 | 173.840 | N/A | 173.840 | 173.840 | | | | |
| 1981-82 | Super | Carb | 15.259 | N/A | 15.259 | 15.259 | 173.840 | N/A | 173.840 | 173.840 | | | | |
| 1981-82 | Super | Oplp | 0.000 | N/A | 0.000 | 0.000 | 0.000 | N/A | 0.000 | 0.000 | | | | |
| 1983+ | Super | MPFI | 11.123 | N/A | 11.123 | 11.123 | 189.000 | N/A | 189.000 | 189.000 | | | | |
| 1983+ | Super | TBI | 18.083 | N/A | 18.083 | 18.083 | 183.590 | N/A | 183.590 | 183.590 | | | | |
| 1983+ | Super | Carb | 12.870 | N/A | 12.870 | 12.870 | 246.850 | N/A | 246.850 | 246.850 | | | | |
| 1983+ | Super | Oplp | 0.000 | N/A | 0.000 | 0.000 | 0.000 | N/A | 0.000 | 0.000 | | | | |

* All emission levels in grams per mile. DET in grams per mile per 10,000 miles.

# MOBILE4.1

## Emitter Group Rates

| Model Year Group | Emission Level Group | Technology Group | Growth Rate per 10,000 Miles | Rate Increase Beyond 50,000 Miles | Percent at 50,000 Miles | Percent at 100,000 Miles |
|---|---|---|---|---|---|---|
| 1981-82 | Normal | MPFI | N/A | N/A | 85.8% | 29.9% |
| 1981-82 | Normal | TBI | N/A | N/A | 89.5% | 37.2% |
| 1981-82 | Normal | Carb | N/A | N/A | 66.4% | 33.3% |
| 1981-82 | Normal | Opip | N/A | N/A | 68.8% | 37.7% |
| 1983+ | Normal | MPFI | N/A | N/A | 90.3% | 65.0% |
| 1983+ | Normal | TBI | N/A | N/A | 87.0% | 45.5% |
| 1983+ | Normal | Carb | N/A | N/A | 84.6% | 60.0% |
| 1983+ | Normal | Opip | N/A | N/A | 91.3% | 82.7% |
| 1981-82 | High | MPFI | 0.0065 | 13.8353 | 3.3% | 48.2% |
| 1981-82 | High | TBI | 0.0065 | 13.8353 | 3.3% | 48.2% |
| 1981-82 | High | Carb | 0.0270 | 0.9643 | 13.5% | 26.5% |
| 1981-82 | High | Opip | 0.0270 | 1.0000 | 13.5% | 27.0% |
| 1983+ | High | MPFI | 0.0090 | 4.4709 | 4.5% | 24.6% |
| 1983+ | High | TBI | 0.0040 | 15.2076 | 2.0% | 32.4% |
| 1983+ | High | Carb | 0.0140 | 2.3200 | 7.0% | 23.2% |
| 1983+ | High | Opip | 0.0130 | 1.0000 | 6.5% | 13.0% |
| 1981-82 | Very High | MPFI | 0.01933 | N/A | 9.7% | 19.3% |
| 1981-82 | Very High | TBI | 0.01198 | N/A | 6.0% | 12.0% |
| 1981-82 | Very High | Carb | 0.03762 | N/A | 18.8% | 37.6% |
| 1981-82 | Very High | Opip | 0.03530 | N/A | 17.7% | 35.3% |
| 1983+ | Very High | MPFI | 0.00840 | N/A | 4.2% | 8.4% |
| 1983+ | Very High | TBI | 0.02012 | N/A | 10.1% | 20.1% |
| 1983+ | Very High | Carb | 0.01487 | N/A | 7.4% | 14.9% |
| 1983+ | Very High | Opip | 0.00433 | N/A | 2.2% | 4.3% |
| 1981-82 | Super | MPFI | 0.00257 | N/A | 1.3% | 2.6% |
| 1981-82 | Super | TBI | 0.00257 | N/A | 1.3% | 2.6% |
| 1981-82 | Super | Carb | 0.00257 | N/A | 1.3% | 2.6% |
| 1981-82 | Super | Opip | 0.00000 | N/A | 0.0% | 0.0% |
| 1983+ | Super | MPFI | 0.00194 | N/A | 1.0% | 1.9% |
| 1983+ | Super | TBI | 0.00194 | N/A | 1.0% | 1.9% |
| 1983+ | Super | Carb | 0.00194 | N/A | 1.0% | 1.9% |
| 1983+ | Super | Opip | 0.00000 | N/A | 0.0% | 0.0% |

# APPENDIX G

## EXHAUST SHORT TEST ACCURACY: IM240 VS. SECOND-CHANCE

## 2500 RPM/IDLE TEST


PFI p. G-2

TBI p. G-5

CARB p. G-8

**Special Note On Appendix G:**

Appendix G shows the accuracy of the IM240 test when a vehicle is failed only if its composite emissions exceed 0.8 g/mi HC or 15 g/mi CO and its Bag 2 emissions alone exceed 0.5 g/mi HC or 12 g/mi CO. In other words, a vehicle can pass by having low emissions in Bag 2 even if Bag 1 emissions were very high. EPA has found that this prevents inappropriately failing clean cars with no sacrifice in identifyimg dirty cars. For this reason, EPA is proposing this approach to IM240 cutpoints.

Please note that second chance Idle/2500 tests were performed on 1983 and newer vehicles only, and therefore were not available for the 1981 and 1982 carbureted vehicles used to construct these charts. In all cases, when a second chance Idle/2500 test was available, the better test was used.

Figure 1
Comparison of IM240 to Second Chance 2500/Idle for
1983 & Newer Port Fuel Injected Vehicles from Hammond Indiana
IM240 Cutpoints = 0.8 & 15 g/mi Composite and 0.5 &12 g/mi Bag 2
Second Chance 2500/Idle Ctpts = 220 ppm & 1.2%

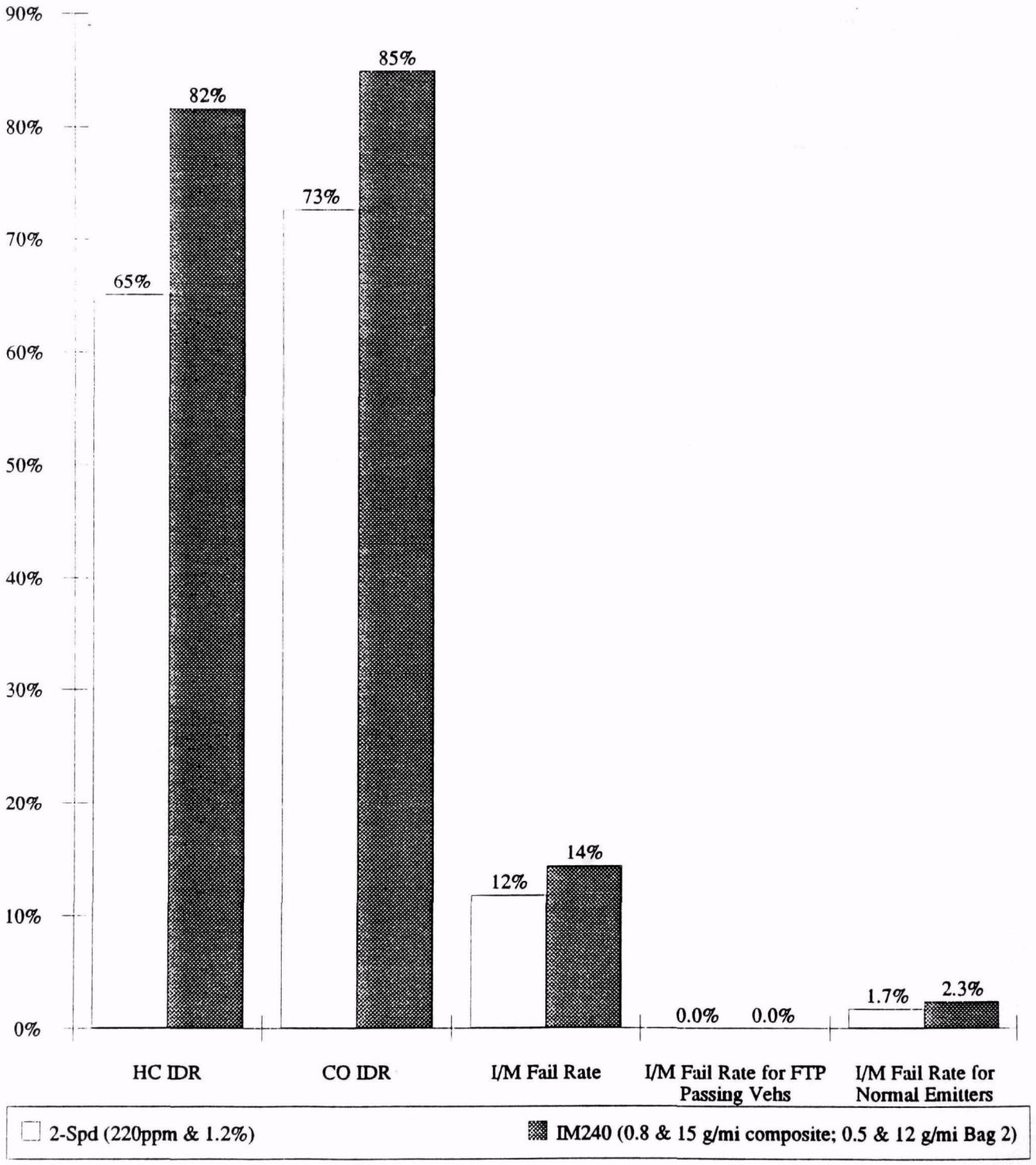


Figure 2
Comparison of IM240 to Second Chance 2500/Idle for
1983 & Newer PFI Vehicles from Hammond Indiana
IM240 Cutpoints = 0.8 & 15 g/mi Composite; 0.5 & 12 g/mi Bag 2
Second Chance 2500/Idle Ctpts = 220 ppm & 1.2% @2500; 100 ppm & 1.0% @Idle

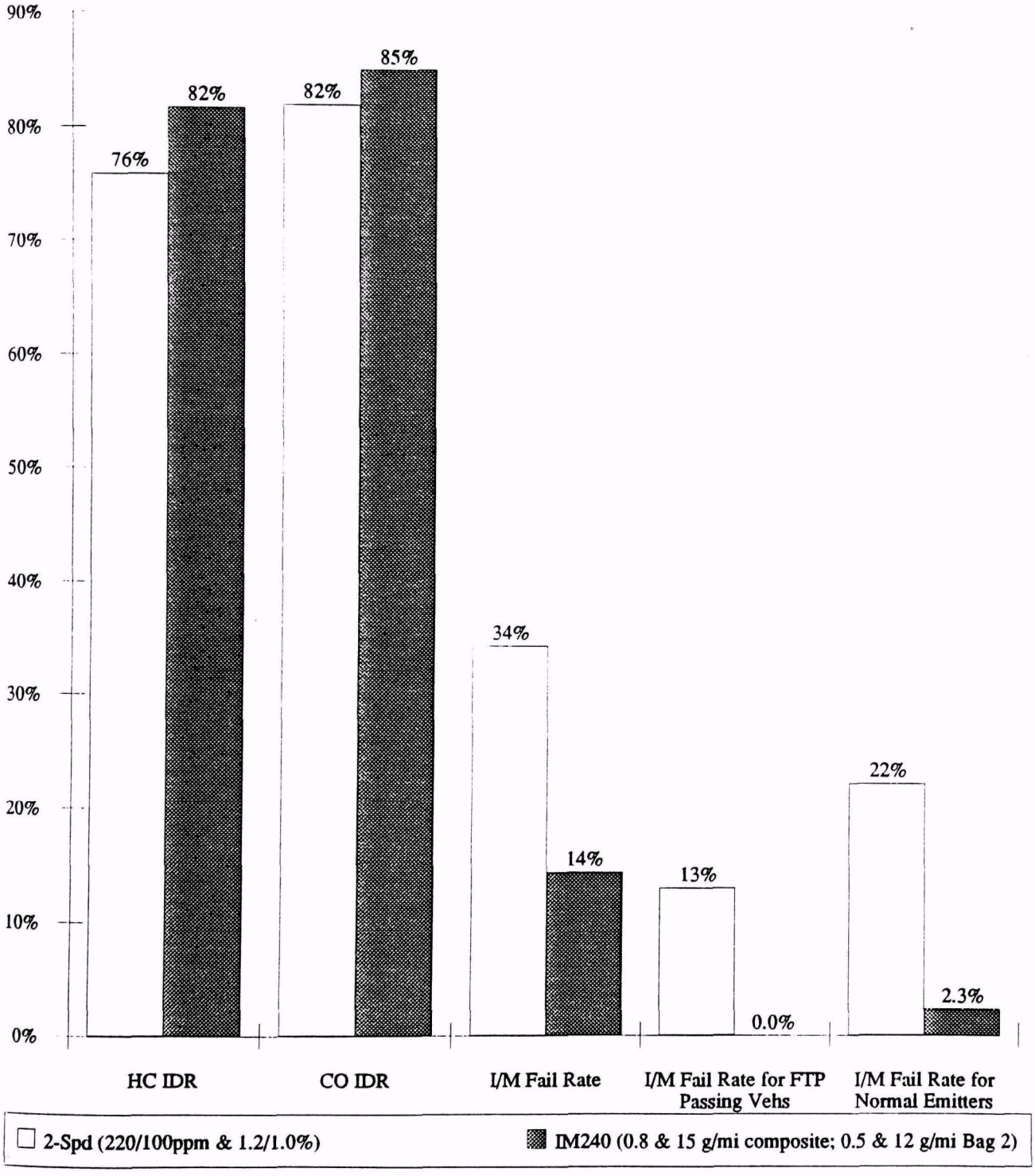


Figure 3
Comparison of IM240 to Second Chance 2500/Idle for
1983 & Newer Port Fuel Injected Vehicles from Hammond Indiana
IM240 Cutpoints = 0.8 & 15 g/mi Composite; 0.5 &12 g/mi Bag 2
Second Chance 2500/Idle Ctpts = 100 ppm & 0.5% both modes

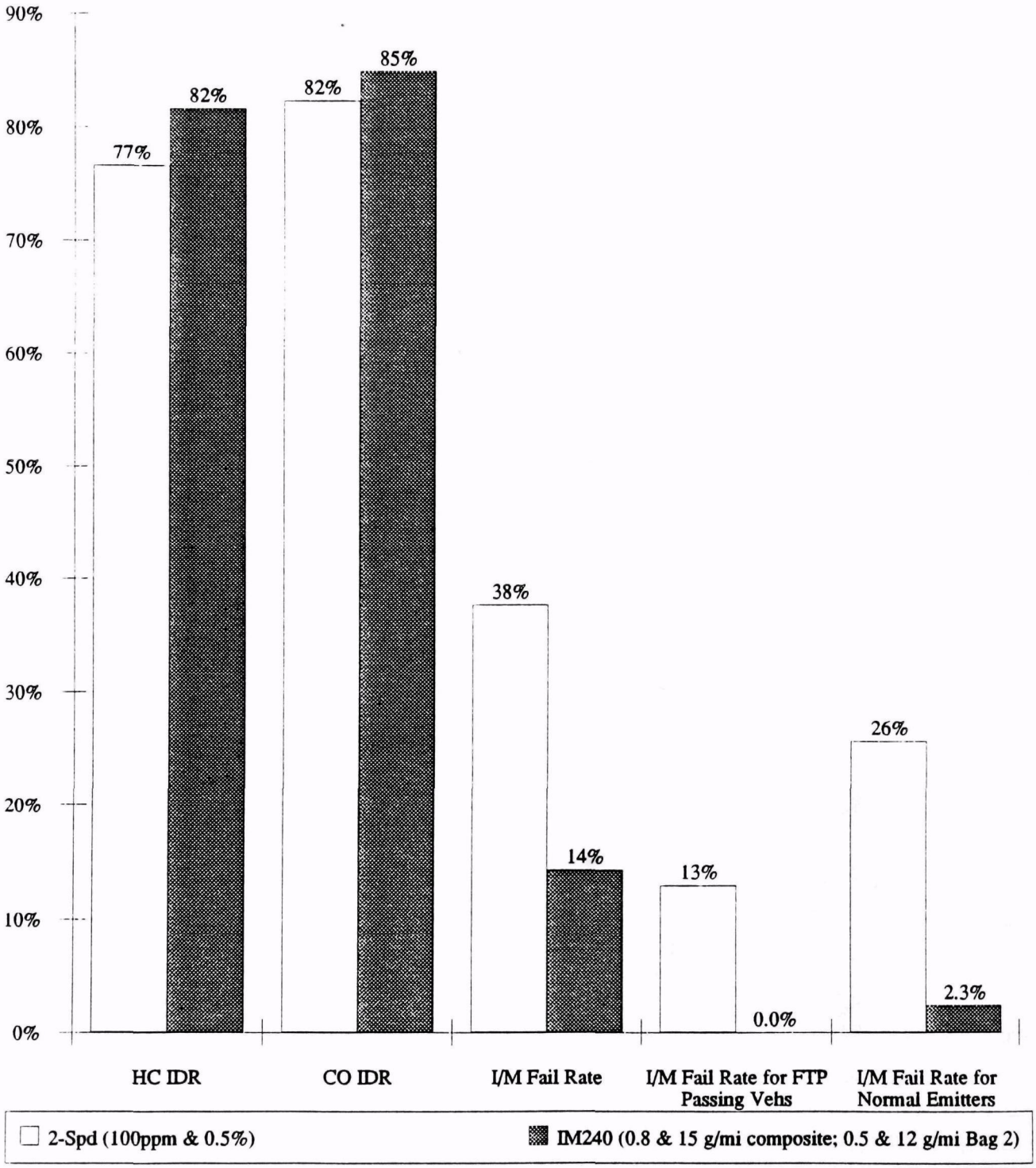


Figure 4
Comparison of IM240 to Second Chance 2500/Idle for
1983 & Newer Throttle Body Injected Vehicles from Hammond Indiana
IM240 Cutpoints = 0.8 & 15 g/mi Composite; 0.5 &12 g/mi Bag 2
Second Chance 2500/Idle Ctpts = 220 ppm & 1.2%

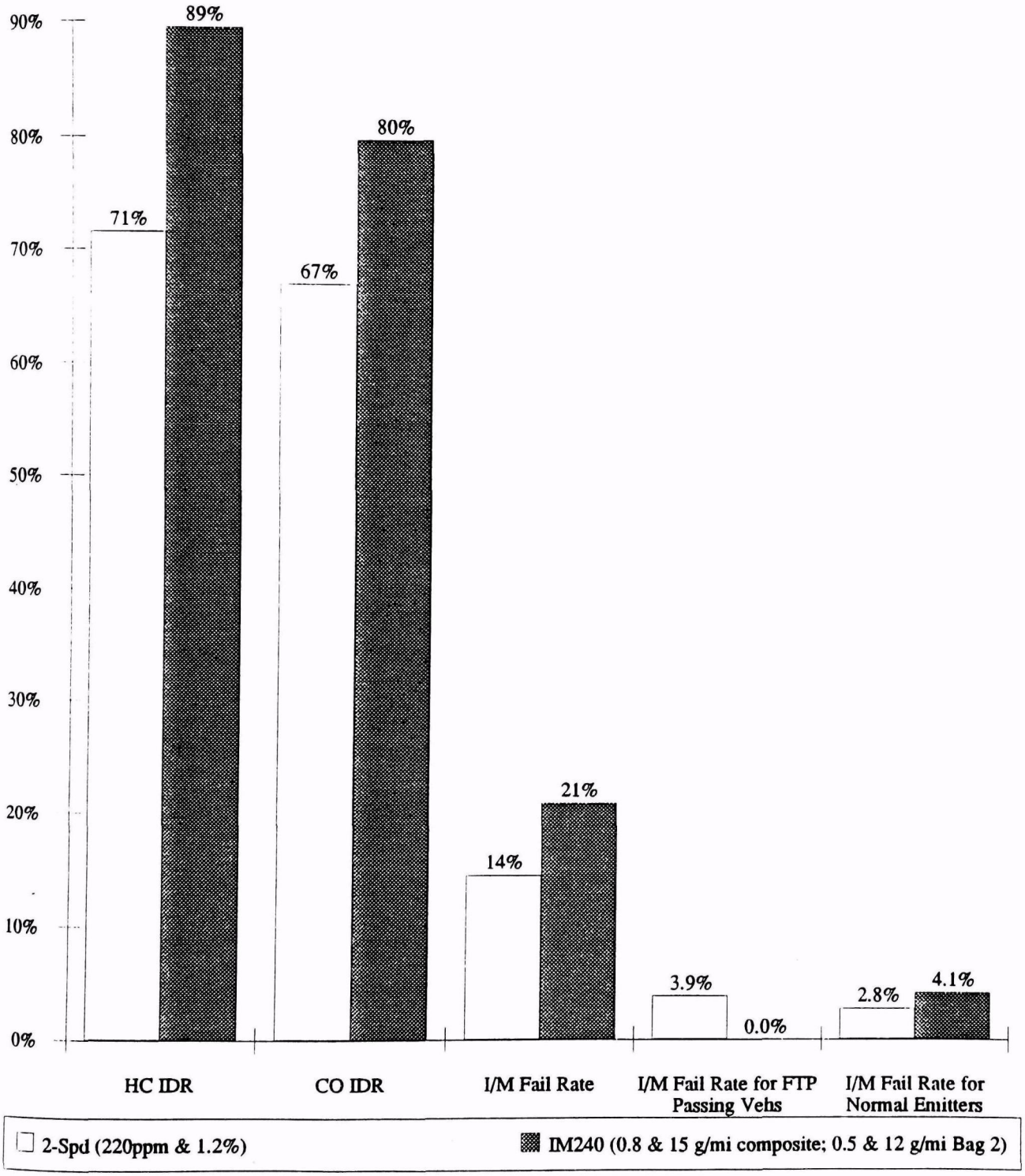


Figure 5
Comparison of IM240 to Second Chance 2500/Idle for
1983 & Newer TBI Vehicles from Hammond Indiana
IM240 Cutpoints = 0.8 & 15 g/mi Composite; 0.5 & 12 g/mi Bag 2
Second Chance 2500/Idle Ctpts = 220 ppm & 1.2% @2500; 100 ppm & 1.0% @Idle

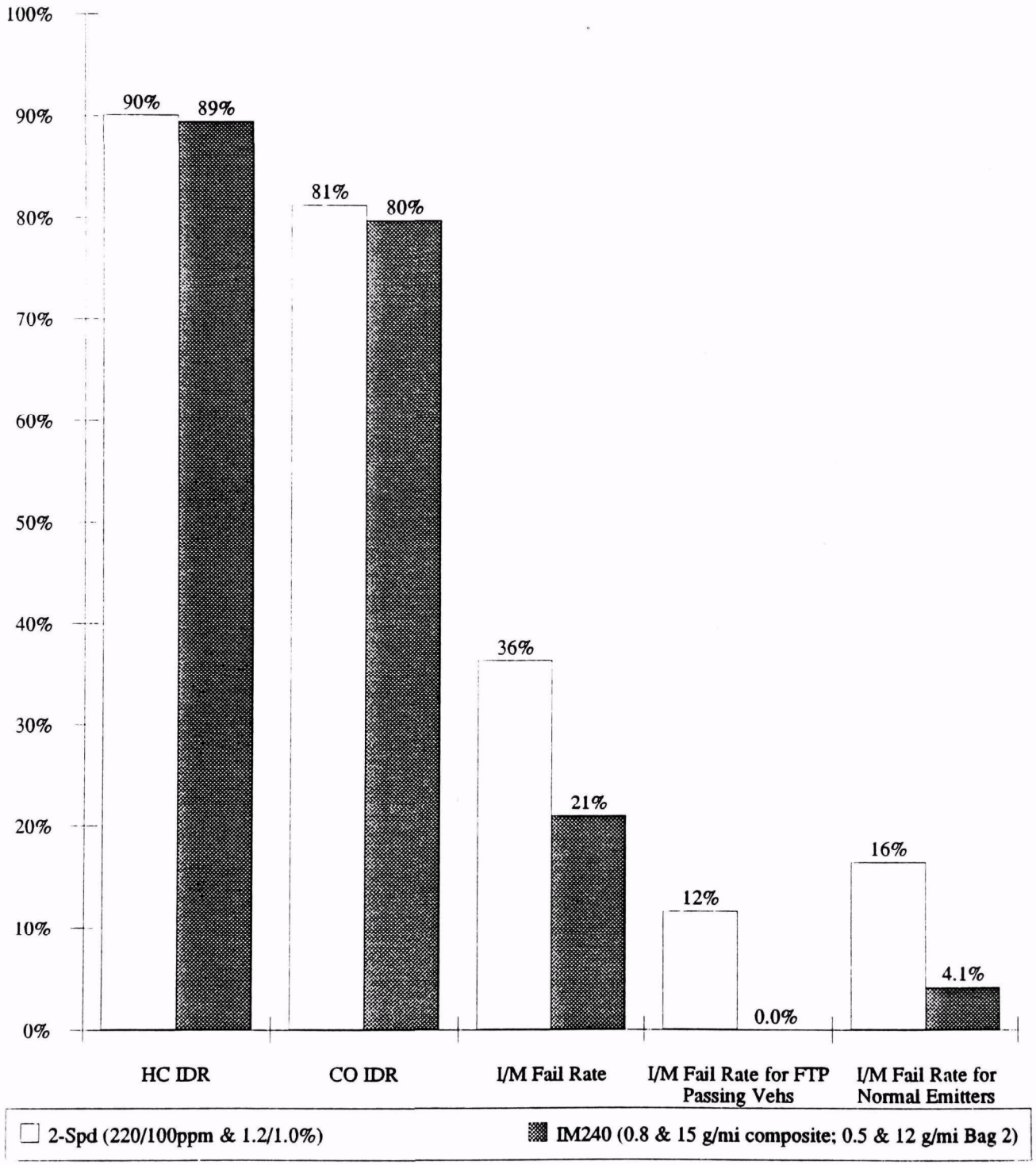


Figure 6
Comparison of IM240 to Second Chance 2500/Idle for
1983 & Newer Throttle Body Injected Vehicles from Hammond Indiana
IM240 Cutpoints = 0.8 & 15 g/mi Composite; 0.5 & 12 g/mi Bag 2
Second Chance 2500/Idle Ctpts = 100 ppm & 0.5% both modes

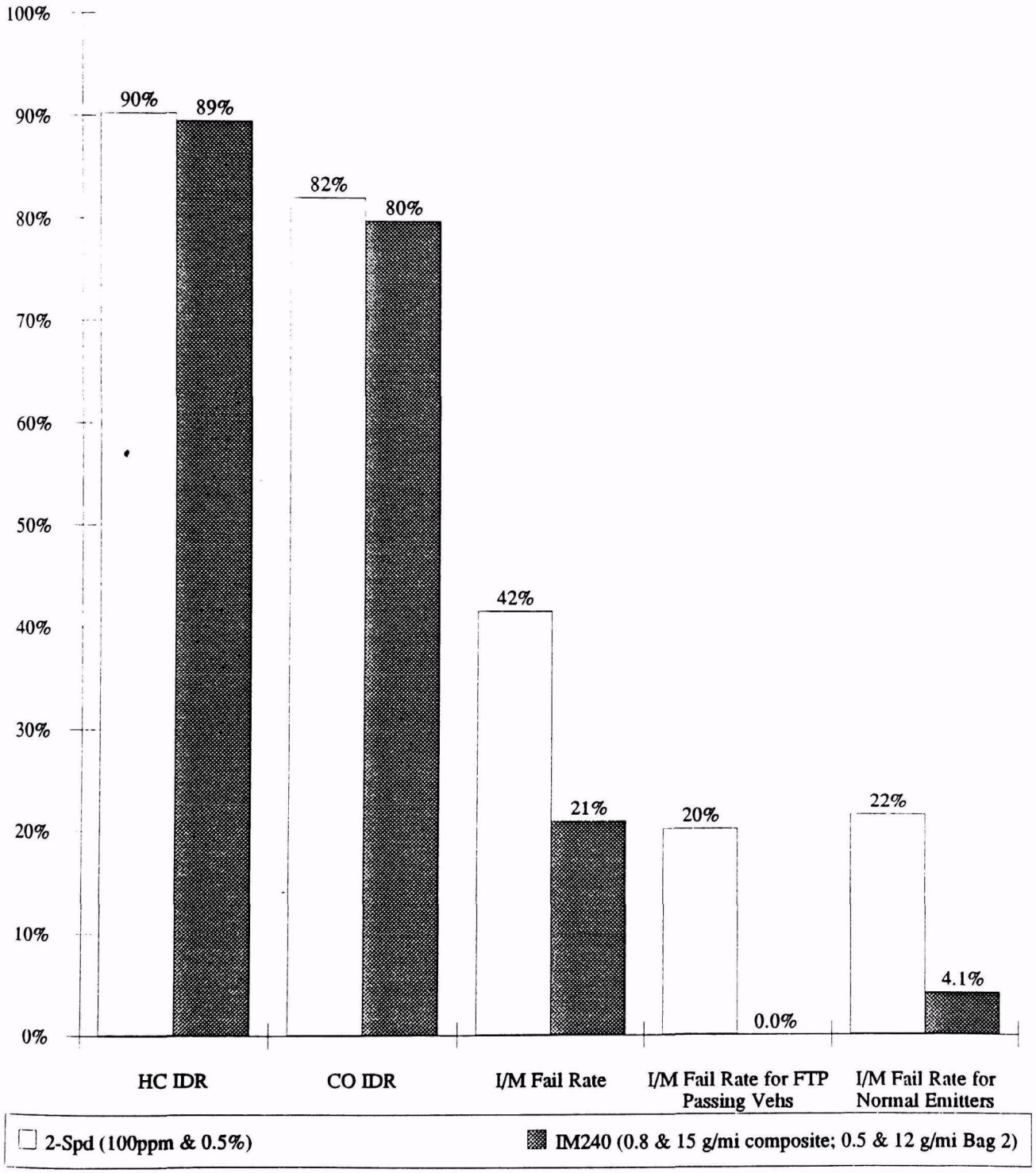


Figure 7
Comparison of IM240 to Second Chance 2500/Idle for
1981 & Newer Carbureted Vehicles from Hammond Indiana
IM240 Cutpoints = 0.8 & 15 g/mi Composite; 0.5 &12 g/mi Bag 2
Second Chance 2500/Idle Ctpts = 220 ppm & 1.2%

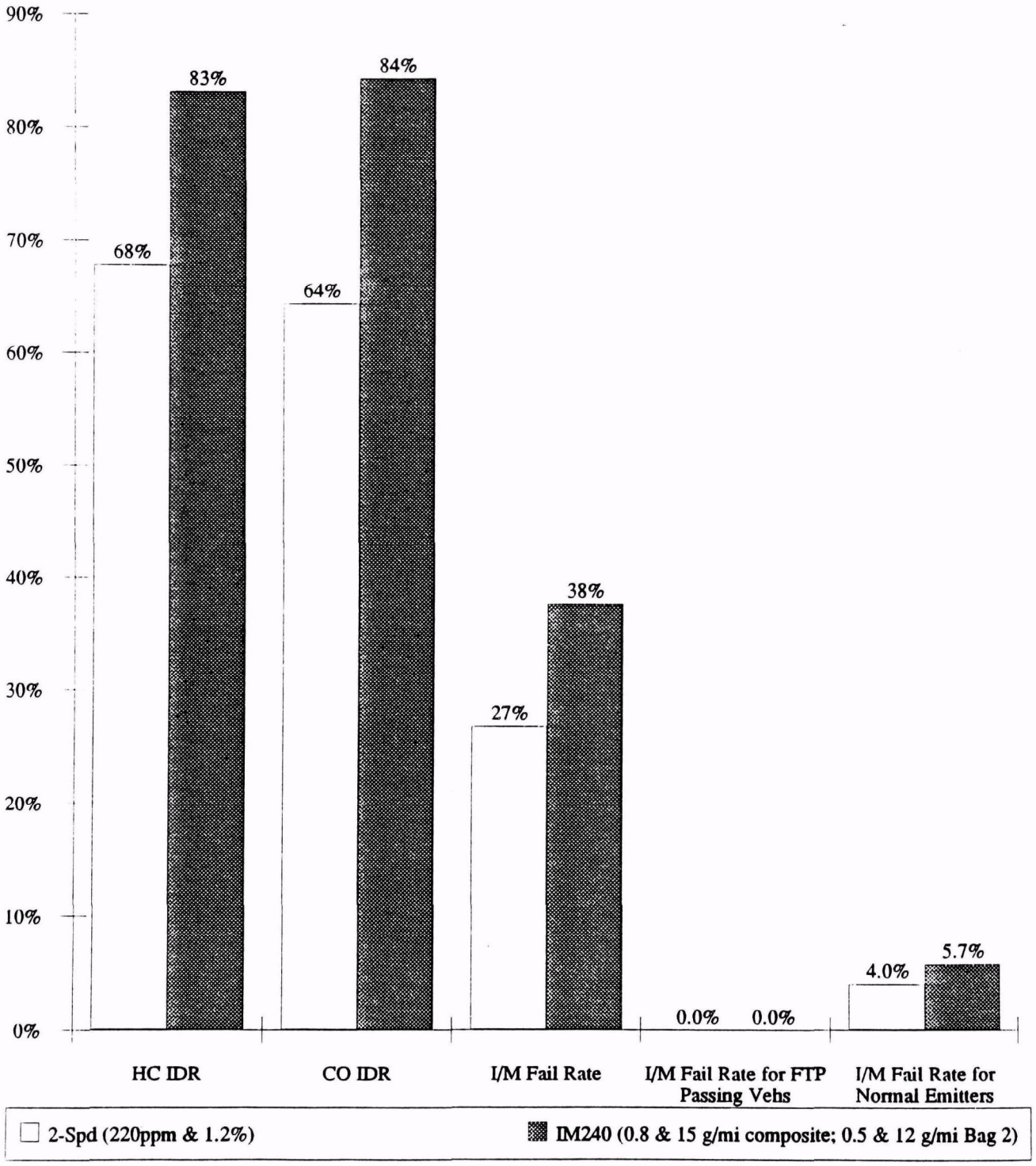


Figure 8
Comparison of IM240 to Second Chance 2500/Idle for
1981 & Newer Carbureted Vehicles from Hammond Indiana
IM240 Cutpoints = 0.8 & 15 g/mi Composite; 0.5 & 12 g/mi Bag 2
Second Chance 2500/Idle Ctpts = 220 ppm & 1.2% @2500; 100 ppm & 1.0% @Idle

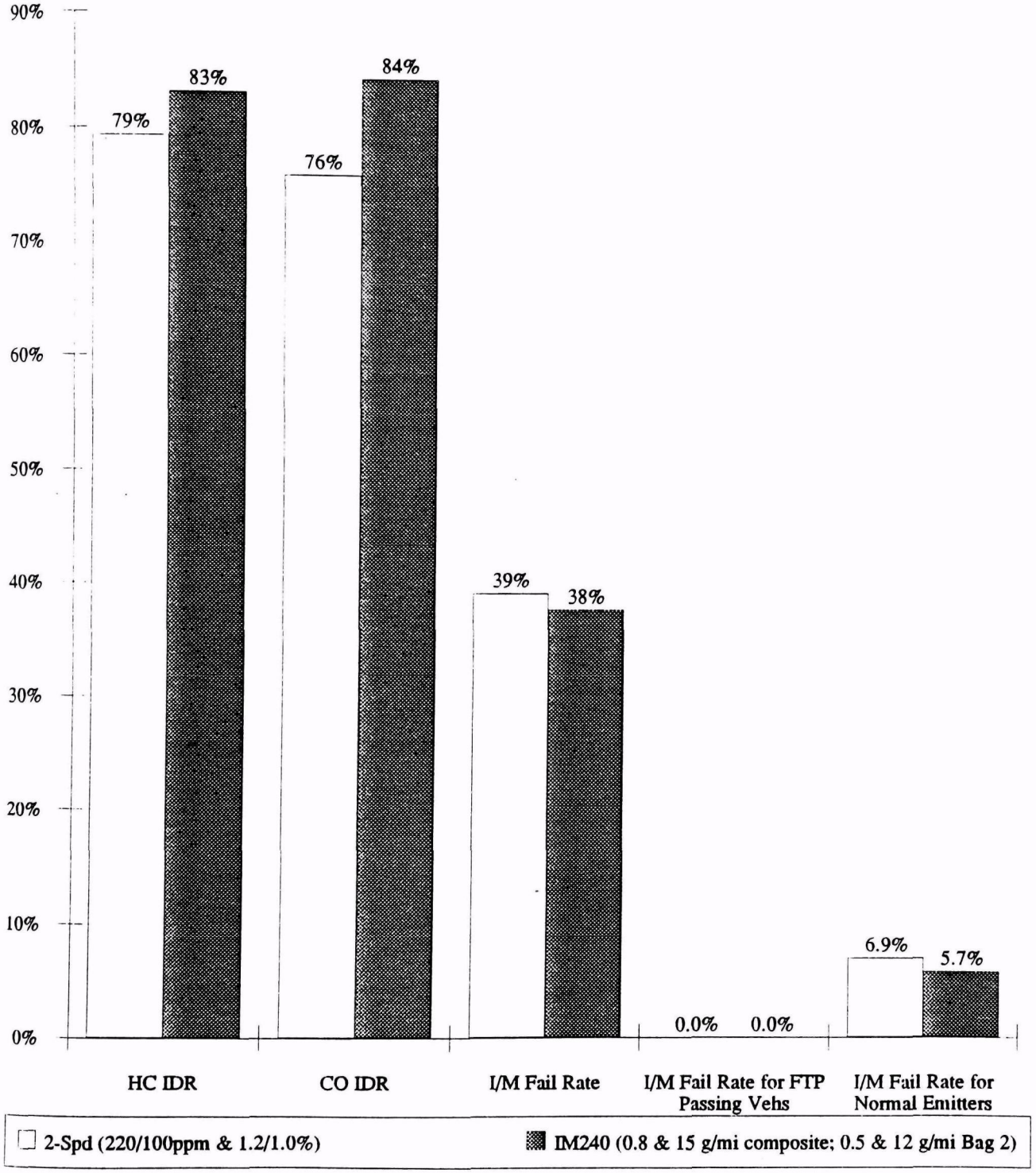
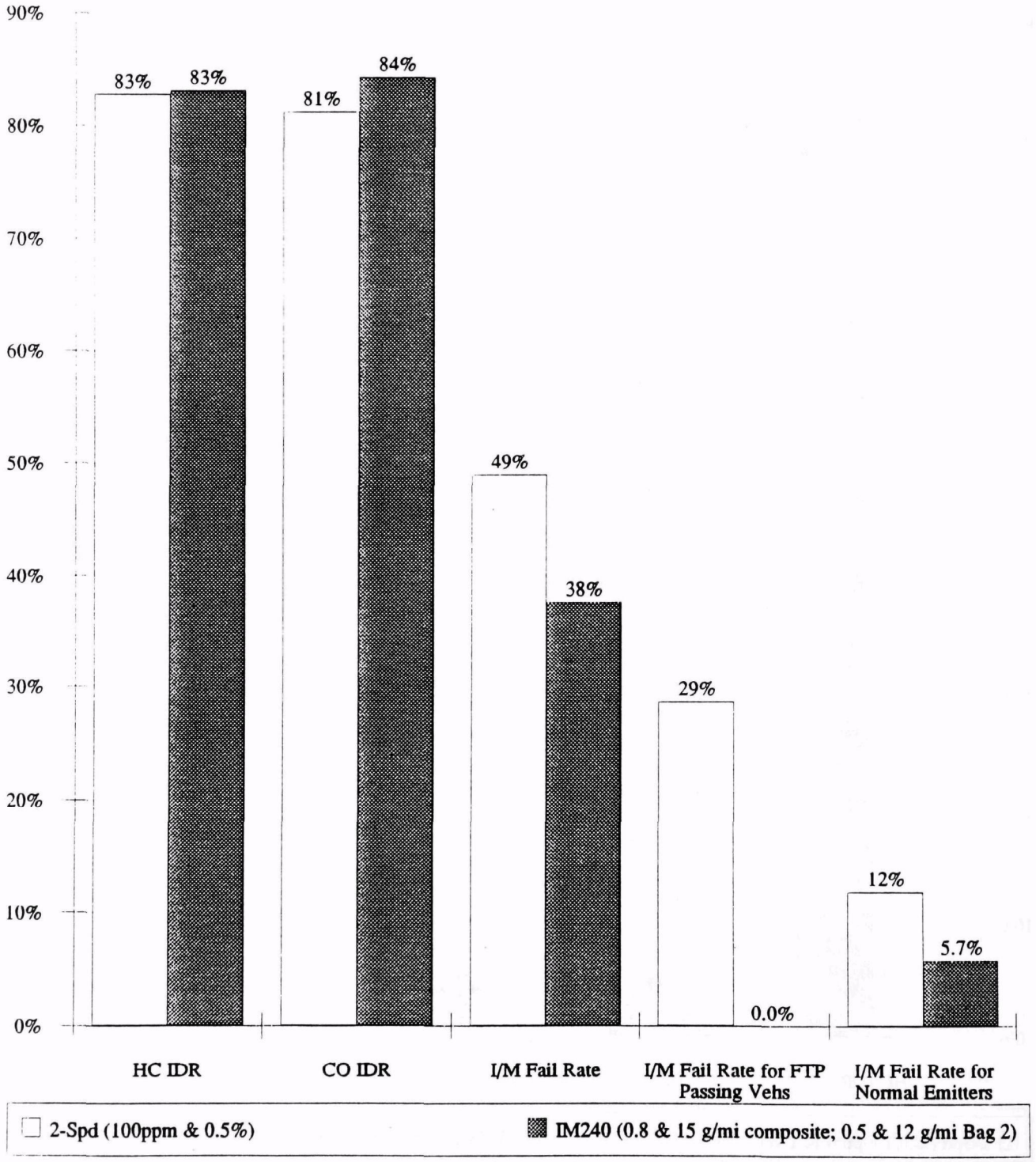


Figure 9
Comparison of IM240 to Second Chance 2500/Idle for
1981 & Newer Carbureted Vehicles from Hammond Indiana
IM240 Cutpoints = 0.8 & 15 g/mi Composite; 0.5 & 12 g/mi Bag 2
Second Chance 2500/Idle Ctpts = 100 ppm & 0.5% both modes



# APPENDIX H

## DATA ANALYSES FOR APPENDIX G: 1983 AND NEWER PFI, TBI, AND CARBURETED VEHICLES


| | |
|---|---|
| PFI | p. H-2 |
| TBI | p. H-15 |
| CARB | p. H-28 |

## Database Description

The data used to calculate these tables consisted of IM240 Lane, second chance 2500/Idle, and FTP test scores for 1983 and newer port fuel injected and throttle body fuel injected vehicles tested at ATL's laboratory in South Bend, Indiana. Carburetor equipped 1981 and newer vehicles are also included, but because no second chance 2500/Idle tests were performed on the 1981 and 1982 vehicles, we only used the first chance results for 1981-82 carbureted cars. For 1983 and later vehicles, we always used the better results from the first or second chance tests for all fuel metering types.

Only vehicles receiving each of these tests were used in these analyses. Vehicles receiving repairs in the interim between the lane tests and the FTP, and vehicles exhibiting at least a 15% variation between lane dynamometer settings and laboratory dynamometer settings were excluded from the database.

These differences in dynamometer settings arose from the use of different dynamometer look-up tables at the lane and lab. Traditional certification tables used for emission factor testing are too detailed for efficient use in the I/M lane so simpler tables were developed for use at the lane. The tables developed for the I/M lane are probably more representative than the traditional tables because they are derived from more vehicles with various optional equipment. After becoming aware of the dynamometer setting differences in the two tables, EPA opted to use the simplified table at both testing sites to avoid future inconsistencies. The resulting database consisted of 74 1983 and newer PFI vehicles and 108 1983 and newer TBI vehicles and was used to construct Appendices E, G, and H . Regressions were not performed for the 122 1981 and newer carbureted vehicles.

## Weighting Factor Explanation

FTP's were performed only on vehicles recruited to the lab for additional testing. Because the recruiting criteria for vehicles at Hammond lane was based on equal quotas for low IM240 emitters and high IM240 emitters it did not ensure a sample representative of the in-use fleet. Weighting factors were used to better simulate a representative sample. The weighting factors were calculated as the ratio of '83 and newer PFI vehicles tested at Hammond I/M lane to PFI vehicles tested at the South Bend lab. The weighting factors for the TBI and carbureted vehicles were calculated similarly. The simulated fleet was then created by multiplying the lab sample results by the weighting factors.

## IM240 Cutpoint Explanation

Appendix H shows the characteristics of the IM240 test when a vehicle is failed only if its composite emissions exceed 0.8 g/mi HC or 15 g/mi CO and its Bag 2 emissions alone exceed 0.5 g/mi HC or 12 g/mi CO. In other words, a vehicle can pass by having low emissions in Bag 2 even if Bag 1 emissions were very high. EPA has found that this prevents inappropriately failing clean cars with no sacrifice in identification of dirty cars, and therefore, is proposing this approach to IM240 cutpoints. Tables calculated using this approach are labeled "Two Ways to Pass Criteria." Tables calculated using composite IM240 cutpoints alone are also included for comparison. These Tables are labeled "Full IM240 Test Criteria". Both tables help illustrate the method of analysis and underlying sample sizes as well as showing how the characteristics of the IM240 and Idle/2500 tests vary with more or less stringent cutpoints.

**1983+ Simulated Lane Sample: "Two Ways to Pass Criteria"**
**PFI Vehicles**

| Lane IM240 Cut-Points Comp+Bag 2 | Excess Emissions Identified HC | CO | Excess Emissions Identified HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 + 0.5/12 | 554.8 | 9889.4 | 87% | 86% | 256 | 16% | 0 | 0.0% | 0.0% |
| 0.6/15 + 0.5/12 | 554.8 | 9889.4 | 87% | 86% | 256 | 16% | 0 | 0.0% | 0.0% |
| 0.6/20 + 0.5/12 | 553.6 | 9798.5 | 87% | 86% | 251 | 16% | 0 | 0.0% | 0.0% |
| 0.7/10 + 0.5/12 | 554.8 | 9889.4 | 87% | 86% | 256 | 16% | 0 | 0.0% | 0.0% |
| 0.7/15 + 0.5/12 | 554.8 | 9889.4 | 87% | 86% | 256 | 16% | 0 | 0.0% | 0.0% |
| 0.7/20 + 0.5/12 | 553.6 | 9798.5 | 87% | 86% | 251 | 16% | 0 | 0.0% | 0.0% |
| 0.75/10 + 0.5/12 | 554.8 | 9889.4 | 87% | 86% | 256 | 16% | 0 | 0.0% | 0.0% |
| 0.75/15 + 0.5/12 | 554.8 | 9889.4 | 87% | 86% | 256 | 16% | 0 | 0.0% | 0.0% |
| 0.75/20 + 0.5/12 | 553.6 | 9798.5 | 87% | 86% | 251 | 16% | 0 | 0.0% | 0.0% |
| 0.8/10 + 0.5/12 | 519.7 | 9715.6 | 82% | 85% | 229 | 14% | 0 | 0.0% | 0.0% |
| 0.8/15 + 0.5/12 | 519.7 | 9715.6 | 82% | 85% | 229 | 14% | 0 | 0.0% | 0.0% |
| 0.8/20 + 0.5/12 | 518.6 | 9624.8 | 81% | 84% | 224 | 14% | 0 | 0.0% | 0.0% |
| 0.85/10 + 0.5/12 | 519.7 | 9715.6 | 82% | 85% | 229 | 14% | 0 | 0.0% | 0.0% |
| 0.85/15 + 0.5/12 | 519.7 | 9715.6 | 82% | 85% | 229 | 14% | 0 | 0.0% | 0.0% |
| 0.85/20 + 0.5/12 | 518.6 | 9624.8 | 81% | 84% | 224 | 14% | 0 | 0.0% | 0.0% |
| 0.9/10 + 0.5/12 | 490.4 | 9639.0 | 77% | 84% | 201 | 13% | 0 | 0.0% | 0.0% |
| 0.9/15 + 0.5/12 | 482.0 | 9468.0 | 76% | 83% | 174 | 11% | 0 | 0.0% | 0.0% |
| 0.9/20 + 0.5/12 | 480.8 | 9377.1 | 76% | 82% | 169 | 11% | 0 | 0.0% | 0.0% |
| 1.0/10 + 0.5/12 | 472.7 | 9592.5 | 74% | 84% | 174 | 11% | 0 | 0.0% | 0.0% |
| 1.0/15 + 0.5/12 | 413.6 | 8890.6 | 65% | 78% | 119 | 7% | 0 | 0.0% | 0.0% |
| 1.0/20 + 0.5/12 | 412.4 | 8799.8 | 65% | 77% | 114 | 7% | 0 | 0.0% | 0.0% |
| 1.1/10 + 0.5/12 | 411.4 | 9268.2 | 65% | 81% | 147 | 9% | 0 | 0.0% | 0.0% |
| 1.1/15 + 0.5/12 | 352.3 | 8566.3 | 55% | 75% | 92 | 6% | 0 | 0.0% | 0.0% |
| 1.1/20 + 0.5/12 | 351.1 | 8475.5 | 55% | 74% | 87 | 5% | 0 | 0.0% | 0.0% |
| 1.2/10 + 0.5/12 | 411.4 | 9268.2 | 65% | 81% | 147 | 9% | 0 | 0.0% | 0.0% |
| 1.2/15 + 0.5/12 | 352.3 | 8566.3 | 55% | 75% | 92 | 6% | 0 | 0.0% | 0.0% |
| 1.2/16 + 0.5/12 | 352.3 | 8566.3 | 55% | 75% | 92 | 6% | 0 | 0.0% | 0.0% |
| 1.2/20 + 0.5/12 | 351.1 | 8475.5 | 55% | 74% | 87 | 5% | 0 | 0.0% | 0.0% |
| 1.6/10 + 0.5/12 | 411.4 | 9268.2 | 65% | 81% | 147 | 9% | 0 | 0.0% | 0.0% |
| 1.6/15 + 0.5/12 | 352.3 | 8566.3 | 55% | 75% | 92 | 6% | 0 | 0.0% | 0.0% |
| 1.6/20 + 0.5/12 | 339.4 | 8243.5 | 53% | 72% | 82 | 5% | 0 | 0.0% | 0.0% |

**1983-85 Simulated Lane Sample: "Two Ways to Pass Criteria"**
**PFI Vehicles**

| Lane IM240 Cut-Points Comp+Bag 2 | Excess Emissions Identified HC | CO | Excess Emissions Identified HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.6/15 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.6/20 + 0.5/12 | 192.3 | 4566.0 | 92% | 94% | 58 | 34% | 0 | 0.0% | 0.0% |
| 0.7/10 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.7/15 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.7/20 + 0.5/12 | 192.3 | 4566.0 | 92% | 94% | 58 | 34% | 0 | 0.0% | 0.0% |
| 0.75/10 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.75/15 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.75/20 + 0.5/12 | 192.3 | 4566.0 | 92% | 94% | 58 | 34% | 0 | 0.0% | 0.0% |
| 0.8/10 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.8/15 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.8/20 + 0.5/12 | 192.3 | 4566.0 | 92% | 94% | 58 | 34% | 0 | 0.0% | 0.0% |
| 0.85/10 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.85/15 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.85/20 + 0.5/12 | 192.3 | 4566.0 | 92% | 94% | 58 | 34% | 0 | 0.0% | 0.0% |
| 0.9/10 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.9/15 + 0.5/12 | 187.6 | 4524.6 | 90% | 93% | 44 | 26% | 0 | 0.0% | 0.0% |
| 0.9/20 + 0.5/12 | 186.7 | 4453.5 | 90% | 91% | 40 | 24% | 0 | 0.0% | 0.0% |
| 1.0/10 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 1.0/15 + 0.5/12 | 187.6 | 4524.6 | 90% | 93% | 44 | 26% | 0 | 0.0% | 0.0% |
| 1.0/20 + 0.5/12 | 186.7 | 4453.5 | 90% | 91% | 40 | 24% | 0 | 0.0% | 0.0% |
| 1.1/10 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 1.1/15 + 0.5/12 | 187.6 | 4524.6 | 90% | 93% | 44 | 26% | 0 | 0.0% | 0.0% |
| 1.1/20 + 0.5/12 | 186.7 | 4453.5 | 90% | 91% | 40 | 24% | 0 | 0.0% | 0.0% |
| 1.2/10 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 1.2/15 + 0.5/12 | 187.6 | 4524.6 | 90% | 93% | 44 | 26% | 0 | 0.0% | 0.0% |
| 1.2/16 + 0.5/12 | 187.6 | 4524.6 | 90% | 93% | 44 | 26% | 0 | 0.0% | 0.0% |
| 1.2/20 + 0.5/12 | 186.7 | 4453.5 | 90% | 91% | 40 | 24% | 0 | 0.0% | 0.0% |
| 1.6/10 + 0.5/12 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 1.6/15 + 0.5/12 | 187.6 | 4524.6 | 90% | 93% | 44 | 26% | 0 | 0.0% | 0.0% |
| 1.6/20 + 0.5/12 | 177.6 | 4271.7 | 85% | 88% | 36 | 21% | 0 | 0.0% | 0.0% |

**1986+ Simulated Lane Sample: "Two Ways to Pass Criteria"**
**PFI Vehicles**

| Lane IM240 Cut-Points Comp+Bag 2 | Excess Emissions Identified HC | Excess Emissions Identified CO | Excess Emissions Identified HC | Excess Emissions Identified CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 + 0.5/12 | 350.0 | 4831.9 | 85% | 79% | 190 | 13% | 0 | 0.0% | 0.0% |
| 0.6/15 + 0.5/12 | 350.0 | 4831.9 | 85% | 79% | 190 | 13% | 0 | 0.0% | 0.0% |
| 0.6/20 + 0.5/12 | 350.0 | 4831.9 | 85% | 79% | 190 | 13% | 0 | 0.0% | 0.0% |
| 0.7/10 + 0.5/12 | 350.0 | 4831.9 | 85% | 79% | 190 | 13% | 0 | 0.0% | 0.0% |
| 0.7/15 + 0.5/12 | 350.0 | 4831.9 | 85% | 79% | 190 | 13% | 0 | 0.0% | 0.0% |
| 0.7/20 + 0.5/12 | 350.0 | 4831.9 | 85% | 79% | 190 | 13% | 0 | 0.0% | 0.0% |
| 0.75/10 + 0.5/12 | 350.0 | 4831.9 | 85% | 79% | 190 | 13% | 0 | 0.0% | 0.0% |
| 0.75/15 + 0.5/12 | 350.0 | 4831.9 | 85% | 79% | 190 | 13% | 0 | 0.0% | 0.0% |
| 0.75/20 + 0.5/12 | 350.0 | 4831.9 | 85% | 79% | 190 | 13% | 0 | 0.0% | 0.0% |
| 0.8/10 + 0.5/12 | 313.3 | 4649.5 | 76% | 76% | 161 | 11% | 0 | 0.0% | 0.0% |
| 0.8/15 + 0.5/12 | 313.3 | 4649.5 | 76% | 76% | 161 | 11% | 0 | 0.0% | 0.0% |
| 0.8/20 + 0.5/12 | 313.3 | 4649.5 | 76% | 76% | 161 | 11% | 0 | 0.0% | 0.0% |
| 0.85/10 + 0.5/12 | 313.3 | 4649.5 | 76% | 76% | 161 | 11% | 0 | 0.0% | 0.0% |
| 0.85/15 + 0.5/12 | 313.3 | 4649.5 | 76% | 76% | 161 | 11% | 0 | 0.0% | 0.0% |
| 0.85/20 + 0.5/12 | 313.3 | 4649.5 | 76% | 76% | 161 | 11% | 0 | 0.0% | 0.0% |
| 0.9/10 + 0.5/12 | 282.5 | 4569.0 | 69% | 75% | 133 | 9% | 0 | 0.0% | 0.0% |
| 0.9/15 + 0.5/12 | 282.5 | 4569.0 | 69% | 75% | 133 | 9% | 0 | 0.0% | 0.0% |
| 0.9/20 + 0.5/12 | 282.5 | 4569.0 | 69% | 75% | 133 | 9% | 0 | 0.0% | 0.0% |
| 1.0/10 + 0.5/12 | 263.8 | 4520.2 | 64% | 74% | 104 | 7% | 0 | 0.0% | 0.0% |
| 1.0/15 + 0.5/12 | 210.7 | 3962.9 | 51% | 65% | 75 | 5% | 0 | 0.0% | 0.0% |
| 1.0/20 + 0.5/12 | 210.7 | 3962.9 | 51% | 65% | 75 | 5% | 0 | 0.0% | 0.0% |
| 1.1/10 + 0.5/12 | 199.5 | 4179.8 | 48% | 69% | 75 | 5% | 0 | 0.0% | 0.0% |
| 1.1/15 + 0.5/12 | 146.3 | 3622.4 | 36% | 60% | 46 | 3% | 0 | 0.0% | 0.0% |
| 1.1/20 + 0.5/12 | 146.3 | 3622.4 | 36% | 60% | 46 | 3% | 0 | 0.0% | 0.0% |
| 1.2/10 + 0.5/12 | 199.5 | 4179.8 | 48% | 69% | 75 | 5% | 0 | 0.0% | 0.0% |
| 1.2/15 + 0.5/12 | 146.3 | 3622.4 | 36% | 60% | 46 | 3% | 0 | 0.0% | 0.0% |
| 1.2/16 + 0.5/12 | 146.3 | 3622.4 | 36% | 60% | 46 | 3% | 0 | 0.0% | 0.0% |
| 1.2/20 + 0.5/12 | 146.3 | 3622.4 | 36% | 60% | 46 | 3% | 0 | 0.0% | 0.0% |
| 1.6/10 + 0.5/12 | 199.5 | 4179.8 | 48% | 69% | 75 | 5% | 0 | 0.0% | 0.0% |
| 1.6/15 + 0.5/12 | 146.3 | 3622.4 | 36% | 60% | 46 | 3% | 0 | 0.0% | 0.0% |
| 1.6/20 + 0.5/12 | 146.3 | 3622.4 | 36% | 60% | 46 | 3% | 0 | 0.0% | 0.0% |

**1983+ Simulated Lane Sample**
**PFI Vehicles**

| Idle/2500 Cut-Points | Excess Emissions Identified HC | Excess Emissions Identified CO | Excess Emissions HC | Excess Emissions CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 220/1.2 | 414.3 | 8316.3 | 65% | 73% | 188 | 12% | 0 | 0.0% | 0.0% |
| 100/1.0-220/1.2 | 482.8 | 9371.0 | 76% | 82% | 549 | 34% | 82 | 5.1% | 12.9% |
| 100/0.5 | 487.4 | 9419.7 | 77% | 82% | 603 | 38% | 82 | 5.1% | 12.9% |

**1983-1985 Simulated Lane Sample**
**PFI Vehicles**

| Idle/2500 Cut-Points | Excess Emissions Identified HC | Excess Emissions Identified CO | Excess Emissions HC | Excess Emissions CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 220/1.2 | 178.5 | 4114.2 | 86% | 84% | 32 | 19% | 0 | 0% | 0% |
| 100/1.0-220/1.2 | 181.9 | 4189.3 | 87% | 86% | 68 | 40% | 0 | 0% | 0% |
| 100/0.5 | 181.9 | 4221.3 | 87% | 87% | 86 | 51% | 0 | 0% | 0% |

**1986+ Simulated Lane Sample**
**PFI Vehicles**

| Idle/2500 Cut-Points | Excess Emissions Identified HC | Excess Emissions Identified CO | Excess Emissions HC | Excess Emissions CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 220/1.2 | 211.6 | 3714.3 | 51% | 61% | 157 | 11% | 0 | 0% | 0% |
| 100/1.0-220/1.2 | 284.5 | 4819.7 | 69% | 79% | 480 | 33% | 86 | 6% | 13% |
| 100/0.5 | 289.4 | 4819.7 | 70% | 79% | 508 | 35% | 86 | 6% | 13% |

**Characterize Hammond Indiana 1983+ Test Fleet as of 9/25**

| Technology | Lane IM240 | Number of Vehicles Actually Tested at the Hammond Lane | Number of Vehicles in the Lab Sample | Weighting Factors for the Lab Sample | Number of Lab Vehicles Passing FTP | Number of Normal Lab Vehicles Failing FTP |
|---|---|---|---|---|---|---|
| PFI | Low | 1505 | 55 | 27.36 | 23 | 24 |
| | High | 97 | 19 | 5.11 | 1 | 2 |
| | Total | 1602 | 74 | | 24 | 26 |

**Characterize Hammond Indiana 1983-1985 Test Fleet as of 9/25**

| Technology | Lane IM240 | Number of Vehicles Actually Tested at the Hammond Lane | Number of Vehicles in the Lab Sample | Weighting Factors for the Lab Sample | Number of Lab Vehicles Passing FTP | Number of Normal Lab Vehicles Failing FTP |
|---|---|---|---|---|---|---|
| PFI | Low | 126 | 7 | 18.00 | 1 | 5 |
| | High | 44 | 11 | 4.00 | 0 | 1 |
| | Total | 170 | 18 | | 1 | 6 |

**Characterize Hammond Indiana 1986+ Test Fleet as of 9/25**

| Technology | Lane IM240 | Number of Vehicles Actually Tested at the Hammond Lane | Number of Vehicles in the Lab Sample | Weighting Factors for the Lab Sample | Number of Lab Vehicles Passing FTP | Number of Normal Lab Vehicles Failing FTP |
|---|---|---|---|---|---|---|
| PFI | Low | 1379 | 48 | 28.73 | 22 | 19 |
| | High | 53 | 8 | 6.63 | 1 | 1 |
| | Total | 1432 | 56 | | 23 | 20 |

**Characterize Simulated 1983+ In-Use Fleet**
**Calculated From the Lab sample and Weighting Factors**

| Technology | Number of Vehicles Actually Tested at the Hammond Lane | Number of Simulated Vehicles Passing FTPs | Total Excess Emissions In Simulated Sample HC | CO |
|---|---|---|---|---|
| PFI | 1602 | 634 | 636.57 | 11441.42 |

**Characterize Simulated 1983-1985 In-Use Fleet**
**Calculated From the Lab sample and Weighting Factors**

| Technology | Number of Vehicles Actually Tested at the Hammond Lane | Number of Simulated Vehicles Passing FTPs | Total Excess Emissions In Simulated Sample HC | CO |
|---|---|---|---|---|
| PFI | 170 | 18 | 208.16 | 4874.20 |

**Characterize Simulated 1986+ In-Use Fleet**
**Calculated From the Lab sample and Weighting Factors**

| Technology | Number of Vehicles Actually Tested at the Hammond Lane | Number of Simulated Vehicles Passing FTPs | Total Excess Emissions In Simulated Sample HC | CO |
|---|---|---|---|---|
| PFI | 1432 | 639 | 412.09 | 6083.07 |

**Note: FTP Category Definitions**

Normal Emitters: FTP HC<0.82 and FTP CO<10.2

High Emitters: FTP HC≥0.82 or FTP CO≥10.2

Very High Emitters: FTP HC≥1.64 or FTP CO≥13.6

Super Emitters: FTP HC≥10.0 or FTP CO≥150.0

**Distribution of Total Excess Emissions by FTP Emitter Categories**

**1983+ PFI Sample**
**Simulated Lane Sample**

| Emissions | Total Excess from Normals | Total Excess from Highs | Total Excess from Very Highs | Total Excess from Supers | Total Excess |
|---|---|---|---|---|---|
| HC (g/mi) | 9% | 13% | 49% | 30% | 100% |
| CO (g/mi) | 9% | 7% | 40% | 43% | 100% |

**1983-1985 PFI Sample**
**Simulated Lane Sample**

| Emissions | Total Excess from Normals | Total Excess from Highs | Total Excess from Very Highs | Total Excess from Supers | Total Excess |
|---|---|---|---|---|---|
| HC (g/mi) | 6% | 4% | 43% | 47% | 100% |
| CO (g/mi) | 5% | 3% | 45% | 48% | 100% |

**1986+ PFI Sample**
**Simulated Lane Sample**

| Emissions | Total Excess from Normals | Total Excess from Highs | Total Excess from Very Highs | Total Excess from Supers | Total Excess |
|---|---|---|---|---|---|
| HC (g/mi) | 10% | 17% | 53% | 20% | 100% |
| CO (g/mi) | 12% | 10% | 34% | 43% | 100% |

## Distribution of Emissions Identified by FTP Emitter Categories

| IM240 Cut-Point Comp + Bag 2 | Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| **1983+ PFI Simulated Lane Sample: "Two Ways to Pass Criteria"** | | | | | |
| 1.6/20 + 0.5/12 | HC | 0% | 0% | 44% | 56% |
| | CO | 0% | 0% | 40% | 60% |
| 1.2/16 + 0.5/12 | HC | 0% | 0% | 46% | 54% |
| | CO | 0% | 0% | 42% | 58% |
| 1.0/15 + 0.5/12 | HC | 0% | 0% | 54% | 46% |
| | CO | 0% | 0% | 44% | 56% |
| 0.8/15 + 0.5/12 | HC | 2% | 9% | 53% | 37% |
| | CO | 2% | 1% | 46% | 51% |
| 0.6/10 + 0.5/12 | HC | 2% | 8% | 56% | 34% |
| | CO | 2% | 1% | 47% | 50% |
| **1983-1985 PFI Simulated Lane Sample: "Two Ways to Pass Criteria"** | | | | | |
| 1.6/20 + 0.5/12 | HC | 0% | 0% | 44% | 56% |
| | CO | 0% | 0% | 46% | 54% |
| 1.2/16 + 0.5/12 | HC | 0% | 0% | 47% | 53% |
| | CO | 0% | 0% | 49% | 51% |
| 1.0/15 + 0.5/12 | HC | 0% | 0% | 47% | 53% |
| | CO | 0% | 0% | 49% | 51% |
| 0.8/15 + 0.5/12 | HC | 3% | 0% | 46% | 51% |
| | CO | 3% | 0% | 48% | 50% |
| 0.6/10 + 0.5/12 | HC | 3% | 0% | 46% | 51% |
| | CO | 3% | 0% | 48% | 50% |
| **1986+ PFI Simulated Lane Sample: "Two Ways to Pass Criteria"** | | | | | |
| 1.6/20 + 0.5/12 | HC | 0% | 0% | 43% | 57% |
| | CO | 0% | 0% | 28% | 72% |
| 1.2/16 + 0.5/12 | HC | 0% | 0% | 43% | 57% |
| | CO | 0% | 0% | 28% | 72% |
| 1.0/15 + 0.5/12 | HC | 0% | 0% | 61% | 39% |
| | CO | 0% | 0% | 34% | 66% |
| 0.8/15 + 0.5/12 | HC | 0% | 16% | 58% | 26% |
| | CO | 0% | 3% | 41% | 56% |
| 0.6/10 + 0.5/12 | HC | 0% | 14% | 62% | 24% |
| | CO | 0% | 3% | 43% | 54% |

## Distribution of Emissions Identified by FTP Emitter Categories

| Idle/2500 Cut-point HC/CO | 1983+ PFI Simulated Lane Sample Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| 220/1.2 | HC | 0% | 9% | 45% | 46% |
| | CO | 0% | 4% | 36% | 60% |
| 100/1.0-220/1.2 | HC | 5% | 11% | 44% | 39% |
| | CO | 6% | 4% | 37% | 53% |
| 100/0.5 | HC | 6% | 11% | 44% | 39% |
| | CO | 6% | 4% | 37% | 53% |

| Idle/2500 Cut-point HC/CO | 1983-1985 PFI Simulated Lane Sample Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| 220/1.2 | HC | 0% | 0% | 45% | 55% |
| | CO | 0% | 0% | 44% | 56% |
| 100/1.0-220/1.2 | HC | 2% | 0% | 44% | 54% |
| | CO | 2% | 0% | 43% | 55% |
| 100/0.5 | HC | 2% | 0% | 44% | 54% |
| | CO | 3% | 0% | 43% | 55% |

| Idle/2500 Cut-point HC/CO | 1986+ PFI Simulated Lane Sample Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| 220/1.2 | HC | 0% | 18% | 42% | 39% |
| | CO | 1% | 9% | 20% | 70% |
| 100/1.0-220/1.2 | HC | 7% | 20% | 43% | 29% |
| | CO | 10% | 8% | 28% | 54% |
| 100/0.5 | HC | 9% | 20% | 43% | 29% |
| | CO | 10% | 8% | 28% | 54% |

**1983+ Simulated Lane Sample: "Full IM240 Test Criteria"**
**PFI Vehicles**

| Lane IM240 Cut-Points | Excess Emissions Identified HC | Excess Emissions Identified CO | Excess Emissions Identified HC | Excess Emissions Identified CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 | 568.2 | 10032.7 | 89% | 88% | 398 | 25% | 32 | 2.0% | 5.1% |
| 0.6/15 | 568.2 | 9984.0 | 89% | 87% | 371 | 23% | 32 | 2.0% | 5.1% |
| 0.6/20 | 567.0 | 9893.2 | 89% | 86% | 366 | 23% | 32 | 2.0% | 5.1% |
| 0.7/10 | 568.2 | 10032.7 | 89% | 88% | 398 | 25% | 32 | 2.0% | 5.1% |
| 0.7/15 | 568.2 | 9984.0 | 89% | 87% | 371 | 23% | 32 | 2.0% | 5.1% |
| 0.7/20 | 567.0 | 9893.2 | 89% | 86% | 366 | 23% | 32 | 2.0% | 5.1% |
| 0.75/10 | 560.0 | 9961.9 | 88% | 87% | 343 | 21% | 32 | 2.0% | 5.1% |
| 0.75/15 | 560.0 | 9913.2 | 88% | 87% | 316 | 20% | 32 | 2.0% | 5.1% |
| 0.75/20 | 558.8 | 9822.3 | 88% | 86% | 306 | 19% | 27 | 1.7% | 4.3% |
| 0.8/10 | 519.7 | 9764.3 | 82% | 85% | 261 | 16% | 5 | 0.3% | 0.8% |
| 0.8/15 | 519.7 | 9715.6 | 82% | 85% | 234 | 15% | 5 | 0.3% | 0.8% |
| 0.8/20 | 518.6 | 9624.8 | 81% | 84% | 224 | 14% | 0 | 0.0% | 0.0% |
| 0.85/10 | 519.7 | 9764.3 | 82% | 85% | 261 | 16% | 5 | 0.3% | 0.8% |
| 0.85/15 | 519.7 | 9715.6 | 82% | 85% | 234 | 15% | 5 | 0.3% | 0.8% |
| 0.85/20 | 518.6 | 9624.8 | 81% | 84% | 224 | 14% | 0 | 0.0% | 0.0% |
| 0.9/10 | 490.4 | 9687.7 | 77% | 85% | 234 | 15% | 5 | 0.3% | 0.8% |
| 0.9/15 | 482.0 | 9468.0 | 76% | 83% | 179 | 11% | 5 | 0.3% | 0.8% |
| 0.9/20 | 480.8 | 9377.1 | 76% | 82% | 169 | 11% | 0 | 0.0% | 0.0% |
| 1.0/10 | 472.7 | 9641.2 | 74% | 84% | 206 | 13% | 5 | 0.3% | 0.8% |
| 1.0/15 | 413.6 | 8890.6 | 65% | 78% | 124 | 8% | 5 | 0.3% | 0.8% |
| 1.0/20 | 412.4 | 8799.8 | 65% | 77% | 114 | 7% | 0 | 0.0% | 0.0% |
| 1.1/10 | 411.4 | 9316.9 | 65% | 81% | 179 | 11% | 5 | 0.3% | 0.8% |
| 1.1/15 | 352.3 | 8566.3 | 55% | 75% | 97 | 6% | 5 | 0.3% | 0.8% |
| 1.1/20 | 351.1 | 8475.5 | 55% | 74% | 87 | 5% | 0 | 0.0% | 0.0% |
| 1.2/10 | 411.4 | 9316.9 | 65% | 81% | 179 | 11% | 5 | 0.3% | 0.8% |
| 1.2/15 | 352.3 | 8566.3 | 55% | 75% | 97 | 6% | 5 | 0.3% | 0.8% |
| 1.2/16 | 352.3 | 8566.3 | 55% | 75% | 92 | 6% | 0 | 0.0% | 0.0% |
| 1.2/20 | 351.1 | 8475.5 | 55% | 74% | 87 | 5% | 0 | 0.0% | 0.0% |
| 1.6/10 | 411.4 | 9316.9 | 65% | 81% | 179 | 11% | 5 | 0.3% | 0.8% |
| 1.6/15 | 352.3 | 8566.3 | 55% | 75% | 97 | 6% | 5 | 0.3% | 0.8% |
| 1.6/20 | 339.4 | 8243.5 | 53% | 72% | 82 | 5% | 0 | 0.0% | 0.0% |

**1983-1985 Simulated Lane Sample: "Full IM240 Test Criteria"**
**PFI Vehicles**

| Lane IM240 Cut-Points | Excess Emissions Identified HC | Excess Emissions Identified CO | HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 | 196.6 | 4684.8 | 94% | 96% | 98 | 58% | 0 | 0.0% | 0.0% |
| 0.6/15 | 196.6 | 4652.8 | 94% | 95% | 80 | 47% | 0 | 0.0% | 0.0% |
| 0.6/20 | 195.7 | 4581.6 | 94% | 94% | 76 | 45% | 0 | 0.0% | 0.0% |
| 0.7/10 | 196.6 | 4684.8 | 94% | 96% | 98 | 58% | 0 | 0.0% | 0.0% |
| 0.7/15 | 196.6 | 4652.8 | 94% | 95% | 80 | 47% | 0 | 0.0% | 0.0% |
| 0.7/20 | 195.7 | 4581.6 | 94% | 94% | 76 | 45% | 0 | 0.0% | 0.0% |
| 0.75/10 | 196.6 | 4684.8 | 94% | 96% | 98 | 58% | 0 | 0.0% | 0.0% |
| 0.75/15 | 196.6 | 4652.8 | 94% | 95% | 80 | 47% | 0 | 0.0% | 0.0% |
| 0.75/20 | 195.7 | 4581.6 | 94% | 94% | 76 | 45% | 0 | 0.0% | 0.0% |
| 0.8/10 | 193.2 | 4669.2 | 93% | 96% | 80 | 47% | 0 | 0.0% | 0.0% |
| 0.8/15 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.8/20 | 192.3 | 4566.0 | 92% | 94% | 58 | 34% | 0 | 0.0% | 0.0% |
| 0.85/10 | 193.2 | 4669.2 | 93% | 96% | 80 | 47% | 0 | 0.0% | 0.0% |
| 0.85/15 | 193.2 | 4637.1 | 93% | 95% | 62 | 36% | 0 | 0.0% | 0.0% |
| 0.85/20 | 192.3 | 4566.0 | 92% | 94% | 58 | 34% | 0 | 0.0% | 0.0% |
| 0.9/10 | 193.2 | 4669.2 | 93% | 96% | 80 | 47% | 0 | 0.0% | 0.0% |
| 0.9/15 | 187.6 | 4524.6 | 90% | 93% | 44 | 26% | 0 | 0.0% | 0.0% |
| 0.9/20 | 186.7 | 4453.5 | 90% | 91% | 40 | 24% | 0 | 0.0% | 0.0% |
| 1.0/10 | 193.2 | 4669.2 | 93% | 96% | 80 | 47% | 0 | 0.0% | 0.0% |
| 1.0/15 | 187.6 | 4524.6 | 90% | 93% | 44 | 26% | 0 | 0.0% | 0.0% |
| 1.0/20 | 186.7 | 4453.5 | 90% | 91% | 40 | 24% | 0 | 0.0% | 0.0% |
| 1.1/10 | 193.2 | 4669.2 | 93% | 96% | 80 | 47% | 0 | 0.0% | 0.0% |
| 1.1/15 | 187.6 | 4524.6 | 90% | 93% | 44 | 26% | 0 | 0.0% | 0.0% |
| 1.1/20 | 186.7 | 4453.5 | 90% | 91% | 40 | 24% | 0 | 0.0% | 0.0% |
| 1.2/10 | 193.2 | 4669.2 | 93% | 96% | 80 | 47% | 0 | 0.0% | 0.0% |
| 1.2/15 | 187.6 | 4524.6 | 90% | 93% | 44 | 26% | 0 | 0.0% | 0.0% |
| 1.2/16 | 187.6 | 4524.6 | 90% | 93% | 44 | 26% | 0 | 0.0% | 0.0% |
| 1.2/20 | 186.7 | 4453.5 | 90% | 91% | 40 | 24% | 0 | 0.0% | 0.0% |
| 1.6/10 | 193.2 | 4669.2 | 93% | 96% | 80 | 47% | 0 | 0.0% | 0.0% |
| 1.6/15 | 187.6 | 4524.6 | 90% | 93% | 44 | 26% | 0 | 0.0% | 0.0% |
| 1.6/20 | 177.6 | 4271.7 | 85% | 88% | 36 | 21% | 0 | 0.0% | 0.0% |

**1986+ Simulated Lane Sample: "Full IM240 Test Criteria"**
**PFI Vehicles**

| Lane IM240 Cut-Points | Excess Emissions Identified HC | Excess Emissions Identified CO | HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 | 358.7 | 4906.3 | 87% | 81% | 283 | 20% | 35 | 2.5% | 5.5% |
| 0.6/15 | 358.7 | 4906.3 | 87% | 81% | 283 | 20% | 35 | 2.5% | 5.5% |
| 0.6/20 | 358.7 | 4906.3 | 87% | 81% | 283 | 20% | 35 | 2.5% | 5.5% |
| 0.7/10 | 358.7 | 4906.3 | 87% | 81% | 283 | 20% | 35 | 2.5% | 5.5% |
| 0.7/15 | 358.7 | 4906.3 | 87% | 81% | 283 | 20% | 35 | 2.5% | 5.5% |
| 0.7/20 | 358.7 | 4906.3 | 87% | 81% | 283 | 20% | 35 | 2.5% | 5.5% |
| 0.75/10 | 350.0 | 4831.9 | 85% | 79% | 225 | 16% | 35 | 2.5% | 5.5% |
| 0.75/15 | 350.0 | 4831.9 | 85% | 79% | 225 | 16% | 35 | 2.5% | 5.5% |
| 0.75/20 | 350.0 | 4831.9 | 85% | 79% | 219 | 15% | 29 | 2.0% | 4.5% |
| 0.8/10 | 313.3 | 4649.5 | 76% | 76% | 168 | 12% | 7 | 0.5% | 1.0% |
| 0.8/15 | 313.3 | 4649.5 | 76% | 76% | 168 | 12% | 7 | 0.5% | 1.0% |
| 0.8/20 | 313.3 | 4649.5 | 76% | 76% | 161 | 11% | 0 | 0.0% | 0.0% |
| 0.85/10 | 313.3 | 4649.5 | 76% | 76% | 168 | 12% | 7 | 0.5% | 1.0% |
| 0.85/15 | 313.3 | 4649.5 | 76% | 76% | 168 | 12% | 7 | 0.5% | 1.0% |
| 0.85/20 | 313.3 | 4649.5 | 76% | 76% | 161 | 11% | 0 | 0.0% | 0.0% |
| 0.9/10 | 282.5 | 4569.0 | 69% | 75% | 139 | 10% | 7 | 0.5% | 1.0% |
| 0.9/15 | 282.5 | 4569.0 | 69% | 75% | 139 | 10% | 7 | 0.5% | 1.0% |
| 0.9/20 | 282.5 | 4569.0 | 69% | 75% | 133 | 9% | 0 | 0.0% | 0.0% |
| 1.0/10 | 263.8 | 4520.2 | 64% | 74% | 110 | 8% | 7 | 0.5% | 1.0% |
| 1.0/15 | 210.7 | 3962.9 | 51% | 65% | 82 | 6% | 7 | 0.5% | 1.0% |
| 1.0/20 | 210.7 | 3962.9 | 51% | 65% | 75 | 5% | 0 | 0.0% | 0.0% |
| 1.1/10 | 199.5 | 4179.8 | 48% | 69% | 82 | 6% | 7 | 0.5% | 1.0% |
| 1.1/15 | 146.3 | 3622.4 | 36% | 60% | 53 | 4% | 7 | 0.5% | 1.0% |
| 1.1/20 | 146.3 | 3622.4 | 36% | 60% | 46 | 3% | 0 | 0.0% | 0.0% |
| 1.2/10 | 199.5 | 4179.8 | 48% | 69% | 82 | 6% | 7 | 0.5% | 1.0% |
| 1.2/15 | 146.3 | 3622.4 | 36% | 60% | 53 | 4% | 7 | 0.5% | 1.0% |
| 1.2/16 | 146.3 | 3622.4 | 36% | 60% | 46 | 3% | 0 | 0.0% | 0.0% |
| 1.2/20 | 146.3 | 3622.4 | 36% | 60% | 46 | 3% | 0 | 0.0% | 0.0% |
| 1.6/10 | 199.5 | 4179.8 | 48% | 69% | 82 | 6% | 7 | 0.5% | 1.0% |
| 1.6/15 | 146.3 | 3622.4 | 36% | 60% | 53 | 4% | 7 | 0.5% | 1.0% |
| 1.6/20 | 146.3 | 3622.4 | 36% | 60% | 46 | 3% | 0 | 0.0% | 0.0% |

## Distribution of Emissions Identified by FTP Emitter Categories

| IM240 Cut-Point HC/CO | Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| **1983+ PFI Simulated Lane Sample: "Full IM240 Test Criteria"** | | | | | |
| 1.6/20 | HC | 0% | 0% | 44% | 56% |
| | CO | 0% | 0% | 40% | 60% |
| 1.2/16 | HC | 0% | 0% | 46% | 54% |
| | CO | 0% | 0% | 42% | 58% |
| 1.0/15 | HC | 0% | 0% | 54% | 46% |
| | CO | 0% | 0% | 44% | 56% |
| 0.8/15 | HC | 2% | 9% | 53% | 37% |
| | CO | 2% | 1% | 46% | 51% |
| 0.6/10 | HC | 4% | 8% | 54% | 33% |
| | CO | 3% | 1% | 46% | 49% |

| IM240 Cut-Point HC/CO | Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| **1983-1985 PFI Simulated Lane Sample: "Full IM240 Test Criteria"** | | | | | |
| 1.6/20 | HC | 0% | 0% | 44% | 56% |
| | CO | 0% | 0% | 46% | 54% |
| 1.2/16 | HC | 0% | 0% | 47% | 53% |
| | CO | 0% | 0% | 49% | 51% |
| 1.0/15 | HC | 0% | 0% | 47% | 53% |
| | CO | 0% | 0% | 49% | 51% |
| 0.8/15 | HC | 3% | 0% | 46% | 51% |
| | CO | 3% | 0% | 48% | 50% |
| 0.6/10 | HC | 5% | 0% | 45% | 50% |
| | CO | 4% | 0% | 47% | 49% |

| IM240 Cut-Point HC/CO | Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| **1986+ PFI Simulated Lane Sample: "Full IM240 Test Criteria"** | | | | | |
| 1.6/20 | HC | 0% | 0% | 43% | 57% |
| | CO | 0% | 0% | 28% | 72% |
| 1.2/16 | HC | 0% | 0% | 43% | 57% |
| | CO | 0% | 0% | 28% | 72% |
| 1.0/15 | HC | 0% | 0% | 61% | 39% |
| | CO | 0% | 0% | 34% | 66% |
| 0.8/15 | HC | 0% | 16% | 58% | 26% |
| | CO | 0% | 3% | 41% | 56% |
| 0.6/10 | HC | 2% | 14% | 61% | 23% |
| | CO | 2% | 3% | 43% | 53% |

**1983+ Simulated Lane Sample: "Two Ways to Pass Criteria"**
**TBI Vehicles**

| Lane IM240 Cut-Points Comp+Bag 2 | Excess Emissions Identified HC | CO | Excess Emissions Identified HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 + 0.5/12 | 761.7 | 10334.1 | 92% | 84% | 445 | 26% | 0 | 0.0% | 0.0% |
| 0.6/15 + 0.5/12 | 754.0 | 9949.6 | 91% | 81% | 403 | 23% | 0 | 0.0% | 0.0% |
| 0.6/20 + 0.5/12 | 753.5 | 9939.4 | 91% | 81% | 398 | 23% | 0 | 0.0% | 0.0% |
| 0.7/10 + 0.5/12 | 754.8 | 10282.4 | 91% | 84% | 424 | 25% | 0 | 0.0% | 0.0% |
| 0.7/15 + 0.5/12 | 747.2 | 9897.9 | 90% | 81% | 381 | 22% | 0 | 0.0% | 0.0% |
| 0.7/20 + 0.5/12 | 723.8 | 9077.9 | 87% | 74% | 346 | 20% | 0 | 0.0% | 0.0% |
| 0.75/10 + 0.5/12 | 754.8 | 10282.4 | 91% | 84% | 424 | 25% | 0 | 0.0% | 0.0% |
| 0.75/15 + 0.5/12 | 747.2 | 9897.9 | 90% | 81% | 381 | 22% | 0 | 0.0% | 0.0% |
| 0.75/20 + 0.5/12 | 723.8 | 9077.9 | 87% | 74% | 346 | 20% | 0 | 0.0% | 0.0% |
| 0.8/10 + 0.5/12 | 754.8 | 10282.4 | 91% | 84% | 424 | 25% | 0 | 0.0% | 0.0% |
| 0.8/15 + 0.5/12 | 740.4 | 9763.5 | 89% | 80% | 360 | 21% | 0 | 0.0% | 0.0% |
| 0.8/20 + 0.5/12 | 717.0 | 8943.4 | 87% | 73% | 325 | 19% | 0 | 0.0% | 0.0% |
| 0.85/10 + 0.5/12 | 754.8 | 10282.4 | 91% | 84% | 424 | 25% | 0 | 0.0% | 0.0% |
| 0.85/15 + 0.5/12 | 740.4 | 9763.5 | 89% | 80% | 360 | 21% | 0 | 0.0% | 0.0% |
| 0.85/20 + 0.5/12 | 717.0 | 8943.4 | 87% | 73% | 325 | 19% | 0 | 0.0% | 0.0% |
| 0.9/10 + 0.5/12 | 750.1 | 10273.0 | 91% | 84% | 403 | 23% | 0 | 0.0% | 0.0% |
| 0.9/15 + 0.5/12 | 735.7 | 9754.1 | 89% | 80% | 339 | 20% | 0 | 0.0% | 0.0% |
| 0.9/20 + 0.5/12 | 712.3 | 8934.1 | 86% | 73% | 303 | 18% | 0 | 0.0% | 0.0% |
| 1.0/10 + 0.5/12 | 722.9 | 10042.5 | 87% | 82% | 381 | 22% | 0 | 0.0% | 0.0% |
| 1.0/15 + 0.5/12 | 697.1 | 9366.4 | 84% | 77% | 296 | 17% | 0 | 0.0% | 0.0% |
| 1.0/20 + 0.5/12 | 673.8 | 8546.4 | 81% | 70% | 261 | 15% | 0 | 0.0% | 0.0% |
| 1.1/10 + 0.5/12 | 698.4 | 9938.1 | 84% | 81% | 360 | 21% | 0 | 0.0% | 0.0% |
| 1.1/15 + 0.5/12 | 578.5 | 8451.9 | 70% | 69% | 168 | 10% | 0 | 0.0% | 0.0% |
| 1.1/20 + 0.5/12 | 547.3 | 7482.2 | 66% | 61% | 128 | 7% | 0 | 0.0% | 0.0% |
| 1.2/10 + 0.5/12 | 698.4 | 9938.1 | 84% | 81% | 360 | 21% | 0 | 0.0% | 0.0% |
| 1.2/15 + 0.5/12 | 578.5 | 8451.9 | 70% | 69% | 168 | 10% | 0 | 0.0% | 0.0% |
| 1.2/16 + 0.5/12 | 564.8 | 7959.7 | 68% | 65% | 147 | 9% | 0 | 0.0% | 0.0% |
| 1.2/20 + 0.5/12 | 547.3 | 7482.2 | 66% | 61% | 128 | 7% | 0 | 0.0% | 0.0% |
| 1.6/10 + 0.5/12 | 684.7 | 9825.6 | 83% | 80% | 355 | 21% | 0 | 0.0% | 0.0% |
| 1.6/15 + 0.5/12 | 539.5 | 8188.8 | 65% | 67% | 145 | 8% | 0 | 0.0% | 0.0% |
| 1.6/20 + 0.5/12 | 501.0 | 7108.0 | 61% | 58% | 100 | 6% | 0 | 0.0% | 0.0% |

**1983-85 Simulated Lane Sample: "Two Ways to Pass Criteria"**
**TBI Vehicles**

| Lane IM240 Cut-Points Comp+Bag 2 | Excess Emissions Identified HC | CO | Excess Emissions Identified HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 + 0.5/12 | 359.9 | 5740.5 | 90% | 87% | 244 | 44% | 0 | 0.0% | 0.0% |
| 0.6/15 + 0.5/12 | 359.7 | 5661.0 | 90% | 86% | 229 | 41% | 0 | 0.0% | 0.0% |
| 0.6/20 + 0.5/12 | 359.7 | 5661.0 | 90% | 86% | 229 | 41% | 0 | 0.0% | 0.0% |
| 0.7/10 + 0.5/12 | 355.1 | 5704.6 | 89% | 87% | 229 | 41% | 0 | 0.0% | 0.0% |
| 0.7/15 + 0.5/12 | 355.0 | 5625.1 | 89% | 86% | 215 | 38% | 0 | 0.0% | 0.0% |
| 0.7/20 + 0.5/12 | 338.3 | 4958.1 | 84% | 75% | 194 | 35% | 0 | 0.0% | 0.0% |
| 0.75/10 + 0.5/12 | 355.1 | 5704.6 | 89% | 87% | 229 | 41% | 0 | 0.0% | 0.0% |
| 0.75/15 + 0.5/12 | 355.0 | 5625.1 | 89% | 86% | 215 | 38% | 0 | 0.0% | 0.0% |
| 0.75/20 + 0.5/12 | 338.3 | 4958.1 | 84% | 75% | 194 | 35% | 0 | 0.0% | 0.0% |
| 0.8/10 + 0.5/12 | 355.1 | 5704.6 | 89% | 87% | 229 | 41% | 0 | 0.0% | 0.0% |
| 0.8/15 + 0.5/12 | 350.3 | 5531.9 | 87% | 84% | 200 | 36% | 0 | 0.0% | 0.0% |
| 0.8/20 + 0.5/12 | 333.6 | 4864.8 | 83% | 74% | 179 | 32% | 0 | 0.0% | 0.0% |
| 0.85/10 + 0.5/12 | 355.1 | 5704.6 | 89% | 87% | 229 | 41% | 0 | 0.0% | 0.0% |
| 0.85/15 + 0.5/12 | 350.3 | 5531.9 | 87% | 84% | 200 | 36% | 0 | 0.0% | 0.0% |
| 0.85/20 + 0.5/12 | 333.6 | 4864.8 | 83% | 74% | 179 | 32% | 0 | 0.0% | 0.0% |
| 0.9/10 + 0.5/12 | 351.9 | 5698.1 | 88% | 87% | 215 | 38% | 0 | 0.0% | 0.0% |
| 0.9/15 + 0.5/12 | 347.0 | 5525.4 | 87% | 84% | 185 | 33% | 0 | 0.0% | 0.0% |
| 0.9/20 + 0.5/12 | 330.4 | 4858.3 | 82% | 74% | 165 | 29% | 0 | 0.0% | 0.0% |
| 1.0/10 + 0.5/12 | 351.9 | 5698.1 | 88% | 87% | 215 | 38% | 0 | 0.0% | 0.0% |
| 1.0/15 + 0.5/12 | 339.2 | 5416.4 | 85% | 82% | 170 | 30% | 0 | 0.0% | 0.0% |
| 1.0/20 + 0.5/12 | 322.5 | 4749.3 | 80% | 72% | 150 | 27% | 0 | 0.0% | 0.0% |
| 1.1/10 + 0.5/12 | 351.9 | 5698.1 | 88% | 87% | 215 | 38% | 0 | 0.0% | 0.0% |
| 1.1/15 + 0.5/12 | 286.4 | 4972.7 | 71% | 76% | 111 | 20% | 0 | 0.0% | 0.0% |
| 1.1/20 + 0.5/12 | 269.8 | 4305.6 | 67% | 65% | 91 | 16% | 0 | 0.0% | 0.0% |
| 1.2/10 + 0.5/12 | 351.9 | 5698.1 | 88% | 87% | 215 | 38% | 0 | 0.0% | 0.0% |
| 1.2/15 + 0.5/12 | 286.4 | 4972.7 | 71% | 76% | 111 | 20% | 0 | 0.0% | 0.0% |
| 1.2/16 + 0.5/12 | 277.0 | 4631.3 | 69% | 70% | 96 | 17% | 0 | 0.0% | 0.0% |
| 1.2/20 + 0.5/12 | 269.8 | 4305.6 | 67% | 65% | 91 | 16% | 0 | 0.0% | 0.0% |
| 1.6/10 + 0.5/12 | 335.6 | 5563.7 | 84% | 85% | 209 | 37% | 0 | 0.0% | 0.0% |
| 1.6/15 + 0.5/12 | 239.9 | 4658.4 | 60% | 71% | 83 | 15% | 0 | 0.0% | 0.0% |
| 1.6/20 + 0.5/12 | 223.2 | 3991.3 | 56% | 61% | 62 | 11% | 0 | 0.0% | 0.0% |

**1986+ Simulated Lane Sample: "Two Ways to Pass Criteria"**
**TBI Vehicles**

| Lane IM240 Cut-Points Comp+Bag 2 | Excess Emissions Identified HC | CO | Excess Emissions Identified HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 + 0.5/12 | 359.1 | 4191.7 | 98% | 83% | 157 | 14% | 0 | 0.0% | 0.0% |
| 0.6/15 + 0.5/12 | 350.0 | 3860.8 | 95% | 76% | 131 | 11% | 0 | 0.0% | 0.0% |
| 0.6/20 + 0.5/12 | 349.6 | 3852.7 | 95% | 76% | 127 | 11% | 0 | 0.0% | 0.0% |
| 0.7/10 + 0.5/12 | 359.1 | 4191.7 | 98% | 83% | 157 | 14% | 0 | 0.0% | 0.0% |
| 0.7/15 + 0.5/12 | 350.0 | 3860.8 | 95% | 76% | 131 | 11% | 0 | 0.0% | 0.0% |
| 0.7/20 + 0.5/12 | 347.1 | 3817.0 | 94% | 76% | 124 | 11% | 0 | 0.0% | 0.0% |
| 0.75/10 + 0.5/12 | 359.1 | 4191.7 | 98% | 83% | 157 | 14% | 0 | 0.0% | 0.0% |
| 0.75/15 + 0.5/12 | 350.0 | 3860.8 | 95% | 76% | 131 | 11% | 0 | 0.0% | 0.0% |
| 0.75/20 + 0.5/12 | 347.1 | 3817.0 | 94% | 76% | 124 | 11% | 0 | 0.0% | 0.0% |
| 0.8/10 + 0.5/12 | 359.1 | 4191.7 | 98% | 83% | 157 | 14% | 0 | 0.0% | 0.0% |
| 0.8/15 + 0.5/12 | 350.0 | 3860.8 | 95% | 76% | 131 | 11% | 0 | 0.0% | 0.0% |
| 0.8/20 + 0.5/12 | 347.1 | 3817.0 | 94% | 76% | 124 | 11% | 0 | 0.0% | 0.0% |
| 0.85/10 + 0.5/12 | 359.1 | 4191.7 | 98% | 83% | 157 | 14% | 0 | 0.0% | 0.0% |
| 0.85/15 + 0.5/12 | 350.0 | 3860.8 | 95% | 76% | 131 | 11% | 0 | 0.0% | 0.0% |
| 0.85/20 + 0.5/12 | 347.1 | 3817.0 | 94% | 76% | 124 | 11% | 0 | 0.0% | 0.0% |
| 0.9/10 + 0.5/12 | 359.1 | 4191.7 | 98% | 83% | 157 | 14% | 0 | 0.0% | 0.0% |
| 0.9/15 + 0.5/12 | 350.0 | 3860.8 | 95% | 76% | 131 | 11% | 0 | 0.0% | 0.0% |
| 0.9/20 + 0.5/12 | 347.1 | 3817.0 | 94% | 76% | 124 | 11% | 0 | 0.0% | 0.0% |
| 1.0/10 + 0.5/12 | 325.7 | 3909.1 | 89% | 77% | 131 | 11% | 0 | 0.0% | 0.0% |
| 1.0/15 + 0.5/12 | 316.6 | 3578.2 | 86% | 71% | 105 | 9% | 0 | 0.0% | 0.0% |
| 1.0/20 + 0.5/12 | 313.6 | 3534.4 | 85% | 70% | 97 | 8% | 0 | 0.0% | 0.0% |
| 1.1/10 + 0.5/12 | 295.7 | 3781.1 | 80% | 75% | 105 | 9% | 0 | 0.0% | 0.0% |
| 1.1/15 + 0.5/12 | 264.3 | 3241.3 | 72% | 64% | 53 | 5% | 0 | 0.0% | 0.0% |
| 1.1/20 + 0.5/12 | 255.2 | 3078.6 | 69% | 61% | 41 | 4% | 0 | 0.0% | 0.0% |
| 1.2/10 + 0.5/12 | 295.7 | 3781.1 | 80% | 75% | 105 | 9% | 0 | 0.0% | 0.0% |
| 1.2/15 + 0.5/12 | 264.3 | 3241.3 | 72% | 64% | 53 | 5% | 0 | 0.0% | 0.0% |
| 1.2/16 + 0.5/12 | 264.3 | 3241.3 | 72% | 64% | 53 | 5% | 0 | 0.0% | 0.0% |
| 1.2/20 + 0.5/12 | 255.2 | 3078.6 | 69% | 61% | 41 | 4% | 0 | 0.0% | 0.0% |
| 1.6/10 + 0.5/12 | 295.7 | 3781.1 | 80% | 75% | 105 | 9% | 0 | 0.0% | 0.0% |
| 1.6/15 + 0.5/12 | 264.3 | 3241.3 | 72% | 64% | 53 | 5% | 0 | 0.0% | 0.0% |
| 1.6/20 + 0.5/12 | 249.4 | 2990.4 | 68% | 59% | 38 | 3% | 0 | 0.0% | 0.0% |

**1983+ Simulated Lane Sample**
**TBI Vehicles**

| Idle/2500 Cut-Points | Excess Emissions Identified HC | CO | Excess Emissions Identified HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 220/1.2 | 591.6 | 8196.5 | 71% | 67% | 249 | 14% | 21 | 1.2% | 3.9% |
| 100/1.0+220/1.2 | 745.5 | 9947.1 | 90% | 81% | 625 | 36% | 64 | 3.7% | 11.6% |
| 100/0.5 | 746.7 | 10039.1 | 90% | 82% | 715 | 42% | 111 | 6.5% | 20.2% |

**1983-1985 Simulated Lane Sample**
**TBI Vehicles**

| Idle/2500 Cut-Points | Excess Emissions Identified HC | CO | Excess Emissions Identified HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 220/1.2 | 289.7 | 5007.8 | 72% | 76% | 138 | 25% | 0 | 0.0% | 0.0% |
| 100/1.0+220/1.2 | 375.4 | 6038.5 | 94% | 92% | 347 | 62% | 0 | 0.0% | 0.0% |
| 100/0.5 | 376.3 | 6070.0 | 94% | 92% | 362 | 65% | 0 | 0.0% | 0.0% |

**1986+ Simulated Lane Sample**
**TBI Vehicles**

| Idle/2500 Cut-Points | Excess Emissions Identified HC | CO | Excess Emissions Identified HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 220/1.2 | 272.9 | 3051.9 | 74% | 60% | 105 | 9% | 26 | 2.2% | 4.7% |
| 100/1.0+220/1.2 | 328.5 | 3543.5 | 89% | 70% | 209 | 18% | 78 | 6.7% | 14.0% |
| 100/0.5 | 328.5 | 3600.7 | 89% | 71% | 291 | 25% | 134 | 11.6% | 24.0% |

**Characterize Hammond Indiana 1983+ Test Fleet as of 9/25**

| Technology | Lane IM240 | Number of Vehicles Actually Tested at the Hammond Lane | Number of Vehicles in the Lab Sample | Weighting Factors for the Lab Sample | Number of Lab Vehicles Passing FTP | Number of Normal Lab Vehicles Failing FTP |
|---|---|---|---|---|---|---|
| TBI | Low | 1555 | 73 | 21.30 | 25 | 32 |
| | High | 166 | 35 | 4.74 | 4 | 6 |
| | Total | 1721 | 108 | | 29 | 38 |

**Characterize Hammond Indiana 1983-1985 Test Fleet as of 9/25**

| Technology | Lane IM240 | Number of Vehicles Actually Tested at the Hammond Lane | Number of Vehicles in the Lab Sample | Weighting Factors for the Lab Sample | Number of Lab Vehicles Passing FTP | Number of Normal Lab Vehicles Failing FTP |
|---|---|---|---|---|---|---|
| TBI | Low | 458 | 31 | 14.77 | 4 | 16 |
| | High | 102 | 18 | 5.67 | 1 | 0 |
| | Total | 560 | 49 | | 5 | 16 |

**Characterize Hammond Indiana 1986+ Test Fleet as of 9/25**

| Technology | Lane IM240 | Number of Vehicles Actually Tested at the Hammond Lane | Number of Vehicles in the Lab Sample | Weighting Factors for the Lab Sample | Number of Lab Vehicles Passing FTP | Number of Normal Lab Vehicles Failing FTP |
|---|---|---|---|---|---|---|
| TBI | Low | 1097 | 42 | 26.12 | 21 | 16 |
| | High | 64 | 17 | 3.76 | 3 | 6 |
| | Total | 1161 | 59 | | 24 | 22 |

**Characterize Simulated 1983+ In-Use Fleet**
**Calculated From the Lab sample and Weighting Factors**

| Technology | Number of Vehicles Actually Tested at the Hammond Lane | Number of Simulated Vehicles Passing FTPs | Total Excess Emissions In Simulated Sample HC | CO |
|---|---|---|---|---|
| TBI | 1721 | 552 | 827.69 | 12239.31 |

**Characterize Simulated 1983-1985 In-Use Fleet**
**Calculated From the Lab sample and Weighting Factors**

| Technology | Number of Vehicles Actually Tested at the Hammond Lane | Number of Simulated Vehicles Passing FTPs | Total Excess Emissions In Simulated Sample HC | CO |
|---|---|---|---|---|
| TBI | 560 | 65 | 400.94 | 6575.68 |

**Characterize Simulated 1986+ In-Use Fleet**
**Calculated From the Lab sample and Weighting Factors**

| Technology | Number of Vehicles Actually Tested at the Hammond Lane | Number of Simulated Vehicles Passing FTPs | Total Excess Emissions In Simulated Sample HC | CO |
|---|---|---|---|---|
| TBI | 1161 | 560 | 367.49 | 5051.31 |

**Note: FTP Category Definitions**

Normal Emitters: FTP HC<0.82 and FTP CO<10.2

High Emitters: FTP HC≥0.82 or FTP CO≥10.2

Very High Emitters: FTP HC≥1.64 or FTP CO≥13.6

Super Emitters: FTP HC≥10.0 or FTP CO≥150.0

**Distribution of Total Excess Emissions by FTP Emitter Categories**

**1983+ TBI Sample**
**Simulated Lane Sample**

| Emissions | Total Excess from Normals | Total Excess from Highs | Total Excess from Very Highs | Total Excess from Supers | Total Excess |
|---|---|---|---|---|---|
| HC (g/mi) | 6% | 18% | 31% | 45% | 100% |
| CO (g/mi) | 11% | 15% | 34% | 39% | 100% |

**1983-1985 TBI Sample**
**Simulated Lane Sample**

| Emissions | Total Excess from Normals | Total Excess from Highs | Total Excess from Very Highs | Total Excess from Supers | Total Excess |
|---|---|---|---|---|---|
| HC (g/mi) | 8% | 19% | 49% | 24% | 100% |
| CO (g/mi) | 8% | 16% | 46% | 31% | 100% |

**1986+ TBI Sample**
**Simulated Lane Sample**

| Emissions | Total Excess from Normals | Total Excess from Highs | Total Excess from Very Highs | Total Excess from Supers | Total Excess |
|---|---|---|---|---|---|
| HC (g/mi) | 2% | 16% | 20% | 62% | 100% |
| CO (g/mi) | 15% | 11% | 25% | 49% | 100% |

## Distribution of Emissions Identified by FTP Emitter Categories

| IM240 Cut-Point | 1983+ TBI Simulated Lane Sample: "Two Ways to Pass Criteria" | | | | |
|---|---|---|---|---|---|
| Comp + Bag 2 | Emission | Normals | Highs | Very Highs | Supers |
| 1.6/20 + 0.5/12 | HC | 1% | 1% | 24% | 74% |
| | CO | 1% | 1% | 30% | 68% |
| 1.2/16 + 0.5/12 | HC | 1% | 3% | 31% | 66% |
| | CO | 1% | 2% | 36% | 60% |
| 1.0/15 + 0.5/12 | HC | 1% | 14% | 32% | 53% |
| | CO | 2% | 7% | 39% | 51% |
| 0.8/15 + 0.5/12 | HC | 2% | 14% | 34% | 50% |
| | CO | 2% | 9% | 40% | 49% |
| 0.6/10 + 0.5/12 | HC | 4% | 14% | 34% | 49% |
| | CO | 5% | 8% | 40% | 47% |

| IM240 Cut-Point | 1983-1985 TBI Simulated Lane Sample: "Two Ways to Pass Criteria" | | | | |
|---|---|---|---|---|---|
| Comp + Bag 2 | Emission | Normals | Highs | Very Highs | Supers |
| 1.6/20 + 0.5/12 | HC | 0% | 4% | 52% | 44% |
| | CO | 0% | 2% | 47% | 50% |
| 1.2/16 + 0.5/12 | HC | 0% | 6% | 58% | 35% |
| | CO | 0% | 4% | 53% | 43% |
| 1.0/15 + 0.5/12 | HC | 1% | 12% | 58% | 29% |
| | CO | 1% | 6% | 56% | 37% |
| 0.8/15 + 0.5/12 | HC | 2% | 14% | 56% | 28% |
| | CO | 1% | 8% | 55% | 36% |
| 0.6/10 + 0.5/12 | HC | 5% | 14% | 55% | 27% |
| | CO | 5% | 8% | 53% | 35% |

| IM240 Cut-Point | 1986+ TBI Simulated Lane Sample: "Two Ways to Pass Criteria" | | | | |
|---|---|---|---|---|---|
| Comp + Bag 2 | Emission | Normals | Highs | Very Highs | Supers |
| 1.6/20 + 0.5/12 | HC | 1% | 0% | 7% | 92% |
| | CO | 2% | 0% | 15% | 83% |
| 1.2/16 + 0.5/12 | HC | 1% | 1% | 11% | 87% |
| | CO | 2% | 1% | 20% | 77% |
| 1.0/15 + 0.5/12 | HC | 1% | 17% | 9% | 72% |
| | CO | 2% | 10% | 18% | 69% |
| 0.8/15 + 0.5/12 | HC | 1% | 16% | 18% | 65% |
| | CO | 2% | 10% | 24% | 64% |
| 0.6/10 + 0.5/12 | HC | 1% | 15% | 20% | 64% |
| | CO | 2% | 9% | 30% | 59% |

## Distribution of Emissions Identified by FTP Emitter Categories

| Idle/2500 Cut-point HC/CO | 1983+ TBI Simulated Lane Sample Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| 220/1.2 | HC | 1% | 11% | 30% | 57% |
| | CO | 2% | 5% | 43% | 50% |
| 100/1.0-220/1.2 | HC | 4% | 16% | 35% | 45% |
| | CO | 5% | 11% | 42% | 41% |
| 100/0.5 | HC | 4% | 16% | 34% | 45% |
| | CO | 6% | 11% | 42% | 41% |

| Idle/2500 Cut-point HC/CO | 1983-1985 TBI Simulated Lane Sample Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| 220/1.2 | HC | 2% | 11% | 53% | 34% |
| | CO | 2% | 5% | 53% | 40% |
| 100/1.0-220/1.2 | HC | 5% | 16% | 52% | 26% |
| | CO | 6% | 11% | 50% | 33% |
| 100/0.5 | HC | 6% | 16% | 52% | 26% |
| | CO | 6% | 11% | 50% | 33% |

| Idle/2500 Cut-point HC/CO | 1986+ TBI Simulated Lane Sample Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| 220/1.2 | HC | 0% | 11% | 14% | 75% |
| | CO | 1% | 4% | 32% | 63% |
| 100/1.0-220/1.2 | HC | 0% | 16% | 22% | 62% |
| | CO | 1% | 10% | 36% | 54% |
| 100/0.5 | HC | 0% | 16% | 22% | 62% |
| | CO | 2% | 9% | 35% | 53% |

**1983+ Simulated Lane Sample: "Full IM240 Test Criteria"**
**TBI Vehicles**

| Lane IM240 Cut-Points | Excess Emissions Identified HC | Excess Emissions Identified CO | HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 | 774.9 | 10550.8 | 94% | 86% | 528 | 31% | 57 | 3.3% | 10.3% |
| 0.6/15 | 767.2 | 10103.6 | 93% | 83% | 464 | 27% | 40 | 2.3% | 7.3% |
| 0.6/20 | 766.7 | 10093.4 | 93% | 82% | 455 | 26% | 36 | 2.1% | 6.4% |
| 0.7/10 | 754.8 | 10345.0 | 91% | 85% | 464 | 27% | 19 | 1.1% | 3.4% |
| 0.7/15 | 747.2 | 9897.9 | 90% | 81% | 400 | 23% | 19 | 1.1% | 3.4% |
| 0.7/20 | 723.8 | 9077.9 | 87% | 74% | 360 | 21% | 14 | 0.8% | 2.6% |
| 0.75/10 | 754.8 | 10345.0 | 91% | 85% | 464 | 27% | 19 | 1.1% | 3.4% |
| 0.75/15 | 747.2 | 9897.9 | 90% | 81% | 400 | 23% | 19 | 1.1% | 3.4% |
| 0.75/20 | 723.8 | 9077.9 | 87% | 74% | 360 | 21% | 14 | 0.8% | 2.6% |
| 0.8/10 | 754.8 | 10345.0 | 91% | 85% | 464 | 27% | 19 | 1.1% | 3.4% |
| 0.8/15 | 740.4 | 9763.5 | 89% | 80% | 379 | 22% | 19 | 1.1% | 3.4% |
| 0.8/20 | 717.0 | 8943.4 | 87% | 73% | 334 | 19% | 9 | 0.6% | 1.7% |
| 0.85/10 | 754.8 | 10345.0 | 91% | 85% | 464 | 27% | 19 | 1.1% | 3.4% |
| 0.85/15 | 740.4 | 9763.5 | 89% | 80% | 379 | 22% | 19 | 1.1% | 3.4% |
| 0.85/20 | 717.0 | 8943.4 | 87% | 73% | 334 | 19% | 9 | 0.6% | 1.7% |
| 0.9/10 | 750.1 | 10335.6 | 91% | 84% | 443 | 26% | 19 | 1.1% | 3.4% |
| 0.9/15 | 735.7 | 9754.1 | 89% | 80% | 358 | 21% | 19 | 1.1% | 3.4% |
| 0.9/20 | 712.3 | 8934.1 | 86% | 73% | 313 | 18% | 9 | 0.6% | 1.7% |
| 1.0/10 | 722.9 | 10105.1 | 87% | 83% | 422 | 24% | 19 | 1.1% | 3.4% |
| 1.0/15 | 697.1 | 9366.4 | 84% | 77% | 315 | 18% | 19 | 1.1% | 3.4% |
| 1.0/20 | 673.8 | 8546.4 | 81% | 70% | 270 | 16% | 9 | 0.6% | 1.7% |
| 1.1/10 | 698.4 | 10000.7 | 84% | 82% | 400 | 23% | 19 | 1.1% | 3.4% |
| 1.1/15 | 578.5 | 8451.9 | 70% | 69% | 187 | 11% | 19 | 1.1% | 3.4% |
| 1.1/20 | 547.3 | 7482.2 | 66% | 61% | 138 | 8% | 9 | 0.6% | 1.7% |
| 1.2/10 | 698.4 | 10000.7 | 84% | 82% | 400 | 23% | 19 | 1.1% | 3.4% |
| 1.2/15 | 578.5 | 8451.9 | 70% | 69% | 187 | 11% | 19 | 1.1% | 3.4% |
| 1.2/16 | 564.8 | 7959.7 | 68% | 65% | 166 | 10% | 19 | 1.1% | 3.4% |
| 1.2/20 | 547.3 | 7482.2 | 66% | 61% | 138 | 8% | 9 | 0.6% | 1.7% |
| 1.6/10 | 684.7 | 9888.2 | 83% | 81% | 396 | 23% | 19 | 1.1% | 3.4% |
| 1.6/15 | 539.5 | 8188.8 | 65% | 67% | 164 | 10% | 19 | 1.1% | 3.4% |
| 1.6/20 | 501.0 | 7108.0 | 61% | 58% | 104 | 6% | 5 | 0.3% | 0.9% |

**1983-1985 Simulated Lane Sample: "Full IM240 Test Criteria"**
**TBI Vehicles**

| Lane IM240 Cut-Points | Excess Emissions Identified HC | Excess Emissions Identified CO | HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 | 369.0 | 5847.3 | 92% | 89% | 279 | 50% | 20 | 3.7% | 31.6% |
| 0.6/15 | 368.9 | 5767.8 | 92% | 88% | 265 | 47% | 20 | 3.7% | 31.6% |
| 0.6/20 | 368.9 | 5767.8 | 92% | 88% | 265 | 47% | 20 | 3.7% | 31.6% |
| 0.7/10 | 355.1 | 5704.6 | 89% | 87% | 235 | 42% | 6 | 1.0% | 8.7% |
| 0.7/15 | 355.0 | 5625.1 | 89% | 86% | 220 | 39% | 6 | 1.0% | 8.7% |
| 0.7/20 | 338.3 | 4958.1 | 84% | 75% | 200 | 36% | 6 | 1.0% | 8.7% |
| 0.75/10 | 355.1 | 5704.6 | 89% | 87% | 235 | 42% | 6 | 1.0% | 8.7% |
| 0.75/15 | 355.0 | 5625.1 | 89% | 86% | 220 | 39% | 6 | 1.0% | 8.7% |
| 0.75/20 | 338.3 | 4958.1 | 84% | 75% | 200 | 36% | 6 | 1.0% | 8.7% |
| 0.8/10 | 355.1 | 5704.6 | 89% | 87% | 235 | 42% | 6 | 1.0% | 8.7% |
| 0.8/15 | 350.3 | 5531.9 | 87% | 84% | 205 | 37% | 6 | 1.0% | 8.7% |
| 0.8/20 | 333.6 | 4864.8 | 83% | 74% | 185 | 33% | 6 | 1.0% | 8.7% |
| 0.85/10 | 355.1 | 5704.6 | 89% | 87% | 235 | 42% | 6 | 1.0% | 8.7% |
| 0.85/15 | 350.3 | 5531.9 | 87% | 84% | 205 | 37% | 6 | 1.0% | 8.7% |
| 0.85/20 | 333.6 | 4864.8 | 83% | 74% | 185 | 33% | 6 | 1.0% | 8.7% |
| 0.9/10 | 351.9 | 5698.1 | 88% | 87% | 220 | 39% | 6 | 1.0% | 8.7% |
| 0.9/15 | 347.0 | 5525.4 | 87% | 84% | 191 | 34% | 6 | 1.0% | 8.7% |
| 0.9/20 | 330.4 | 4858.3 | 82% | 74% | 170 | 30% | 6 | 1.0% | 8.7% |
| 1.0/10 | 351.9 | 5698.1 | 88% | 87% | 220 | 39% | 6 | 1.0% | 8.7% |
| 1.0/15 | 339.2 | 5416.4 | 85% | 82% | 176 | 31% | 6 | 1.0% | 8.7% |
| 1.0/20 | 322.5 | 4749.3 | 80% | 72% | 155 | 28% | 6 | 1.0% | 8.7% |
| 1.1/10 | 351.9 | 5698.1 | 88% | 87% | 220 | 39% | 6 | 1.0% | 8.7% |
| 1.1/15 | 286.4 | 4972.7 | 71% | 76% | 117 | 21% | 6 | 1.0% | 8.7% |
| 1.1/20 | 269.8 | 4305.6 | 67% | 65% | 96 | 17% | 6 | 1.0% | 8.7% |
| 1.2/10 | 351.9 | 5698.1 | 88% | 87% | 220 | 39% | 6 | 1.0% | 8.7% |
| 1.2/15 | 286.4 | 4972.7 | 71% | 76% | 117 | 21% | 6 | 1.0% | 8.7% |
| 1.2/16 | 277.0 | 4631.3 | 69% | 70% | 102 | 18% | 6 | 1.0% | 8.7% |
| 1.2/20 | 269.8 | 4305.6 | 67% | 65% | 96 | 17% | 6 | 1.0% | 8.7% |
| 1.6/10 | 335.6 | 5563.7 | 84% | 85% | 215 | 38% | 6 | 1.0% | 8.7% |
| 1.6/15 | 239.9 | 4658.4 | 60% | 71% | 88 | 16% | 6 | 1.0% | 8.7% |
| 1.6/20 | 223.2 | 3991.3 | 56% | 61% | 62 | 11% | 0 | 0.0% | 0.0% |

**1986+ Simulated Lane Sample: "Full IM240 Test Criteria"**
**TBI Vehicles**

| Lane IM240 Cut-Points | Excess Emissions Identified HC | CO | Excess Emissions Identified HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 | 359.1 | 4268.5 | 98% | 85% | 195 | 17% | 11 | 1.0% | 2.0% |
| 0.6/15 | 350.0 | 3860.8 | 95% | 76% | 142 | 12% | 11 | 1.0% | 2.0% |
| 0.6/20 | 349.6 | 3852.7 | 95% | 76% | 135 | 12% | 8 | 0.6% | 1.3% |
| 0.7/10 | 359.1 | 4268.5 | 98% | 85% | 195 | 17% | 11 | 1.0% | 2.0% |
| 0.7/15 | 350.0 | 3860.8 | 95% | 76% | 142 | 12% | 11 | 1.0% | 2.0% |
| 0.7/20 | 347.1 | 3817.0 | 94% | 76% | 131 | 11% | 8 | 0.6% | 1.3% |
| 0.75/10 | 359.1 | 4268.5 | 98% | 85% | 195 | 17% | 11 | 1.0% | 2.0% |
| 0.75/15 | 350.0 | 3860.8 | 95% | 76% | 142 | 12% | 11 | 1.0% | 2.0% |
| 0.75/20 | 347.1 | 3817.0 | 94% | 76% | 131 | 11% | 8 | 0.6% | 1.3% |
| 0.8/10 | 359.1 | 4268.5 | 98% | 85% | 195 | 17% | 11 | 1.0% | 2.0% |
| 0.8/15 | 350.0 | 3860.8 | 95% | 76% | 142 | 12% | 11 | 1.0% | 2.0% |
| 0.8/20 | 347.1 | 3817.0 | 94% | 76% | 127 | 11% | 4 | 0.3% | 0.7% |
| 0.85/10 | 359.1 | 4268.5 | 98% | 85% | 195 | 17% | 11 | 1.0% | 2.0% |
| 0.85/15 | 350.0 | 3860.8 | 95% | 76% | 142 | 12% | 11 | 1.0% | 2.0% |
| 0.85/20 | 347.1 | 3817.0 | 94% | 76% | 127 | 11% | 4 | 0.3% | 0.7% |
| 0.9/10 | 359.1 | 4268.5 | 98% | 85% | 195 | 17% | 11 | 1.0% | 2.0% |
| 0.9/15 | 350.0 | 3860.8 | 95% | 76% | 142 | 12% | 11 | 1.0% | 2.0% |
| 0.9/20 | 347.1 | 3817.0 | 94% | 76% | 127 | 11% | 4 | 0.3% | 0.7% |
| 1.0/10 | 325.7 | 3985.9 | 89% | 79% | 168 | 15% | 11 | 1.0% | 2.0% |
| 1.0/15 | 316.6 | 3578.2 | 86% | 71% | 116 | 10% | 11 | 1.0% | 2.0% |
| 1.0/20 | 313.6 | 3534.4 | 85% | 70% | 101 | 9% | 4 | 0.3% | 0.7% |
| 1.1/10 | 295.7 | 3857.9 | 80% | 76% | 142 | 12% | 11 | 1.0% | 2.0% |
| 1.1/15 | 264.3 | 3241.3 | 72% | 64% | 64 | 6% | 11 | 1.0% | 2.0% |
| 1.1/20 | 255.2 | 3078.6 | 69% | 61% | 45 | 4% | 4 | 0.3% | 0.7% |
| 1.2/10 | 295.7 | 3857.9 | 80% | 76% | 142 | 12% | 11 | 1.0% | 2.0% |
| 1.2/15 | 264.3 | 3241.3 | 72% | 64% | 64 | 6% | 11 | 1.0% | 2.0% |
| 1.2/16 | 264.3 | 3241.3 | 72% | 64% | 64 | 6% | 11 | 1.0% | 2.0% |
| 1.2/20 | 255.2 | 3078.6 | 69% | 61% | 45 | 4% | 4 | 0.3% | 0.7% |
| 1.6/10 | 295.7 | 3857.9 | 80% | 76% | 142 | 12% | 11 | 1.0% | 2.0% |
| 1.6/15 | 264.3 | 3241.3 | 72% | 64% | 64 | 6% | 11 | 1.0% | 2.0% |
| 1.6/20 | 249.4 | 2990.4 | 68% | 59% | 41 | 4% | 4 | 0.3% | 0.7% |

## Distribution of Emissions Identified by FTP Emitter Categories

**IM240 1983+ TBI Simulated Lane Sample: "Full IM240 Test Criteria"**

| Cut-Point HC/CO | Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| 1.6/20 | HC | 1% | 1% | 24% | 74% |
| | CO | 1% | 1% | 30% | 68% |
| 1.2/16 | HC | 1% | 3% | 31% | 66% |
| | CO | 1% | 2% | 36% | 60% |
| 1.0/15 | HC | 1% | 14% | 32% | 53% |
| | CO | 2% | 7% | 39% | 51% |
| 0.8/15 | HC | 2% | 14% | 34% | 50% |
| | CO | 2% | 9% | 40% | 49% |
| 0.6/10 | HC | 4% | 15% | 33% | 48% |
| | CO | 5% | 10% | 40% | 46% |

**IM240 1983-1985 TBI Simulated Lane Sample: "Full IM240 Test Criteria"**

| Cut-Point HC/CO | Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| 1.6/20 | HC | 0% | 4% | 52% | 44% |
| | CO | 0% | 2% | 47% | 50% |
| 1.2/16 | HC | 0% | 6% | 58% | 35% |
| | CO | 0% | 4% | 53% | 43% |
| 1.0/15 | HC | 1% | 12% | 58% | 29% |
| | CO | 1% | 6% | 56% | 37% |
| 0.8/15 | HC | 2% | 14% | 56% | 28% |
| | CO | 1% | 8% | 55% | 36% |
| 0.6/10 | HC | 5% | 16% | 53% | 27% |
| | CO | 5% | 9% | 52% | 34% |

**IM240 1986+ TBI Simulated Lane Sample: "Full IM240 Test Criteria"**

| Cut-Point HC/CO | Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| 1.6/20 | HC | 1% | 0% | 7% | 92% |
| | CO | 2% | 0% | 15% | 83% |
| 1.2/16 | HC | 1% | 1% | 11% | 87% |
| | CO | 2% | 1% | 20% | 77% |
| 1.0/15 | HC | 1% | 17% | 9% | 72% |
| | CO | 2% | 10% | 18% | 69% |
| 0.8/15 | HC | 1% | 16% | 18% | 65% |
| | CO | 2% | 10% | 24% | 64% |
| 0.6/10 | HC | 1% | 15% | 20% | 64% |
| | CO | 4% | 9% | 30% | 58% |

**1981+ Simulated Lane Sample: "Two Ways to Pass Criteria"**
**CARB Vehicles**

| Lane IM240 Cut-Points Comp+Bag 2 | Excess Emissions Identified HC | Excess Emissions Identified CO | HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 + 0.5/12 | 3122.6 | 45640.9 | 94% | 93% | 1354 | 60% | 0 | 0.0% | 0.0% |
| 0.6/15 + 0.5/12 | 3090.9 | 44022.2 | 93% | 90% | 1219 | 54% | 0 | 0.0% | 0.0% |
| 0.6/20 + 0.5/12 | 3090.9 | 44022.2 | 93% | 90% | 1219 | 54% | 0 | 0.0% | 0.0% |
| 0.7/10 + 0.5/12 | 3034.3 | 45082.8 | 92% | 92% | 1219 | 54% | 0 | 0.0% | 0.0% |
| 0.7/15 + 0.5/12 | 2964.3 | 42387.3 | 89% | 87% | 1004 | 45% | 0 | 0.0% | 0.0% |
| 0.7/20 + 0.5/12 | 2953.0 | 42129.4 | 89% | 86% | 992 | 44% | 0 | 0.0% | 0.0% |
| 0.75/10 + 0.5/12 | 2902.9 | 44554.8 | 88% | 91% | 1165 | 52% | 0 | 0.0% | 0.0% |
| 0.75/15 + 0.5/12 | 2832.9 | 41859.4 | 86% | 86% | 950 | 42% | 0 | 0.0% | 0.0% |
| 0.75/20 + 0.5/12 | 2810.3 | 41373.6 | 85% | 85% | 926 | 41% | 0 | 0.0% | 0.0% |
| 0.8/10 + 0.5/12 | 2850.7 | 44286.3 | 86% | 91% | 1112 | 50% | 0 | 0.0% | 0.0% |
| 0.8/15 + 0.5/12 | 2753.2 | 41220.2 | 83% | 84% | 842 | 38% | 0 | 0.0% | 0.0% |
| 0.8/20 + 0.5/12 | 2730.6 | 40734.4 | 82% | 83% | 819 | 37% | 0 | 0.0% | 0.0% |
| 0.85/10 + 0.5/12 | 2832.4 | 43998.2 | 85% | 90% | 1085 | 48% | 0 | 0.0% | 0.0% |
| 0.85/15 + 0.5/12 | 2734.9 | 40932.1 | 83% | 84% | 815 | 36% | 0 | 0.0% | 0.0% |
| 0.85/20 + 0.5/12 | 2712.3 | 40446.3 | 82% | 83% | 792 | 35% | 0 | 0.0% | 0.0% |
| 0.9/10 + 0.5/12 | 2832.4 | 43998.2 | 85% | 90% | 1085 | 48% | 0 | 0.0% | 0.0% |
| 0.9/15 + 0.5/12 | 2734.9 | 40932.1 | 83% | 84% | 815 | 36% | 0 | 0.0% | 0.0% |
| 0.9/20 + 0.5/12 | 2687.8 | 40026.2 | 81% | 82% | 768 | 34% | 0 | 0.0% | 0.0% |
| 1.0/10 + 0.5/12 | 2832.4 | 43998.2 | 85% | 90% | 1085 | 48% | 0 | 0.0% | 0.0% |
| 1.0/15 + 0.5/12 | 2734.9 | 40932.1 | 83% | 84% | 815 | 36% | 0 | 0.0% | 0.0% |
| 1.0/20 + 0.5/12 | 2666.5 | 39681.5 | 80% | 81% | 730 | 33% | 0 | 0.0% | 0.0% |
| 1.1/10 + 0.5/12 | 2832.4 | 43998.2 | 85% | 90% | 1085 | 48% | 0 | 0.0% | 0.0% |
| 1.1/15 + 0.5/12 | 2734.9 | 40932.1 | 83% | 84% | 815 | 36% | 0 | 0.0% | 0.0% |
| 1.1/20 + 0.5/12 | 2666.5 | 39681.5 | 80% | 81% | 730 | 33% | 0 | 0.0% | 0.0% |
| 1.2/10 + 0.5/12 | 2832.4 | 43998.2 | 85% | 90% | 1085 | 48% | 0 | 0.0% | 0.0% |
| 1.2/15 + 0.5/12 | 2734.9 | 40932.1 | 83% | 84% | 815 | 36% | 0 | 0.0% | 0.0% |
| 1.2/16 + 0.5/12 | 2717.1 | 40626.5 | 82% | 83% | 788 | 35% | 0 | 0.0% | 0.0% |
| 1.2/20 + 0.5/12 | 2666.5 | 39681.5 | 80% | 81% | 730 | 33% | 0 | 0.0% | 0.0% |
| 1.6/10 + 0.5/12 | 2803.3 | 43825.2 | 85% | 90% | 1061 | 47% | 0 | 0.0% | 0.0% |
| 1.6/15 + 0.5/12 | 2705.8 | 40759.1 | 82% | 83% | 792 | 35% | 0 | 0.0% | 0.0% |
| 1.6/20 + 0.5/12 | 2604.5 | 39280.9 | 79% | 80% | 683 | 30% | 0 | 0.0% | 0.0% |

**1981+ Simulated Lane Sample**
**Carbureted Vehicles**

| Idle/2500 Cut-Points | Excess Emissions Identified HC | Excess Emissions Identified CO | HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 220/1.2 | 2246.1 | 31472.1 | 68% | 64% | 599 | 27% | 0 | 0% | 0% |
| 100/1.0+220/1.2 | 2626.8 | 37064.9 | 79% | 76% | 874 | 39% | 0 | 0% | 0% |
| 100/0.5 | 2741.1 | 39716.4 | 83% | 81% | 1095 | 49% | 54 | 2% | 29% |

**Characterize Hammond Indiana 1981+ Test Fleet as of 9/25**

| Technology | Lane IM240 | Number of Vehicles Actually Tested at the Hammond Lane | Number of Vehicles in the Lab Sample | Weighting Factors for the Lab Sample | Number of Lab Vehicles Passing FTP | Number of Normal Lab Vehicles Failing FTP |
|---|---|---|---|---|---|---|
| Carbureted | Low | 1427 | 53 | 26.92 | 7 | 25 |
| | High | 812 | 69 | 11.77 | 0 | 4 |
| | Total | 2239 | 122 | | 7 | 29 |

**Characterize Simulated In-Use 81+ CARB Fleet**
**Calculated From the Lab sample and Weighting Factors**

| Technology | Number of Vehicles Actually Tested at the Hammond Lane | Number of Simulated Vehicles Passing FTPs | Total Excess Emissions In Simulated Sample HC | CO |
|---|---|---|---|---|
| Carbureted | 2239 | 188 | 3312.86 | 48915.00 |

**Distrubution of Total Excess Emission by Emitter Group**

**1981+ CARB Sample**
**Simulated Lane Sample**

| Emissions | Total Excess from Normals | Total Excess from Highs | Total Excess from Very Highs | Total Excess from Supers | Total Excess |
|---|---|---|---|---|---|
| HC (g/mi) | 3% | 7% | 59% | 31% | 100% |
| CO (g/mi) | 2% | 4% | 69% | 24% | 100% |

**Distrubution of Excess Emissions Identified by Emitter Group**

**IM240 Cut-Point** — **1981+ CARB Simulated Lane Sample: "Two Ways to Pass Criteria"**

| Comp + Bag 2 | Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| 1.6/20 + 0.5/12 | HC | 0% | 1% | 59% | 39% |
| | CO | 0% | 1% | 68% | 30% |
| 1.2/16 + 0.5/12 | HC | 0% | 1% | 61% | 38% |
| | CO | 0% | 1% | 69% | 29% |
| 1.0/15 + 0.5/12 | HC | 0% | 1% | 61% | 37% |
| | CO | 0% | 1% | 69% | 29% |
| 0.8/15 + 0.5/12 | HC | 0% | 1% | 61% | 37% |
| | CO | 0% | 1% | 70% | 29% |
| 0.6/10 + 0.5/12 | HC | 1% | 6% | 61% | 33% |
| | CO | 1% | 4% | 70% | 26% |

**Distrubution of Excess Emissions Identified by Emitter Group**

**Idle/2500 Cut-point** — **1981+ CARB Simulated Lane Sample**

| HC/CO | Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| 220/1.2 | HC | 1% | 1% | 52% | 46% |
| | CO | 1% | 1% | 60% | 38% |
| 100/1.0-220/1.2 | HC | 1% | 2% | 58% | 39% |
| | CO | 1% | 2% | 65% | 32% |
| 100/0.5 | HC | 1% | 3% | 59% | 37% |
| | CO | 1% | 2% | 67% | 30% |

**1981+ Simulated Lane Sample: "Full IM240 Test Criteria"**
**Carbureted Vehicles**

| Lane IM240 Cut-Points | Excess Emissions Identified HC | Excess Emissions Identified CO | HC | CO | Number of Simulated Failures | Failure Rate | Number of Simulated Ec's | Ec Rate | Failure Rate for FTP Passing Vehicles |
|---|---|---|---|---|---|---|---|---|---|
| 0.6/10 | 3131.7 | 45839.4 | 95% | 94% | 1485 | 66% | 54 | 2.4% | 28.6% |
| 0.6/15 | 3099.9 | 44220.7 | 94% | 90% | 1350 | 60% | 54 | 2.4% | 28.6% |
| 0.6/20 | 3099.9 | 44220.7 | 94% | 90% | 1350 | 60% | 54 | 2.4% | 28.6% |
| 0.7/10 | 3043.3 | 45281.3 | 92% | 93% | 1350 | 60% | 54 | 2.4% | 28.6% |
| 0.7/15 | 2973.1 | 42541.2 | 90% | 87% | 1108 | 49% | 54 | 2.4% | 28.6% |
| 0.7/20 | 2960.1 | 42201.6 | 89% | 86% | 1085 | 48% | 54 | 2.4% | 28.6% |
| 0.75/10 | 2912.0 | 44753.3 | 88% | 91% | 1297 | 58% | 54 | 2.4% | 28.6% |
| 0.75/15 | 2841.7 | 42013.2 | 86% | 86% | 1054 | 47% | 54 | 2.4% | 28.6% |
| 0.75/20 | 2817.4 | 41445.8 | 85% | 85% | 1019 | 46% | 54 | 2.4% | 28.6% |
| 0.8/10 | 2859.7 | 44484.8 | 86% | 91% | 1243 | 56% | 54 | 2.4% | 28.6% |
| 0.8/15 | 2762.0 | 41374.0 | 83% | 85% | 947 | 42% | 54 | 2.4% | 28.6% |
| 0.8/20 | 2737.7 | 40806.6 | 83% | 83% | 911 | 41% | 54 | 2.4% | 28.6% |
| 0.85/10 | 2841.4 | 44196.7 | 86% | 90% | 1216 | 54% | 54 | 2.4% | 28.6% |
| 0.85/15 | 2743.7 | 41085.9 | 83% | 84% | 920 | 41% | 54 | 2.4% | 28.6% |
| 0.85/20 | 2719.4 | 40518.5 | 82% | 83% | 884 | 39% | 54 | 2.4% | 28.6% |
| 0.9/10 | 2838.2 | 44196.7 | 86% | 90% | 1162 | 52% | 27 | 1.2% | 14.3% |
| 0.9/15 | 2740.4 | 41085.9 | 83% | 84% | 866 | 39% | 27 | 1.2% | 14.3% |
| 0.9/20 | 2691.7 | 40098.4 | 81% | 82% | 807 | 36% | 27 | 1.2% | 14.3% |
| 1.0/10 | 2838.2 | 44196.7 | 86% | 90% | 1135 | 51% | 0 | 0.0% | 0.0% |
| 1.0/15 | 2740.4 | 41085.9 | 83% | 84% | 839 | 37% | 0 | 0.0% | 0.0% |
| 1.0/20 | 2670.4 | 39753.8 | 81% | 81% | 741 | 33% | 0 | 0.0% | 0.0% |
| 1.1/10 | 2838.2 | 44196.7 | 86% | 90% | 1135 | 51% | 0 | 0.0% | 0.0% |
| 1.1/15 | 2740.4 | 41085.9 | 83% | 84% | 839 | 37% | 0 | 0.0% | 0.0% |
| 1.1/20 | 2670.4 | 39753.8 | 81% | 81% | 741 | 33% | 0 | 0.0% | 0.0% |
| 1.2/10 | 2838.2 | 44196.7 | 86% | 90% | 1135 | 51% | 0 | 0.0% | 0.0% |
| 1.2/15 | 2740.4 | 41085.9 | 83% | 84% | 839 | 37% | 0 | 0.0% | 0.0% |
| 1.2/16 | 2721.0 | 40698.7 | 82% | 83% | 800 | 36% | 0 | 0.0% | 0.0% |
| 1.2/20 | 2670.4 | 39753.8 | 81% | 81% | 741 | 33% | 0 | 0.0% | 0.0% |
| 1.6/10 | 2809.1 | 44023.7 | 85% | 90% | 1112 | 50% | 0 | 0.0% | 0.0% |
| 1.6/15 | 2707.5 | 40840.6 | 82% | 83% | 804 | 36% | 0 | 0.0% | 0.0% |
| 1.6/20 | 2604.5 | 39280.9 | 79% | 80% | 683 | 30% | 0 | 0.0% | 0.0% |

**Distrubution of Excess Emissions Identified by Emitter Group**

| IM240 Cut-Point HC/CO | Emission | Normals | Highs | Very Highs | Supers |
|---|---|---|---|---|---|
| | | **1981+ CARB Simulated Lane Sample: "Full IM240 Test Criteria"** | | | |
| 1.6/20 | HC | 0% | 1% | 59% | 39% |
| | CO | 0% | 1% | 68% | 30% |
| 1.2/16 | HC | 0% | 1% | 61% | 38% |
| | CO | 1% | 1% | 69% | 29% |
| 1.0/15 | HC | 0% | 1% | 61% | 37% |
| | CO | 1% | 1% | 69% | 29% |
| 0.8/15 | HC | 1% | 1% | 61% | 37% |
| | CO | 1% | 1% | 69% | 29% |
| 0.6/10 | HC | 1% | 6% | 60% | 33% |
| | CO | 1% | 4% | 69% | 26% |

# APPENDIX I

## EVAPORATIVE SYSTEM PURGE AND PRESSURE DIAGRAMS

## Pressure Test Procedure

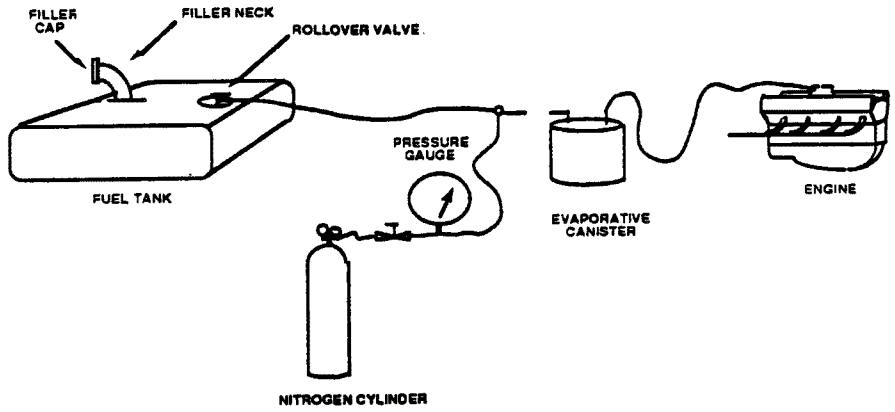
The evaporative pressure test is used to determine the integrity of a vehicle's evaporative system, and fuel tank. It is conducted by introducing nitrogen pressure into the fuel tank through the tank-to-canister vapor vent line near the canister. The Nitrogen is introduced into the system until the pressure in the fuel tank stabilizes at about 14 inches of water (0.5 PSI). Fuel tank pressurization is done by continually modulating the Nitrogen flow into the fuel system by successive opening and closing of the control valve by the operator. Modulating the Nitrogen flow into the system allows a higher pressure Nitrogen flow to be safely used to pressurize the system. Without modulating the flow, the Nitrogen pressure would have to be low, thus considerably lengthing the test. If too high a pressure is used, a weak vapor hose might bulge and rupture.

After the vehicle's evaporative system is pressurized, it is allowed to stand for up to two minutes to determine if it can continue to hold pressure. A vehicle is recorded as a failure if the fuel system pressure drops to less than 8 inches of water within the 2 minute time frame.

## Pressure Test Equipment

Figure 2 shows a schematic of the Pressure test set-up which is used. The required equipment includes an air or nitrogen gas bottle, a standard regulator, and a magnehelic to provide finer control while pressurizing a vehicle's evaporative system. Other pieces of equipment include clamps to close off vapor lines and other assorted fittings.

PRESSURE TEST



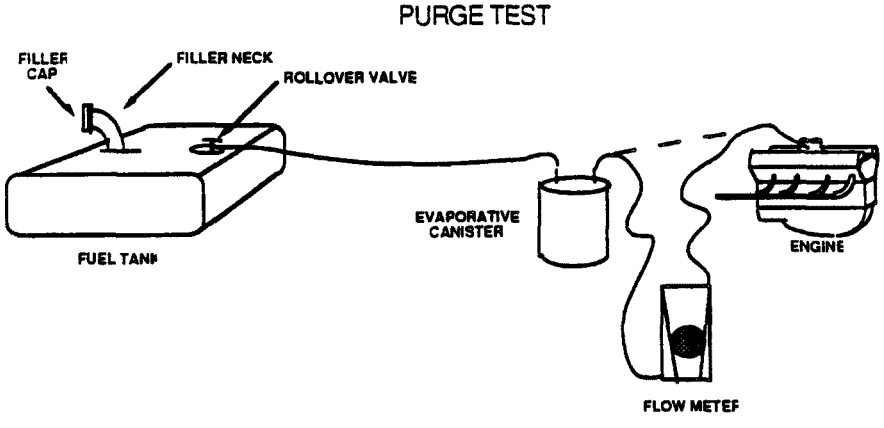
## Purge Test Procedure

The evaporative purge test is conducted during an IM240 transient dynamometer test to detect vehicles whose evaporative canister purge system are inoperative. The test procedure includes disconnecting the test vehicle's vapor purge line running from the canister to the engine, and installing a gas flowmeter in the line. On most vehicles this is a relatively simple and quick procedure. However, in some cases the canister and its purge lines are difficult to find in the allotted time, and as a result, the vehicles cannot be tested.

After installing the flow meter in the evaporative purge system, the vehicle is operated over the IM240 transient cycle, and the cumulative vapor purge flow in units of liters are recorded. The vehicle is recorded as a failure if its cumulative vapor purge is less than 1.0 liter.

## Purge Test Equipment

Figure 1 shows a schematic of the Purge test set-up which is used. The required equipment includes a transient dynamometer (not shown in Figure 1) on which to conduct the IM240, and a gas flowmeter which measures the instantaneous and cumulative vapor purge flow between the evaporative canister and the engine during the IM240 test. The dynamometer which is used is a standard Clayton ECE-50 twin roll with 125 pound inertia weights and Road Load power control. The flowmeter which is used is a Sierra Total flow meter series 730 capable of measuring flows from 0 to 50 liters per minute.



# APPENDIX J

# EVAPORATIVE SYSTEM FAILURES AND REPAIRS

# Running Loss Emission Levels of Cars Recruited for Repair

**at 95 F and 9.0 RVP Fuel**
**(3 LA-4 Cycles)**

| | Average Running Losses | | | |
|---|---|---|---|---|
| Manufacturer | Purge Failures g/mi | Pressure Failures g/mi | Repair Reduction g/mi ** | After Repair g/mi ** |
| General Motors | 8.46 | 8.29 | 5.66 | 3.22 |
| FORD | 6.51 | 7.03 | 6.26 | 0.55 |
| Chrysler | 5.16 | 4.20 | 5.12 | 0.07 |
| OTHER | 3.94 | 3.88 | 3.38 | 0.23 |
| ALL | 7.06 | 7.99 | 5.67 | 1.76 |

**Notes**

* A total of 47 cars were tested that failed either the purge test, the pressure test, or both tests. The Purge and Pressure Failure Columns are based on 47 cars.

** A total of 40 cars were repaired. Average Repair Reductions and After Repair running losses in the above Table are based on 40 cars.

## Number Of Failures by Type

| Manufactuer | Total Failures | Purge Failures | Solenoid / Electrical | Purge Line | Unknown | Pressure Failures | Vent Line | Gas Cap | Tank/ Sending Unit |
|---|---|---|---|---|---|---|---|---|---|
| General Motors | 22 | 11 | 6 | 4 | 1 | 11 | 1 | 9 | 1 |
| FORD | 16 | 12 | 6 | 6 | 0 | 4 | 3 | 0 | 1 |
| Chrysler | 5 | 4 | 1 | 3 | 0 | 1 | 0 | 0 | 1 |
| OTHER | 4 | 2 | 1 | 1 | 0 | 2 | 0 | 1 | 1 |
| ALL | 47 | 29 | 14 | 13 | 1 | 18 | 5 | 10 | 4 |

As of 11/12/91

| | | | | | | As of 11 / 12 / 91 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VEH | MYR | MAKE | MODEL | ENG.FAM | Purg | Pres | TEST | TOTAL RL g/ml | RL Reduct g/ml | Hot Soak | Diurnal | COMMENTS |
| 1455 | 88 | CHEVY | CORS | 2.0L TBI | PASS | FAIL | RECV | 5.88 | | | | Gas Cap Leaks |
| 1455 | 88 | CHEVY | CORS | 2.0L TBI | PASS | PASS | RM1 | 3.06 | 2.81 | | | |
| 1456 | 90 | CHEVY | LUMI | L1G3.1V8XGZ5 | FAIL | PASS | RECV | 11.86 | | | | Bad Purge Solenoid |
| 1456 | 90 | CHEVY | LUMI | L1G3.1V8XGZ5 | PASS | PASS | RM1 | 1.88 | 9.98 | | | |
| 1459 | 90 | CHEVY | LUMI | 3.1L PFI | FAIL | PASS | RECV | 27.00 | | | | Purge Solenoid Inoperative |
| 1459 | 90 | CHEVY | LUMI | 3.1L PFI | PASS | PASS | RM1 | 13.85 | 13.15 | | | |
| 1532 | 86 | CHEVY | Z28 | G1G5.0V8NTA8 | FAIL | PASS | RECV | 14.02 | | | | Purge Line from Canister Disconnected |
| 1532 | 86 | CHEVY | Z28 | G1G5.0V8NTA8 | PASS | FAIL | RM1 | 14.70 | | | | Gas Cap Leaking |
| 1532 | 86 | CHEVY | Z28 | G1G5.0V8NTA8 | PASS | PASS | RM2 | 14.22 | -0.20 | | | Leak Possibly at Sending Unit Gasket |
| 1580 | 90 | CHEVY | CAVA | L1G2.2V5JFG2 | PASS | FAIL | RECV | 5.63 | | | | Gas Cap Leaks |
| 1580 | 90 | CHEVY | CAVA | L1G2.2V5JFG2 | PASS | PASS | RM1 | 0.34 | 5.30 | | | |
| 1712 | 87 | CHEVY | CAVA | 2.0L TBI | PASS | FAIL | RECV | 8.48 | | 0.45 | 0.43 | Vent Line Leaks at connection with Steel Lin |
| 1712 | 87 | CHEVY | CAVA | 2.0L TBI | PASS | PASS | RM1 | 7.78 | 0.69 | | | |
| 1461 | 87 | PONTIAC | GRN AM | 2.5L TBI | PASS | FAIL | RECV | 11.53 | | | | Gas Cap Leaks, Filler Neck rusted at Cap |
| 1461 | 87 | PONTIAC | GRN AM | 2.5L TBI | PASS | PASS | RM1 | 0.10 | 11.44 | | | |
| 1530 | 84 | PONTIAC | 6000 | 2.5l TBI | PASS | FAIL | RECV | 7.73 | | | | Gas Cap Does not Seal |
| 1530 | 84 | PONTIAC | 6000 | 2.5l TBI | PASS | PASS | RM1 | 0.11 | 7.63 | | | |
| 1578 | 86 | PONTIAC | SUNB | G2G1.8V5TDG2 | PASS | FAIL | RECV | 11.70 | | | | Gas Cap Leaks |
| 1578 | 86 | PONTIAC | SUNB | G2G1.8V5TDG2 | PASS | PASS | RM1 | 14.45 | -2.75 | | | |
| 1457 | 85 | BUICK | CENT | 2.5L TBI | PASS | FAIL | RECV | 4.65 | | | | Crack in Seam of Gas Tank and Filler Neck |
| 1457 | 85 | BUICK | CENT | 2.5L TBI | PASS | PASS | RM1 | 0.11 | 4.54 | | | |
| 1524 | 85 | BUICK | LESA | 5.0L | FAIL | PASS | RECV | 3.31 | | | | TVS Broken |
| 1524 | 85 | BUICK | LESA | 5.0L | PASS | PASS | RM1 | 0.11 | 3.20 | | | |
| 1533 | 88 | BUICK | REGAL | 2.8L PFI | FAIL | PASS | RECV | 0.07 | | | | Unknown Problems |
| 1542 | 85 | BUICK | PARK | F4G3.8V8XEB3 | PASS | FAIL | RECV | 2.86 | | | | Gas Cap Does not Seal |
| 1542 | 85 | BUICK | PARK | F4G3.8V8XEB3 | PASS | PASS | RM1 | 0.44 | 2.42 | | | |
| 1544 | 86 | BUICK | CENT | G2G2.5V5TPG9 | FAIL | PASS | RECV | 10.43 | | | | Vac Line from Manifold to Purg Valve Broker |
| 1544 | 86 | BUICK | CENT | G2G2.5V5TPG9 | PASS | PASS | RM1 | 1.05 | 9.38 | | | |
| 1584 | 86 | BUICK | CENT | G2G2.5V5TPG9 | FAIL | PASS | RECV | 7.54 | | | | Purge Line Weathered. Collaspes when hot |
| 1584 | 86 | BUICK | CENT | G2G2.5V5TPG9 | PASS | PASS | RM1 | 0.14 | 7.40 | | | |
| 1672 | 86 | BUICK | LESA | G4G3.8V8XEB4 | FAIL | PASS | RECV | 7.80 | | | | Purge Solenoid Wiring Disconnected |
| 1672 | 86 | BUICK | LESA | G4G3.8V8XEB4 | PASS | PASS | RM1 | 0.87 | 6.93 | | | |

| | | | | | | As of 11 / 12 / 91 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VEH | MYR | MAKE | MODEL | ENG.FAM | Purg | Pres | TEST | TOTAL RL g/mi | RL Reduct g/mi | Hot Soak | Diurnal | COMMENTS |
| 1585 | 87 | OLDS | DELT | H2G3.8V8XEB7 | FAIL | PASS | RECV | 5.53 | | | | Purge Line Disconnected |
| 1585 | 87 | OLDS | DELT | H2G3.8V8XEB7 | PASS | PASS | RM1 | 2.14 | 3.39 | | | |
| 1661 | 85 | OLDS | CUTL | F2G2.5V5TPG8 | PASS | FAIL | RECV | 8.80 | | | | Gas Cap Leaks |
| 1661 | 85 | OLDS | CUTL | F2G2.5V5TPG8 | PASS | PASS | RM1 | 0.22 | 8.58 | | | |
| 1720 | 88 | OLDS | CUTL | 2.8L PFI | PASS | FAIL | RECV | 9.20 | | 0.76 | 1.76 | Gas Cap has a holed Drilled in it |
| 1526 | 85 | CADILLAC | SEVI | 4.1L TBI | FAIL | PASS | RECV | 5.48 | | | | Canister Purge Solenoid Inoperative |
| 1552 | 84 | CADILLAC | SEVI | E6G4.1V5NKA7 | FAIL | PASS | RECV | 7.11 | | | | Canister Purge Solenoid Bad |
| 1552 | 84 | CADILLAC | SEVI | E6G4.1V5NKA7 | PASS | PASS | RM1 | 0.20 | 6.91 | | | |
| 1560 | 86 | CADILLAC | ELDO | G6G4.1V5NKA9 | FAIL | PASS | RECV | 6.88 | | | | Purge Vapor Line on top of Can. Disconnect |
| 1560 | 86 | CADILLAC | ELDO | G6G4.1V5NKA9 | PASS | PASS | RM1 | 0.16 | 6.71 | | | |

| | | | | | | As of 11 / 12 / 91 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Veh | MYR | MAKE | MODEL | ENG.FAM | Purg | Pres | TEST | TOTAL RL g/mi | RL Reduct g/mi | Hot Soak | Diurnal | COMMENTS |
| 1460 | 85 | FORD | CROWN | 5.0L TBI | FAIL | PASS | RECV | 7.15 | | | | Electronic Purge Solenoid Inoperative |
| 1460 | 85 | FORD | CROWN | 5.0L TBI | PASS | PASS | RM1 | 0.25 | 6.90 | | | |
| 1462 | 88 | FORD | MUST | 2.3L PFI | PASS | FAIL | RECV | 9.17 | | | | Plastic Vent Line from Canister Missing |
| 1462 | 88 | FORD | MUST | 2.3L PFI | PASS | PASS | RM1 | 2.39 | 6.78 | | | |
| 1525 | 89 | FORD | MUST | 5.0L PFI | FAIL | PASS | RECV | 11.63 | | | | Connector at Can. does not make connectio |
| 1525 | 89 | FORD | MUST | 5.0L PFI | PASS | PASS | RM1 | 0.82 | 10.81 | | | |
| 1563 | 85 | FORD | TEMP | FFM2.3V5HCF4 | FAIL | PASS | RECV | 5.26 | | | | Purge Solenoid Inoperative |
| 1563 | 85 | FORD | TEMP | FFM2.3V5HCF4 | PASS | PASS | RM1 | 0.24 | 5.03 | | | |
| 1574 | 87 | FORD | ESCO | HFM1.9V5FFF1 | PASS | FAIL | RECV | 3.58 | | | | Sending Unit Gasket does not seal |
| 1574 | 87 | FORD | ESCO | HFM1.9V5FFF1 | PASS | PASS | RM1 | 0.11 | 3.48 | | | |
| 1575 | 89 | FORD | TAUR | KFM2.5V5HCF1 | FAIL | PASS | RECV | 10.41 | | | | Purge Vac Line burned through |
| 1575 | 89 | FORD | TAUR | KFM2.5V5HCF1 | PASS | PASS | RM1 | 0.08 | 10.33 | | | |
| 1647 | 86 | FORD | MUST | GFM5.0V5HBF9 | PASS | FAIL | RECV | 8.60 | | | | Fuel Tank Vent line disconnected at Canister |
| 1647 | 86 | FORD | MUST | GFM5.0V5HBF9 | PASS | PASS | RM1 | 0.36 | 8.24 | | | |
| 1676 | 84 | FORD | CROWN | EFM5.0V5HBF7 | FAIL | PASS | RECV | 4.43 | | | | Purge Vac Line Misrouted |
| 1676 | 84 | FORD | CROWN | EFM5.0V5HBF7 | PASS | PASS | RM1 | 1.81 | 2.62 | | | |
| 1450 | 88 | MERCURY | TRAC | JFM1.6V5FZK0 | FAIL | PASS | RECV | 1.22 | | | | Broken Purge Line Fittings |
| 1450 | 88 | MERCURY | TRAC | JFM1.6V5FZK0 | PASS | PASS | RM1 | 0.17 | 1.06 | | | |
| 1537 | 86 | MERCURY | COUG | 3.8L TBI | PASS | FAIL | RECV | 6.76 | | | | Vapor Line Disconnected at Rollover Valve |
| 1537 | 86 | MERCURY | COUG | 3.8L TBI | PASS | PASS | RM1 | 0.05 | 6.71 | | | |
| 1561 | 85 | MERCURY | TOPA | FFM2.3V5HCF4 | FAIL | PASS | RECV | 3.88 | | | | Purge Solenoid Inoperative |
| 1561 | 85 | MERCURY | TOPA | FFM2.3V5HCF4 | PASS | PASS | RM1 | 0.10 | 3.78 | | | |
| 1689 | 85 | MERCURY | MARQ | 5.0 L TBI | FAIL | PASS | RECV | 3.49 | | 0.68 | 0.74 | TVS is stuck in the Closed Position |
| 1689 | 85 | MERCURY | MARQ | 5.0 L TBI | PASS | PASS | RM1 | 0.25 | 3.24 | | | |
| 1802 | 83 | MERCURY | MARQ | 5.0L TBI | FAIL | FAIL | RECV | 6.28 | | | | Recv - Tank Vent line plugged. Battery Acid |
| 1802 | 83 | MERCURY | MARQ | 5.0L TBI | FAIL | FAIL | RM1 | 6.34 | | | | destroyed Canister. |
| 1802 | 83 | MERCURY | MARQ | 5.0L TBI | PASS | PASS | RM2 | 0.12 | 6.16 | | | RM1 - Repaired Purge Lines |
| | | | | | | | | | | | | RM2 - New Normalized Canister |
| 1548 | 88 | LINCOLN | MARK | JFM5.0V5HBF3 | FAIL | PASS | RECV | 12.26 | | | | Electrical Connection at Purge Solenoid Bad |
| 1548 | 88 | LINCOLN | MARK | JFM5.0V5HBF3 | PASS | PASS | RM1 | 1.40 | 10.86 | | | |
| 1639 | 81 | LINCOLN | TOWN | 5.0CCF | FAIL | PASS | RECV | 4.09 | | | | Electrical Grounding Problem near ECM |
| 1713 | 86 | LINCOLN | TOWN | 5.0L PFI | FAIL | PASS | RECV | 8.06 | | | | Purge Hose Disconnected |
| 1713 | 86 | LINCOLN | TOWN | 5.0L PFI | PASS | PASS | RM1 | 0.09 | | | | |
| 1713 | 86 | LINCOLN | TOWN | 5.0L PFI | PASS | PASS | REP | 0.12 | 7.94 | | | |

| | PRESSURE FAILURES | | FIRST THREE BAGS | Fuel Consumption | Total Fuel+RL HC | Parts | | Labor | | '@ $50/HR | '@ $50/HR | PARTS | '@ $50/HR LABOR | FUEL ECONOMY | '@ $50/HR TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | HC Red | HC Red | HC fuel Red | Savings | Cost | Cost | Time | Labor | Cost | Cost | Cost / Red | Cost / Red | SAVINGS | Cost / Red |
| VEHICLE | DIAGNOSIS OR REPAIRS | g / tst | g / mile | g/mile | g/mile | BASIS | Parts | BASIS | TIME | Labor | Total | $/g/mile | $/g/mile | gal/mile | $/g/mile |
| 1530 | NEW OEM GAS CAP | 171.60 | 5.88 | 17.35 | 23.23 | Est | $7.00 | Est | 0.25 | $12.50 | $19.50 | $0.30 | $0.54 | 0.0096 | $0.84 |
| 1532 | REPLACE GAS CAP | -4.40 | 0.04 | 8.23 | 8.27 | Act | $3.62 | Act | 0.25 | $12.50 | $16.12 | $0.44 | $1.51 | 0.0034 | $1.95 |
| 1537 | RECONNECTED FUEL TANK VAPOR LINE TO ROLLOVER VALVE | 151.00 | 4.54 | 1.63 | 6.17 | Est | $0.00 | Est | 0.50 | $25.00 | $25.00 | $0.00 | $4.05 | 0.0025 | $4.05 |
| 1541 | REPLACED OVERFLOW HOSE WHICH WAS SPLIT | 56.50 | 2.99 | -1.33 | 1.66 | Est | $0.00 | Est | 0.50 | $25.00 | $25.00 | $0.00 | $15.04 | 0.0007 | $15.04 |
| 1542 | REPLACED FILLER NECK AND GAS CAP | 54.40 | 1.54 | -24.88 | -23.34 | Act | $33.40 | Act | 1.00 | $50.00 | $83.40 | ($1.43) | ($2.14) | -0.0096 | ($3.57) |
| 1574 | GASKET AROUND SENDING UNIT DOES NOT SEAL PROPERLY | 76.40 | 2.88 | 26.11 | 28.99 | Est | $93.11 | Est | 1.00 | $50.00 | $143.11 | $3.21 | $1.73 | 0.0120 | $4.94 |
| 1578 | GAS CAP LEAKS | -61.90 | 2.98 | 9.11 | 12.09 | Est | $7.00 | Est | 0.25 | $12.50 | $19.50 | $0.58 | $1.03 | 0.0050 | $1.61 |
| 1580 | GAS CAP LEAKS | 119.10 | 4.57 | 15.86 | 20.43 | Est | $7.00 | Est | 0.25 | $12.50 | $19.50 | $0.34 | $0.61 | 0.0084 | $0.95 |
| 1647 | RECONNECT FUEL TANK VENT LINE TO CANISTER | 185.40 | 4.29 | -4.73 | -0.44 | Est | $0.00 | Est | 0.50 | $25.00 | $25.00 | $0.00 | ($57.34) | -0.0002 | ($57.34) |
| 1661 | GAS CAP LEAKS | 193.00 | 6.56 | 4.45 | 11.01 | Est | $7.00 | Est | 0.25 | $12.50 | $19.50 | $0.64 | $1.14 | 0.0045 | $1.77 |
| 1667 | GAS CAP LEAKS | 115.30 | 5.02 | '---- | '---- | Est | $7.20 | Est | 0.25 | $12.50 | $19.70 | '---- | '---- | '---- | '---- |
| | | | | | | | | | | | | | | | |
| Average | | 96.04 | 3.75 | 5.18 | 8.81 | | $15.03 | | 0.45 | $22.73 | $37.76 | $1.71 | $2.58 | 0.0036 | $4.29 |

| | PURGE FAILURES | | FIRST THREE BAGS | Fuel Consumption | Total Fuel+RL HC | Parts | | Labor | | '@ $50/HR | '@ $50/HR | PARTS | '@ $50/HR LABOR | FUEL ECONOMY | '@ $50/HR TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | HC Red | HC Red | HC fuel Red | Savings | Cost | Cost | Time | Labor | Cost | Cost | Cost / Red | Cost / Red | SAVINGS | Cost / Red |
| VEHICLE | DIAGNOSIS OR REPAIRS | g / tst | g / mile | g/mile | g/mile | BASIS | Parts | BASIS | TIME | Labor | Total | $/g/mile | $/g/mile | gal/mile | $/g/mile |
| 1524 | REPLACE THERMAL-VACUUM SWITCH | 71.90 | 1.37 | -3.52 | -2.15 | Est | $20.41 | Est | 0.50 | $25.00 | $45.41 | ($9.48) | ($11.62) | -0.0009 | ($21.10) |
| 1525 | REPLACE MALE END OF CONNECTOR TO CANISTER PURGE SOLEN | 243.20 | 7.35 | -13.67 | -6.32 | Est | $29.46 | Est | 0.50 | $25.00 | $54.46 | ($4.66) | ($3.96) | -0.0026 | ($8.62) |
| 1544 | VAC LINE RECONNECTED FROM MANIFOLD TO PURGE VALVE | 211.00 | 7.21 | 1.51 | 8.72 | Est | $0.00 | Est | 0.50 | $25.00 | $25.00 | $0.00 | $2.87 | 0.0036 | $2.87 |
| 1548 | PURGE SOLENOID REPLACED | 244.30 | 6.43 | 7.68 | 14.11 | Act | $38.53 | Act | 6.00 | $300.00 | $338.53 | $2.73 | $21.26 | 0.0058 | $23.99 |
| 1552 | REPLACED FAULTY CANISTER PURGE SOLENOID | 155.50 | 5.42 | -2.35 | 3.07 | Est | $29.46 | Est | 0.50 | $25.00 | $54.46 | $9.61 | $8.15 | 0.0013 | $17.76 |
| 1555 | TEE FITTING REPLACED | 123.10 | 3.61 | 4.69 | 8.30 | Est | $1.00 | Act | 0.50 | $25.00 | $26.00 | $0.12 | $3.01 | 0.0034 | $3.13 |
| 1560 | PURGE LINE RECONNECTED | 150.99 | 5.63 | 14.78 | 20.41 | Act | $0.00 | Act | 0.50 | $25.00 | $25.00 | $0.00 | $1.22 | 0.0084 | $1.22 |
| 1561 | PURGE SOLENOID REPLACED | 84.90 | 3.20 | 0.08 | 3.28 | Act | $37.04 | Act | 0.50 | $25.00 | $62.04 | $11.29 | $7.62 | 0.0014 | $18.91 |
| 1563 | PURGE SOLENOID REPLACED | 113.10 | 4.16 | -5.83 | -1.67 | Act | $130.15 | Act | 1.50 | $75.00 | $205.15 | ($77.84) | ($44.86) | -0.0007 | ($122.70) |
| 1575 | PURGE VACUUM LINE TO THE ENGINE HAS A HOLE BURNED THR | 232.46 | 8.51 | 18.10 | 26.61 | Est | $0.00 | Est | 0.50 | $25.00 | $25.00 | $0.00 | $0.94 | 0.0110 | $0.94 |
| 1584 | PURGE LINE IS WEATHERED AND COLLAPSES WHEN HOT | 166.60 | 4.03 | -9.80 | -5.77 | Est | $0.00 | Est | 0.50 | $25.00 | $25.00 | $0.00 | ($4.33) | -0.0024 | ($4.33) |
| 1585 | PURGE LINE IS DISCONNECTED | 76.30 | 4.02 | 41.00 | 45.02 | Est | $0.00 | Est | 0.50 | $25.00 | $25.00 | $0.00 | $0.56 | 0.0186 | $0.56 |
| 1587 | PURGE LINE IS BROKEN NEAR ENGINE | 130.00 | 4.14 | -0.63 | 3.51 | Est | $0.00 | Est | 0.50 | $25.00 | $25.00 | $0.00 | $7.12 | 0.0015 | $7.12 |
| 1640 | THERMAL VACUUM SWITCH REPLACED | 56.60 | 1.40 | 41.02 | 42.42 | Act | $20.41 | Est | 0.50 | $25.00 | $45.41 | $0.48 | $0.59 | 0.0175 | $1.07 |
| | | | | | | | | | | | | | | | |
| Average | | 147.14 | 4.75 | 6.65 | 11.40 | | $21.89 | | 0.96 | $48.21 | $70.10 | $1.92 | $4.23 | 0.0047 | $6.15 |

| | | | | | | As of 11 / 12 / 91 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VEH | MYR | MAKE | MODEL | ENG.FAM | Purg | Pres | TEST | TOTAL RL g/mi | RL Reduct g/mi | Hot Soak | Diurnal | COMMENTS |
| 1555 | 88 | CHRYSLER | LEBA | JCR2.5V5FBE6 | FAIL | PASS | RECV | 5.52 | | | | Tee fitting in purge line broken at Throttle Bo |
| 1555 | 88 | CHRYSLER | LEBA | JCR2.5V5FBE6 | PASS | PASS | RM1 | 0.05 | 5.47 | | | |
| 1458 | 87 | DODGE | LANC | 2.2L TBI | PASS | FAIL | RECV | 4.20 | | | | Vehicle has a Broken Rollover Valve |
| 1458 | 87 | DODGE | LANC | 2.2L TBI | PASS | PASS | RM1 | 0.08 | 4.12 | | | |
| 1587 | 86 | DODGE | DAYT | GCR2.2V5FAAX | FAIL | PASS | RECV | 5.86 | | | | Purge Line Broken near Engine |
| 1587 | 86 | DODGE | DAYT | GCR2.2V5FAAX | PASS | PASS | RM1 | 0.08 | 5.78 | | | |
| 1635 | 84 | DODGE | DAYT | ECR2.2V5FAA8 | FAIL | PASS | RECV | 5.43 | | | | Canister Purge Line is Burned in Half |
| 1559 | 89 | PLYMOUTH | ACCL | KCR2.5V5FBD6 | FAIL | PASS | RECV | 3.81 | | | | Purge Valve Stuck |

| | | | | | | As of 11 / 12 / 91 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VEH | MYR | MAKE | MODEL | ENG.FAM | Purg | Pres | TEST | TOTAL RL g/mi | RL Reduct g/mi | Hot Soak | Diurnal | COMMENTS |
| 1541 | 83 | RENAULT | ALLI | DAM1.4V5FFD3 | PASS | FAIL | RECV | 2.57 | | | | Fuel Sending Unit Gasket |
| 1541 | 83 | RENAULT | ALLI | DAM1.4V5FFD3 | PASS | PASS | RM1 | 0.06 | 2.51 | | | |
| 1568 | 86 | MAZDA | RX-7 | GTK1.3V5HFD8 | FAIL | PASS | RECV | 4.79 | | | | Purges thru Oil Filler. Oil cap does not seal |
| 1640 | 84 | TOYOTA | CELI | ETY2.8V5FBB5 | FAIL | PASS | RECV | 3.08 | | | | TVS is Broken |
| 1640 | 84 | TOYOTA | CELI | ETY2.8V5FBB5 | PASS | PASS | RM1 | 0.57 | 2.51 | | | |
| 1667 | 85 | RENAULT | ALLI | FAM1.4V5FFA2 | PASS | FAIL | RECV | 5.19 | | | | Gas Cap Leaks |
| 1667 | 85 | RENAULT | ALLI | FAM1.4V5FFA2 | PASS | PASS | RM1 | 0.07 | 5.12 | | | |

# APPENDIX K

## MOBILE4.1 PERFORMANCE STANDARD ANALYSES, BY OPTION

```
1Run #8p Mod. High Option,  Performance Standard Options (annual)
 MOBILE4.1(4Nov91)
0
-M120 Warning:
+              MOBILE4.1 does not model most 1993 and later Clean Air Act
               requirements: Emission Factors for CY 1993 or later are affected.
0I/M program selected:
0    Start year (January 1):              1983
     Pre-1981 MYR stringency rate:         20%
     First model year covered:            1968
     Last model year covered:             2020
     Waiver rate (pre-1981):               1.%
     Waiver rate (1981 and newer):         1.%
     Compliance Rate:                     98.%
     Inspection type:                     Centralized
     Inspection frequency                 Annual
     Vehicle types covered:               LDGV - Yes
                                         LDGT1 - Yes
                                         LDGT2 - Yes
                                          HDGV - No
     1981 & later MYR test type:          2500 rpm / Idle

 ************************************************************************
 **                                                                    **
 **  MOBILE4.1 IM240 Transient Annual I/M Credits .8/15 (8/5/91)       **
 **                                                                    **
 ************************************************************************

 Oldest model year covered by:
     IM240 Transient Test                 1986
     Purge System Check                   1986
     Fuel System Pressure Check           1983
0Anti-tampering program selected:
0    Start year (January 1):              1983
     First model year covered:            1984
     Last model year covered:             2020
     Vehicle types covered:               LDGV , LDGT1, LDGT2
0    Type:                                Centralized
     Frequency:                           Annual
     Compliance Rate:                     98.0%
0    Air pump system disablements:        No
     Catalyst removals:                   Yes
     Fuel inlet restrictor disablements:  Yes
     Tailpipe lead deposit test:          No
     EGR disablement:                     No
     Evaporative system disablements:     No
     PCV system disablements:             No
     Missing gas caps:                    No
0                                  Minimum Temp:  72. (F)        Maximum Temp:  92. (F)
                    Period 1 RVP: 11.5      Period 2 RVP:  8.7       Period 2 Start Yr: 1992
0VOC HC emission factors include evaporative HC emission factors.
0
0Cal. Year: 2000        I/M Program: Yes        Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                  Anti-tam. Program: Yes      Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
0  Veh. Type:       LDGV      LDGT1      LDGT2       LDGT       HDGV       LDDV       LDDT       HDDV       MC      All Veh
+
 Veh. Speeds:      19.6       19.6       19.6                  19.6       19.6       19.6       19.6       19.6
     VMT Mix:     0.584      0.199      0.080                 0.035      0.002      0.001      0.093      0.007
0Composite Emission Factors (Gm/Mile)
 VOC       HC:    1.16       1.50       1.69       1.56       4.54       0.65       0.84       2.15       4.96      1.503
 Exhaust   HC:    0.48       0.81       0.90       0.83       2.07       0.65       0.84       2.15       1.89      0.796
 Evaporat HC:     0.16       0.17       0.24       0.19       1.44                                         2.52      0.213
 Refuel L HC:     0.19       0.25       0.25       0.25       0.40                                                   0.192
 Runing L HC:     0.23       0.19       0.20       0.19       0.51                                                   0.204
 Rsting L HC:     0.11       0.10       0.10       0.10       0.12                                         0.54      0.098
 Exhaust   CO:    6.17       7.39       8.58       7.73      36.27       1.60       1.74      11.21      24.78      8.230
 Exhaust NOX:     0.72       1.05       1.13       1.07       4.51       1.37       1.50       9.30       0.77      1.753
```

**Mobile output from CEM 4.1 1/24/92**

Run #2 : Basic I/M
MOBILE4.1(4Nov91)

M120 Warning: MOBILE4.1 does not model most 1993 and later Clean Air Act requirements; Emission Factors for CY 1993 or later are affected.

I/M program selected:

| | |
|---|---|
| Start year (January 1): | 1983 |
| Pre-1981 MYR stringency rate: | 20% |
| First model year covered: | 1968 |
| Last model year covered: | 2020 |
| Waiver rate (pre-1981): | 0.% |
| Waiver rate (1981 and newer): | 0.% |
| Compliance Rate: | 100.% |
| Inspection type: | Centralized |
| Inspection frequency | Annual |
| Vehicle types covered: | LDGV - Yes |
| | LDGT1 - No |
| | LDGT2 - No |
| | HDGV - No |
| 1981 & later MYR test type: | Idle |

Oldest model year covered by:

| | |
|---|---|
| IM240 Transient Test | 2020 |
| Purge System Check | 2020 |
| Fuel System Pressure Check | 2020 |

Minimum Temp: 72. (F) Maximum Temp: 92. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

VOC HC emission factors include evaporative HC emission factors.

---

Cal. Year: 2000 I/M Program: Yes Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 19.6 | 19.6 | 19.6 | | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | |
| VMT Mix: | 0.584 | 0.199 | 0.080 | | 0.035 | 0.002 | 0.001 | 0.093 | 0.007 | |
| Composite Emission Factors (Gm/Mile) | | | | | | | | | | |
| VOC HC: | 1.58 | 2.25 | 2.59 | 2.35 | 4.54 | 0.65 | 0.84 | 2.15 | 4.96 | 1.971 |
| Exhaust HC: | 0.52 | 1.20 | 1.37 | 1.25 | 2.07 | 0.65 | 0.84 | 2.15 | 1.89 | 0.937 |
| Evaporat HC: | 0.36 | 0.35 | 0.46 | 0.38 | 1.44 | | | | 2.52 | 0.381 |
| Refuel L HC: | 0.19 | 0.25 | 0.25 | 0.25 | 0.40 | | | | | 0.192 |
| Runing L HC: | 0.42 | 0.36 | 0.40 | 0.37 | 0.51 | | | | | 0.364 |
| Rsting L HC: | 0.11 | 0.10 | 0.10 | 0.10 | 0.12 | | | | 0.54 | 0.098 |
| Exhaust CO: | 6.88 | 11.96 | 14.40 | 12.66 | 36.27 | 1.60 | 1.74 | 11.21 | 24.78 | 10.021 |
| Exhaust NOX: | 0.73 | 1.15 | 1.25 | 1.18 | 4.51 | 1.37 | 1.50 | 9.30 | 0.77 | 1.783 |

---

Cal. Year: 2000 I/M Program: No Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 19.6 | 19.6 | 19.6 | | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | |
| VMT Mix: | 0.584 | 0.199 | 0.080 | | 0.035 | 0.002 | 0.001 | 0.093 | 0.007 | |
| Composite Emission Factors (Gm/Mile) | | | | | | | | | | |
| VOC HC: | 1.77 | 2.25 | 2.59 | 2.35 | 4.54 | 0.65 | 0.84 | 2.15 | 4.96 | 2.084 |
| Exhaust HC: | 0.71 | 1.20 | 1.37 | 1.25 | 2.07 | 0.65 | 0.84 | 2.15 | 1.89 | 1.049 |
| Evaporat HC: | 0.36 | 0.35 | 0.46 | 0.38 | 1.44 | | | | 2.52 | 0.382 |
| Refuel L HC: | 0.19 | 0.25 | 0.25 | 0.25 | 0.40 | | | | | 0.192 |
| Runing L HC: | 0.42 | 0.36 | 0.40 | 0.37 | 0.51 | | | | | 0.364 |
| Rsting L HC: | 0.11 | 0.10 | 0.10 | 0.10 | 0.12 | | | | 0.54 | 0.098 |
| Exhaust CO: | 10.05 | 11.96 | 14.40 | 12.66 | 36.27 | 1.60 | 1.74 | 11.21 | 24.78 | 11.874 |
| Exhaust NOX: | 0.75 | 1.15 | 1.25 | 1.18 | 4.51 | 1.37 | 1.50 | 9.30 | 0.77 | 1.799 |

---

CEM4.1 : Run #2 : Basic I/M

01/24/92 13:41:59

Local Parameters Selected:

Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

Base RVP: 11.5
In-use RVP: 8.7 In-use Start Yr: 1992 Minimum Temp: 72. (F)
Maximum Temp: 92. (F)

| Vehicle Type: | LDGV | LDGT1 | LDGT2 | HDGV | LDDV | LDDT | HDDV | MC |
|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 |

I/M Program Selected:

I/M start year (January 1): 1983 Stringency: 20
Tampering deterrence start: 1983
Oldest model year covered: 1968-2020 Fixed
I/M inspection frequency: Annual
I/M program type: Centralized
1981 & later MYR test type: Idle
Vehicle types covered: LDGV
I/M waiver rate (pre-1981): 0.0%
I/M waiver rate (post-1981): 0.0%
I/M compliance rate: 100.0%

IM240 test model year coverage: 2020+
Purge check model year coverage: 2020+
Pressure check model year coverage: 2020+

Cost Assumptions

I/M inspection cost: (per insp) $ 8.00
Avg. Gasoline Cost(per gallon): $ 1.25

Fleet Assumptions

| | LDGV | LDT1 | LDT2 | HDGV | LDDV | LDDT | HDDV | MC |
|---|---|---|---|---|---|---|---|---|
| Vehicle percentages: | 63.2 | 19.7 | 8.1 | 3.6 | 0.2 | 0.2 | 3.3 | 1.8 |

Growth rate: 0.0 % per year
Fleet size is 1000000. vehicles in base year 1986

| Repair Costs | Pre-81 | 81+ |
|---|---|---|
| Avg. I/M repair cost : $ | 50. | 75. |

( IM240 repair = $ 150. NOx repair= $ 0. )

Benefits (1000 tons/yr) and Costs (1000 $/yr) are averaged over the calendar years 2000 thru 2000.

| Calendar Year 2000<br>Fleet Size 1000000 | TotVOC | CO | ExhHC | Evap | Refuel | RnLoss | RstLos |
|---|---|---|---|---|---|---|---|
| Baseline No-Program Emissions: | 21.955 | 123.217 | 10.929 | 4.024 | 2.067 | 3.897 | 1.038 |

Program Benefits and Costs

| | VOC | CO | Cost | |
|---|---|---|---|---|
| Average Annual ATP Benefit,Fee | 0.000 | 0.000 | 0. | |
| Evap/RunLoss Benefit, Fee | 0.006 | | 0. | |
| Evap/RunLoss MPG Benefit | | | ( 0.) | |
| Avg Annual I/M Benefit, Fee | 1.033 | 17.762 | 5074. | |
| Avg Annual ATP Repair Cost | | | 0. | |
| Avg Ann. Prg/Press Repair Cost | | | 0. | |
| Avg Ann. IM Repair Cost,FailRt | | | 3536. | 0.0483 |
| Average Annual IM Fuel Savings | | | ( 2198.) | |
| Exhaust Tampering Deterrence | 0.142 | 1.646 | | |
| Ann Avg | 1.181 | 19.408 | 6412. | |
| ( | 2936 | 48237 | kilograms per day ) | |

| Evap | RnLoss | ExhHC |
|---|---|---|
| 0.005 | 0.001 | 1.175 |

CEM4.1 : Run #10 High Option (Biennial) 01/24/92 13:43:18

Local Parameters Selected:

Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

Base RVP: 11.5
In-use RVP: 8.7 In-use Start Yr: 1992 Minimum Temp: 72. (F)
Maximum Temp: 92. (F)

| Vehicle Type: | LDGV | LDGT1 | LDGT2 | HDGV | LDDV | LDDT | HDDV | MC |
|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 |

I/M Program Selected:

I/M start year (January 1): 1983 Stringency: 20
Tampering deterrence start: 1983
Oldest model year covered: 1968-2020 Fixed
I/M inspection frequency: Biennial
I/M program type: Centralized
1981 & later MYR test type: 2500 rpm / Idle IM240 test model year coverage: 1984+
Vehicle types covered: LDGV, LDGT1, LDGT2 Purge check model year coverage: 1984+
I/M waiver rate (pre-1981): 1.0% Pressure check model year coverage: 1971+
I/M waiver rate (post-1981): 1.0%
I/M compliance rate: 98.0%

Anti-Tampering Program Selected:

ATP start year (January 1): 1983 ATP compliance rate: 98.0%
ATP inspection frequency: Biennial ATP program type: Centralized
Oldest model year covered: 1975-2020 Fixed
Vehicle types covered: LDGV , LDGT1, LDGT2
Parameters covered by ATP: Air Pump / Catalyst / Fuel Inlet / Plumbtesmo /
Evap System / PCV System / Gas Cap /

Cost Assumptions

| | |
|---|---|
| I/M inspection cost: (per insp) | $ 8.00 |
| ATP inspection cost: (per insp) | $ 0.50 |
| Purge inspect cost (per insp) : | $ 6.53 |
| Pressure insp cost (per insp) : | $ 0.69 |
| IM240 insp incremnt over Purge: | $ 0.87 |
| Avg. Gasoline Cost(per gallon): | $ 1.25 |

Fleet Assumptions

| | LDGV | LDT1 | LDT2 | HDGV | LDDV | LDDT | HDDV | MC |
|---|---|---|---|---|---|---|---|---|
| Vehicle percentages: | 63.2 | 19.7 | 9.1 | 3.6 | 0.2 | 0.2 | 3.3 | 1.8 |

Growth rate: 0.0 % per year

Fleet size is 1000000. vehicles in base year 1986

| Repair Costs | Pre-81 | 81+ | |
|---|---|---|---|
| Avg. I/M repair cost : | $ 50. | 75. | ( IM240 repair = $ 120. NOx repair= $ 0. ) |
| Air Pump repair cost : | $ 15. | 15. | |
| Catalyst replacemnent cost: | $ 150. | 165. | |
| Misfueled catalyst cost : | $ 175. | 190. | |
| Evap. system repair cost : | $ 5. | 5. | |
| PCV system repair cost : | $ 5. | 5. | |
| Gas cap repair cost : | $ 5. | 5. | |
| Purge repair cost : | $ 70. | 70. | |
| Pressure repair cost : | $ 38. | 38. | |

Benefits (1000 tons/yr) and Costs (1000 $/yr) are averaged over the calendar years 2000 thru 2000.

| Calendar Year 2000 | TotVOC | CO | ExhHC | Evap | Refuel | RnLoss | RstLos |
|---|---|---|---|---|---|---|---|
| Fleet Size 1000000 | | | | | | | |
| Baseline No-Program Emissions: | 21.955 | 123.217 | 10.929 | 4.024 | 2.067 | 3.897 | 1.038 |

Program Benefits and Costs

| | VOC | CO | Cost | |
|---|---|---|---|---|
| Average Annual ATP Benefit,Fee | 0.496 | 4.648 | 228. | |
| Evap/RunLoss Benefit, Fee | 3.583 | | 3057. | |
| Evap/RunLoss MPG Benefit | | | ( 3363.) | |
| Avg Annual I/M Benefit, Fee | 1.925 | 30.973 | 4006. | |
| Avg Annual ATP Repair Cost | | | 888. | |
| Avg Ann. Prg/Press Repair Cost | | | 3577. | |
| Avg Ann. IM Repair Cost,FailRt | | | 7015. | 0.0894 |
| Average Annual IM Fuel Savings | | | ( 9979.) | |
| Exhaust Tampering Deterrence | 0.210 | 2.315 | | |
| | 6.214 | 37.937 | 5429. | |

| Evap | RnLoss | ExhHC | Ann Avg | | |
|---|---|---|---|---|---|
| 1.873 | 1.710 | 2.631 | ( 15443 | 94290 | kilograms per day ) |

Local Parameters Selected:

Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

Base RVP: 11.5
In-use RVP: 8.7
In-use Start Yr: 1992
Minimum Temp: 72. (F)
Maximum Temp: 92. (F)

| Vehicle Type: | LDGV | LDGT1 | LDGT2 | HDGV | LDDV | LDDT | HDDV | MC |
|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 |

I/M Program Selected:

I/M start year (January 1): 1983
Tampering deterrence start: 1983
Oldest model year covered: 1968-2020 Fixed
I/M inspection frequency: Annual
I/M program type: Centralized
1981 & later MYR test type: Idle
Vehicle types covered: LDGV, LDGT1, LDGT2
I/M waiver rate (pre-1981): 1.0%
I/M waiver rate (post-1981): 1.0%
I/M compliance rate: 98.0%
Stringency: 20
IM240 test model year coverage: 2020+
Purge check model year coverage: 2020+
Pressure check model year coverage: 2020+

Anti-Tampering Program Selected:

ATP start year (January 1): 1983
ATP inspection frequency: Annual
Oldest model year covered: 1981-2020 Fixed
Vehicle types covered: LDGV , LDGT1, LDGT2
Parameters covered by ATP: Catalyst / Fuel Inlet /
ATP compliance rate: 98.0%
ATP program type: Centralized

Cost Assumptions

I/M inspection cost: (per insp) $ 8.00
ATP inspection cost: (per insp) $ 0.50
Avg. Gasoline Cost(per gallon): $ 1.25

Fleet Assumptions

| | LDGV | LDT1 | LDT2 | HDGV | LDDV | LDDT | HDDV | MC |
|---|---|---|---|---|---|---|---|---|
| Vehicle percentages: | 63.2 | 19.7 | 8.1 | 3.6 | 0.2 | 0.2 | 3.3 | 1.8 |

Growth rate: 0.0 % per year
Fleet size is 1000000. vehicles in base year 1986

| Repair Costs | Pre-81 | 81+ |
|---|---|---|
| Avg. I/M repair cost : $ | 50. | 75. |
| Air Pump repair cost : $ | 15. | 15. |
| Catalyst replacement cost: $ | 150. | 165. |
| Misfueled catalyst cost : $ | 175. | 190. |
| Evap. system repair cost : $ | 5. | 5. |
| PCV system repair cost : $ | 5. | 5. |
| Gas cap repair cost : $ | 5. | 5. |

( IM240 repair = $ 150. NOx repair= $ 0. )

Benefits (1000 tons/yr) and Costs (1000 $/yr) are averaged over the calendar years 2000 thru 2000.

| Calendar Year 2000<br>Fleet Size 1000000 | TotVOC | CO | ExhHC | Evap | Refuel | RnLoss | RstLos |
|---|---|---|---|---|---|---|---|
| Baseline No-Program Emissions: | 21.955 | 123.217 | 10.929 | 4.024 | 2.067 | 3.897 | 1.038 |

Program Benefits and Costs

| | VOC | CO | Cost | |
|---|---|---|---|---|
| Average Annual ATP Benefit,Fee | 0.287 | 1.684 | 439. | |
| Evap/RunLoss Benefit, Fee | 0.034 | | 0. | |
| Evap/RunLoss MPG Benefit | | | ( 0.) | |
| Avg Annual I/M Benefit, Fee | 1.697 | 26.634 | 7280. | |
| Avg Annual ATP Repair Cost | | | 584. | |
| Avg Ann. Prg/Press Repair Cost | | | 0. | |
| Avg Ann. IM Repair Cost,FailRt | | | 5192. | 0.0738 |
| Average Annual IM Fuel Savings | | | ( 3609.) | |
| Exhaust Tampering Deterrence | 0.210 | 2.315 | | |
| | 2.229 | 30.633 | 9885. | |

| Evap | RnLoss | ExhHC | Ann Avg | |
|---|---|---|---|---|
| 0.032 | 0.003 | 2.194 | ( 5539 | 76136 kilograms per day ) |

CEM4.1 : Run #5 Medium Option 01/24/92 13:42:28

Local Parameters Selected:

Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

Base RVP: 11.5
In-use RVP: 8.7 In-use Start Yr: 1992 Minimum Temp: 72. (F)
Maximum Temp: 92. (F)

| Vehicle Type: | LDGV | LDGT1 | LDGT2 | HDGV | LDDV | LDDT | HDDV | MC |
|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 |

I/M Program Selected:

I/M start year (January 1): 1983 Stringency: 20
Tampering deterrence start: 1983
Oldest model year covered: 1968-2020 Fixed
I/M inspection frequency: Annual
I/M program type: Centralized
1981 & later MYR test type: Idle IM240 test model year coverage: 2020+
Vehicle types covered: LDGV, LDGT1, LDGT2 Purge check model year coverage: 2020+
I/M waiver rate (pre-1981): 1.0% Pressure check model year coverage: 1971+
I/M waiver rate (post-1981): 1.0%
I/M compliance rate: 98.0%

Anti-Tampering Program Selected:

ATP start year (January 1): 1983 ATP compliance rate: 98.0%
ATP inspection frequency: Annual ATP program type: Centralized
Oldest model year covered: 1981-2020 Fixed
Vehicle types covered: LDGV , LDGT1, LDGT2
Parameters covered by ATP: Catalyst / Fuel Inlet /

| Cost Assumptions | | Fleet Assumptions | LDGV | LDT1 | LDT2 | HDGV | LDDV | LDDT | HDDV | MC |
|---|---|---|---|---|---|---|---|---|---|---|
| I/M inspection cost: (per insp) | $ 8.00 | Vehicle percentages: | 63.2 | 19.7 | 8.1 | 3.6 | 0.2 | 0.2 | 3.3 | 1.9 |
| ATP inspection cost: (per insp) | $ 0.50 | Growth rate: 0.0 % per year | | | | | | | | |
| Purge inspect cost (per insp) : | $ 6.53 | | | | | | | | | |
| Pressure insp cost (per insp) : | $ 1.94 | | | | | | | | | |
| IM240 insp incremnt over Purge: | $ 0.87 | | | | | | | | | |
| Avg. Gasoline Cost(per gallon): | $ 1.25 | | | | | | | | | |

Fleet size is 1000000. vehicles in base year 1986

| Repair Costs | Pre-81 | 81+ |
|---|---|---|
| Avg. I/M repair cost : | $ 50. | 75. |
| Air Pump repair cost : | $ 15. | 15. |
| Catalyst replacement cost: | $ 150. | 165. |
| Misfueled catalyst cost : | $ 175. | 190. |
| Evap. system repair cost : | $ 5. | 5. |
| PCV system repair cost : | $ 5. | 5. |
| Gas cap repair cost : | $ 5. | 5. |
| Purge repair cost : | $ 70. | 70. |
| Pressure repair cost : | $ 38. | 38. |

( IM240 repair = $ 150. NOx repair= $ 0. )

Benefits (1000 tons/yr) and Costs (1000 $/yr) are averaged over the calendar years 2000 thru 2000.

| Calendar Year 2000 | TotVOC | CO | ExhHC | Evap | Refuel | RnLoss | RstLos |
|---|---|---|---|---|---|---|---|
| Fleet Size 1000000 | | | | | | | |
| Baseline No-Program Emissions: | 21.955 | 123.217 | 10.929 | 4.024 | 2.067 | 3.897 | 1.038 |

Program Benefits and Costs

| | VOC | CO | Cost | |
|---|---|---|---|---|
| Average Annual ATP Benefit,Fee | 0.287 | 1.684 | 439. | |
| Evap/RunLoss Benefit, Fee | 2.262 | | 1765. | |
| Evap/RunLoss MPG Benefit | | | ( 1766.) | |
| Avg Annual I/M Benefit, Fee | 1.697 | 26.634 | 7280. | |
| Avg Annual ATP Repair Cost | | | 584. | |
| Avg Ann. Prg/Press Repair Cost | | | 1743. | |
| Avg Ann. IM Repair Cost,FailRt | | | 5192. | 0.0738 |
| Average Annual IM Fuel Savings | | | ( 3609.) | |
| Exhaust Tampering Deterrence | 0.210 | 2.315 | | |
| Ann Avg | 4.456 | 30.633 | 11628. | |

| Evap | RnLoss | ExhHC | | | | |
|---|---|---|---|---|---|---|
| 1.383 | 0.878 | 2.194 | ( | 11075 | 76136 | kilograms per day ) |

**Mobile output from CEM 4.1 1/24/92**

Run #10 High Option (Biennial)
MOBILE4.1(4Nov91)

M120 Warning: MOBILE4.1 does not model most 1993 and later Clean Air Act requirements; Emission Factors for CY 1993 or later are affected.

I/M program selected:

| | |
|---|---|
| Start year (January 1): | 1983 |
| Pre-1981 MYR stringency rate: | 20% |
| First model year covered: | 1968 |
| Last model year covered: | 2020 |
| Waiver rate (pre-1981): | 1.% |
| Waiver rate (1981 and newer): | 1.% |
| Compliance Rate: | 98.% |
| Inspection type: | Centralized |
| Inspection frequency | Biennial |
| Vehicle types covered: | LDGV - Yes |
| | LDGT1 - Yes |
| | LDGT2 - Yes |
| | HDGV - No |
| 1981 & later MYR test type: | 2500 rpm / Idle |

**********
** **
** MOBILE4.1 IM240 Transient Biennial I/M Credits .8/15 (8/5/91) **
** **
**********

Oldest model year covered by:

| | |
|---|---|
| IM240 Transient Test | 1984 |
| Purge System Check | 1984 |
| Fuel System Pressure Check | 1971 |

Anti-tampering program selected:

| | |
|---|---|
| Start year (January 1): | 1983 |
| First model year covered: | 1975 |
| Last model year covered: | 2020 |
| Vehicle types covered: | LDGV , LDGT1, LDGT2 |
| Type: | Centralized |
| Frequency: | Biennial |
| Compliance Rate: | 98.0% |
| Air pump system disablements: | Yes |
| Catalyst removals: | Yes |
| Fuel inlet restrictor disablements: | Yes |
| Tailpipe lead deposit test: | Yes |
| EGR disablement: | No |
| Evaporative system disablements: | Yes |
| PCV system disablements: | Yes |
| Missing gas caps: | Yes |

Minimum Temp: 72. (F) Maximum Temp: 92. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

VOC HC emission factors include evaporative HC emission factors.

---

Cal. Year: 2000 I/M Program: Yes Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 19.6 | 19.6 | 19.6 | | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | |
| VMT Mix: | 0.584 | 0.199 | 0.080 | | 0.035 | 0.002 | 0.001 | 0.093 | 0.007 | |
| Composite Emission Factors (Gm/Mile) | | | | | | | | | | |
| VOC HC: | 1.16 | 1.47 | 1.67 | 1.53 | 4.54 | 0.65 | 0.84 | 2.15 | 4.96 | 1.495 |
| Exhaust HC: | 0.48 | 0.80 | 0.89 | 0.82 | 2.07 | 0.65 | 0.84 | 2.15 | 1.89 | 0.796 |
| Evaporat HC: | 0.16 | 0.15 | 0.23 | 0.18 | 1.44 | | | | 2.52 | 0.206 |
| Refuel L HC: | 0.19 | 0.25 | 0.25 | 0.25 | 0.40 | | | | | 0.192 |
| Runing L HC: | 0.23 | 0.18 | 0.20 | 0.19 | 0.51 | | | | | 0.203 |
| Rsting L HC: | 0.11 | 0.10 | 0.10 | 0.10 | 0.12 | | | | 0.54 | 0.098 |
| Exhaust CO: | 6.32 | 7.06 | 8.20 | 7.38 | 36.27 | 1.60 | 1.74 | 11.21 | 24.78 | 8.223 |
| Exhaust NOX: | 0.72 | 1.05 | 1.13 | 1.07 | 4.51 | 1.37 | 1.50 | 9.30 | 0.77 | 1.750 |

---

Cal. Year: 2000 I/M Program: No Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 19.6 | 19.6 | 19.6 | | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | |
| VMT Mix: | 0.584 | 0.199 | 0.080 | | 0.035 | 0.002 | 0.001 | 0.093 | 0.007 | |
| Composite Emission Factors (Gm/Mile) | | | | | | | | | | |
| VOC HC: | 1.77 | 2.25 | 2.59 | 2.35 | 4.54 | 0.65 | 0.84 | 2.15 | 4.96 | 2.084 |
| Exhaust HC: | 0.71 | 1.20 | 1.37 | 1.25 | 2.07 | 0.65 | 0.84 | 2.15 | 1.89 | 1.049 |
| Evaporat HC: | 0.36 | 0.35 | 0.46 | 0.38 | 1.44 | | | | 2.52 | 0.382 |
| Refuel L HC: | 0.19 | 0.25 | 0.25 | 0.25 | 0.40 | | | | | 0.192 |
| Runing L HC: | 0.42 | 0.36 | 0.40 | 0.37 | 0.51 | | | | | 0.364 |
| Rsting L HC: | 0.11 | 0.10 | 0.10 | 0.10 | 0.12 | | | | 0.54 | 0.098 |
| Exhaust CO: | 10.05 | 11.96 | 14.40 | 12.66 | 36.27 | 1.60 | 1.74 | 11.21 | 24.78 | 11.874 |
| Exhaust NOX: | 0.75 | 1.15 | 1.25 | 1.18 | 4.51 | 1.37 | 1.50 | 9.30 | 0.77 | 1.799 |

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Mobile output from CEM 4.1. 1/24/92

Run #5 Medium Option
MOBILE4.1(4Nov91)

M120 Warning: MOBILE4.1 does not model most 1993 and later Clean Air Act requirements; Emission Factors for CY 1993 or later are affected.

I/M program selected:

| | |
|---|---|
| Start year (January 1): | 1983 |
| Pre-1981 MYR stringency rate: | 20% |
| First model year covered: | 1968 |
| Last model year covered: | 2020 |
| Waiver rate (pre-1981): | 1.% |
| Waiver rate (1981 and newer): | 1.% |
| Compliance Rate: | 98.% |
| Inspection type: | Centralized |
| Inspection frequency | Annual |
| Vehicle types covered: | LDGV - Yes |
| | LDGT1 - Yes |
| | LDGT2 - Yes |
| | HDGV - No |
| 1981 & later MYR test type: | Idle |

Oldest model year covered by:

| | |
|---|---|
| IM240 Transient Test | 2020 |
| Purge System Check | 2020 |
| Fuel System Pressure Check | 1971 |

Anti-tampering program selected:

| | |
|---|---|
| Start year (January 1): | 1983 |
| First model year covered: | 1981 |
| Last model year covered: | 2020 |
| Vehicle types covered: | LDGV , LDGT1, LDGT2 |
| Type: | Centralized |
| Frequency: | Annual |
| Compliance Rate: | 98.0% |
| Air pump system disablements: | No |
| Catalyst removals: | Yes |
| Fuel inlet restrictor disablements: | Yes |
| Tailpipe lead deposit test: | No |
| EGR disablement: | No |
| Evaporative system disablements: | No |
| PCV system disablements: | No |
| Missing gas caps: | No |

Minimum Temp: 72. (F) Maximum Temp: 92. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

VOC HC emission factors include evaporative HC emission factors.

Cal. Year: 2000 I/M Program: Yes Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 19.6 | 19.6 | 19.6 | | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | |
| VMT Mix: | 0.584 | 0.199 | 0.080 | | 0.035 | 0.002 | 0.001 | 0.093 | 0.007 | |
| Composite Emission Factors (Gm/Mile) | | | | | | | | | | |
| VOC HC: | 1.35 | 1.66 | 1.90 | 1.73 | 4.54 | 0.65 | 0.84 | 2.15 | 4.96 | 1.661 |
| Exhaust HC: | 0.52 | 0.86 | 0.97 | 0.89 | 2.07 | 0.65 | 0.84 | 2.15 | 1.89 | 0.838 |
| Evaporat HC: | 0.21 | 0.20 | 0.28 | 0.22 | 1.44 | | | | 2.52 | 0.252 |
| Refuel L HC: | 0.19 | 0.25 | 0.25 | 0.25 | 0.40 | | | | | 0.192 |
| Runing L HC: | 0.32 | 0.26 | 0.29 | 0.27 | 0.51 | | | | | 0.281 |
| Rsting L HC: | 0.11 | 0.10 | 0.10 | 0.10 | 0.12 | | | | 0.54 | 0.098 |
| Exhaust CO: | 7.01 | 8.07 | 9.48 | 8.47 | 36.27 | 1.60 | 1.74 | 11.21 | 24.78 | 8.927 |
| Exhaust NOX: | 0.72 | 1.05 | 1.13 | 1.07 | 4.51 | 1.37 | 1.50 | 9.30 | 0.77 | 1.752 |

Cal. Year: 2000 I/M Program: No Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 19.6 | 19.6 | 19.6 | | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | |
| VMT Mix: | 0.584 | 0.199 | 0.080 | | 0.035 | 0.002 | 0.001 | 0.093 | 0.007 | |
| Composite Emission Factors (Gm/Mile) | | | | | | | | | | |
| VOC HC: | 1.77 | 2.25 | 2.59 | 2.35 | 4.54 | 0.65 | 0.84 | 2.15 | 4.96 | 2.084 |
| Exhaust HC: | 0.71 | 1.20 | 1.37 | 1.25 | 2.07 | 0.65 | 0.84 | 2.15 | 1.89 | 1.049 |
| Evaporat HC: | 0.36 | 0.35 | 0.46 | 0.38 | 1.44 | | | | 2.52 | 0.382 |
| Refuel L HC: | 0.19 | 0.25 | 0.25 | 0.25 | 0.40 | | | | | 0.192 |
| Runing L HC: | 0.42 | 0.36 | 0.40 | 0.37 | 0.51 | | | | | 0.364 |
| Rsting L HC: | 0.11 | 0.10 | 0.10 | 0.10 | 0.12 | | | | 0.54 | 0.098 |
| Exhaust CO: | 10.05 | 11.96 | 14.40 | 12.66 | 36.27 | 1.60 | 1.74 | 11.21 | 24.78 | 11.874 |
| Exhaust NOX: | 0.75 | 1.15 | 1.25 | 1.18 | 4.51 | 1.37 | 1.50 | 9.30 | 0.77 | 1.799 |

**Mobile output from CEM 4.1 1/24/92**

Run #3 : Low Option
MOBILE4.1(4Nov91)

M120 Warning: MOBILE4.1 does not model most 1993 and later Clean Air Act requirements; Emission Factors for CY 1993 or later are affected.

I/M program selected:

| | |
|---|---|
| Start year (January 1): | 1983 |
| Pre-1981 MYR stringency rate: | 20% |
| First model year covered: | 1968 |
| Last model year covered: | 2020 |
| Waiver rate (pre-1981): | 1.% |
| Waiver rate (1981 and newer): | 1.% |
| Compliance Rate: | 98.% |
| Inspection type: | Centralized |
| Inspection frequency | Annual |
| Vehicle types covered: | LDGV - Yes |
| | LDGT1 - Yes |
| | LDGT2 - Yes |
| | HDGV - No |
| 1981 & later MYR test type: | Idle |

Oldest model year covered by:

| | |
|---|---|
| IM240 Transient Test | 2020 |
| Purge System Check | 2020 |
| Fuel System Pressure Check | 2020 |

Anti-tampering program selected:

| | |
|---|---|
| Start year (January 1): | 1983 |
| First model year covered: | 1981 |
| Last model year covered: | 2020 |
| Vehicle types covered: | LDGV , LDGT1, LDGT2 |
| Type: | Centralized |
| Frequency: | Annual |
| Compliance Rate: | 98.0% |
| Air pump system disablements: | No |
| Catalyst removals: | Yes |
| Fuel inlet restrictor disablements: | Yes |
| Tailpipe lead deposit test: | No |
| EGR disablement: | No |
| Evaporative system disablements: | No |
| PCV system disablements: | No |
| Missing gas caps: | No |

Minimum Temp: 72. (F) Maximum Temp: 92. (F)
Period 1 RVP: 11.5 Period 2 RVP: 8.7 Period 2 Start Yr: 1992

VOC HC emission factors include evaporative HC emission factors.

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Cal. Year: 2000 I/M Program: Yes Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 19.6 | 19.6 | 19.6 | | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | |
| VMT Mix: | 0.584 | 0.199 | 0.080 | | 0.035 | 0.002 | 0.001 | 0.093 | 0.007 | |
| Composite Emission Factors (Gm/Mile) | | | | | | | | | | |
| VOC HC: | 1.58 | 1.90 | 2.18 | 1.98 | 4.54 | 0.65 | 0.84 | 2.15 | 4.96 | 1.870 |
| Exhaust HC: | 0.52 | 0.86 | 0.97 | 0.89 | 2.07 | 0.65 | 0.84 | 2.15 | 1.89 | 0.838 |
| Evaporat HC: | 0.36 | 0.34 | 0.45 | 0.37 | 1.44 | | | | 2.52 | 0.379 |
| Refuel L HC: | 0.19 | 0.25 | 0.25 | 0.25 | 0.40 | | | | | 0.192 |
| Runing L HC: | 0.41 | 0.36 | 0.40 | 0.37 | 0.51 | | | | | 0.363 |
| Rsting L HC: | 0.11 | 0.10 | 0.10 | 0.10 | 0.12 | | | | 0.54 | 0.098 |
| Exhaust CO: | 7.01 | 8.07 | 9.48 | 8.47 | 36.27 | 1.60 | 1.74 | 11.21 | 24.78 | 8.927 |
| Exhaust NOX: | 0.72 | 1.05 | 1.13 | 1.07 | 4.51 | 1.37 | 1.50 | 9.30 | 0.77 | 1.752 |

---

Cal. Year: 2000 I/M Program: No Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

| Veh. Type: | LDGV | LDGT1 | LDGT2 | LDGT | HDGV | LDDV | LDDT | HDDV | MC | All Veh |
|---|---|---|---|---|---|---|---|---|---|---|
| Veh. Speeds: | 19.6 | 19.6 | 19.6 | | 19.6 | 19.6 | 19.6 | 19.6 | 19.6 | |
| VMT Mix: | 0.584 | 0.199 | 0.080 | | 0.035 | 0.002 | 0.001 | 0.093 | 0.007 | |
| Composite Emission Factors (Gm/Mile) | | | | | | | | | | |
| VOC HC: | 1.77 | 2.25 | 2.59 | 2.35 | 4.54 | 0.65 | 0.84 | 2.15 | 4.96 | 2.084 |
| Exhaust HC: | 0.71 | 1.20 | 1.37 | 1.25 | 2.07 | 0.65 | 0.84 | 2.15 | 1.89 | 1.049 |
| Evaporat HC: | 0.36 | 0.35 | 0.46 | 0.38 | 1.44 | | | | 2.52 | 0.382 |
| Refuel L HC: | 0.19 | 0.25 | 0.25 | 0.25 | 0.40 | | | | | 0.192 |
| Runing L HC: | 0.42 | 0.36 | 0.40 | 0.37 | 0.51 | | | | | 0.364 |
| Rsting L HC: | 0.11 | 0.10 | 0.10 | 0.10 | 0.12 | | | | 0.54 | 0.098 |
| Exhaust CO: | 10.05 | 11.96 | 14.40 | 12.66 | 36.27 | 1.60 | 1.74 | 11.21 | 24.78 | 11.874 |
| Exhaust NOX: | 0.75 | 1.15 | 1.25 | 1.18 | 4.51 | 1.37 | 1.50 | 9.30 | 0.77 | 1.799 |

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# APPENDIX L

# IDENTIFYING EXCESS EMITTERS WITH A REMOTE SENSING DEVICE: A PRELIMINARY ANALYSIS

911672

# Identifying Excess Emitters with a Remote Sensing Device: A Preliminary Analysis

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U.S. Environmental Protection Agency

## ABSTRACT

There has been considerable interest in applying remote measuring methods to sample in-use vehicle emissions, and to characterize fleet emission behavior. A Remote Sensing Device (RSD) was used to measure on-road carbon monoxide (CO) emissions from approximately 350 in-use vehicles that had undergone transient mass emission testing at a centralized I/M lane. On-road hydrocarbon (HC) emissions were also measured by the RSD on about 50 of these vehicles. Analysis of the data indicates that the RSD identified a comparable number of the high CO emitters as the two speed I/M test only when an RSD cutpoint much more stringent than current practice was used. Both RSD and I/M had significant errors of omission in identifying High CO Emitters based on the mass emission test. The test data were also used to study the ability of the RSD to characterize fleet CO emissions.

## INTRODUCTION

Researchers at the University of Denver and elsewhere [1]*, [2], [3], [4] are in the process of developing systems to remotely measure the concentration emissions from vehicles operating on the public roads. These systems work by focusing a beam, or in some cases multiple beams, of infrared light across the roadway into an infrared detector. The instrument determines the concentration of the pollutant in the path of the beam based on the amount of infrared light absorbed by the detector at specified wavelengths, and the theoretical relationship of carbon monoxide to carbon dioxide in auto exhaust. Early equipment had only carbon monoxide (CO) capability, while later equipment may have the potential to measure other emissions species (primarily hydrocarbons - HC).

Two potential uses of remote sensing devices (RSD) have been proposed by various sources. They are: (1) the on-road identification of gross polluting vehicles (commonly called High Emitters) for subsequent repair, and (2) the monitoring of on-road vehicle emissions in a specified area over a period of time for program evaluation purposes. Such potential uses can only come to fruition, however, if the remote sensing techniques are shown to provide accurate and reliable results that reflect the vehicle's true emission levels over a variety of normal operating conditions (e.g., acceleration, cruise, hot/cold operation, etc.).

Several test programs with remote sensing devices have been conducted by a variety of organizations including; the University of Denver (by Professor Donald Stedman), General Motors [4], the EPA Environmental

* Numbers in brackets denote references listed at the end of the paper.

Monitoring and Support Laboratory (EMSL) in Las Vegas [2], and the California Air Resources Board (CARB) [5]. Many of these studies have involved measuring the RSD concentration emissions from thousands of vehicles [1], [3]. Others were concerned with verifying the accuracy of the RSD measurements by directing small samples of exhaust with a known concentration into the RSD beam and comparing the results to more traditional analyzers [2]. Another involved a roadside pull-over program conducted by CARB which compared RSD results to I/M tailpipe and tampering checks on in-use vehicles [5]. However, none of these programs provided a quantitative comparison between RSD results and corresponding transient dynamometer mass emission results on the same set of cars.

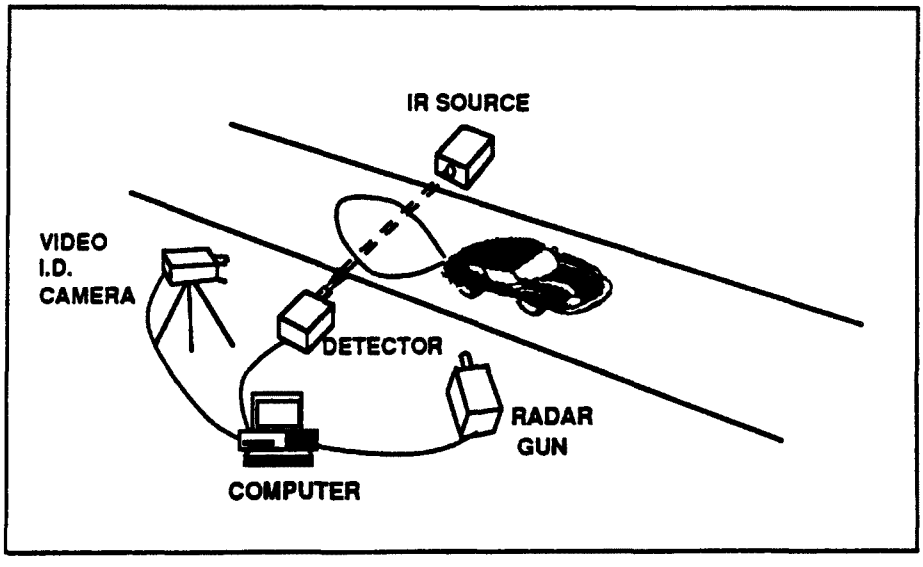
The goal of this study was to fill this gap and to provide a comparison between RSD results and dynamometer results on the same cars. The driving schedule which was utilized for the comparison was the IM240. It is a new transient driving schedule developed by the EPA [8] that consists of the first two "hills" of the new car certification procedure, the Federal Test Procedure (FTP), with some modifications (further details are discussed later in the paper). Although linear correlations between the RSD and IM240 emissions were performed, most of the investigation was focused on whether the RSD emissions from a given vehicle would categorically match IM240 mass emissions from the same vehicle. For example, it was of interest to know if a vehicle with a high RSD concentration would also have high IM240 mass emissions, and vice versa. The effectiveness of the RSD system in identifying gross emitters and excess emissions was also evaluated relative to the capability of the standard Indiana I/M test using the IM240 as the yardstick for excess emissions. Finally, the effect of external variables, such as vehicle operating mode, owner response, weather conditions, and siting factors were also investigated as to whether they affect the ability of the RSD system to correctly identify vehicles with high emissions.

All RSD and IM240 testing was conducted in Hammond, Indiana, by Automotive Testing Laboratories Inc. (ATL) under contract to the U.S. Environmental Protection Agency.

## TEST EQUIPMENT

Figure 1 shows a schematic of the RSD system in a roadside setting. The principal parts of the system include the IR detector and source; a video camera to record the license plates of passing vehicles; a modified police radar gun; a personal computer equipped with an A/D board; and special software developed by the University of Denver researchers. Also included in the system are the special calibration equipment and several gas bottles.

Figure 1
**REMOTE SENSING DEVICE SCHEMATIC**




The RSD system operates by continuously monitoring the intensity of the IR source. When a vehicle breaks the beam path, the reference voltage drops to zero which signals the presence of the vehicle. Span voltages collected before the beam is blocked and zero voltages during the blockage are recorded. As the vehicle exits the beam, samples are taken over one second at 125 Hertz. The CO2 spectral region is isolated by filtering at 4.3 μm and the CO spectral region is filtered at

4.6 μm. The instantaneous CO and CO2 values are then regressed using a linear least squares procedure. From the slope of this regression the average CO/CO2 molar ratio (Q) and the average HC/CO2 molar ratio (Q') are obtained and reported. The HC ratio is calibrated and reported in terms of propane.

The average Q and Q' molar ratios over the one second sample time are the only emission measurements that are recorded during an RSD test. Only these are recorded because the size, position and distribution of the exhaust plume is not known. Therefore, to help safeguard the quality of the subsequent emission calculations which are based on these theoretical relationships, the system employs a built in feature to evaluate the reasonableness of the observed molar ratio. If an unreasonable molar ratio is observed, the RSD reports a 'non-linearity error'.

The majority of testing was conducted using the original RSD design developed by Dr. Stedman. This unit (designated in the paper as RSD #1) had a liquid nitrogen cooled detector, and measured only carbon monoxide (CO). It used two indium antimonide photovoltaic detectors. A second unit was used in the later stages of testing. This second RSD unit (designated as RSD #2) was air cooled, and had both HC and CO measurement capability. The two systems also had slightly different versions of software controlling the data acquisition and processing.

## DESCRIPTION OF TESTING

Two different RSD testing formats were employed during this study. These formats included track testing at the ATL (Bendix) test facility in New Carlisle, Indiana, and on-road testing of in-use vehicles in Hammond, Indiana. The RSD track testing was very limited, lasting only three days at the beginning of the test program, and employed the first RSD unit (RSD #1). The purpose of the track testing was to compare RSD results collected under controlled track conditions with FTP results on the same set of vehicles. A second purpose was to evaluate the repeatability of the RSD emissions by replicate testing of the same vehicle under controlled conditions. A total of ten (10) cars were tested at two test-track sites. At the first test-track site, five cars received multiple RSD tests on a level roadway at speeds of 5, 10, 20, 30, and 40 MPH. At the second track site, five other cars were tested several times on an inclined roadway with a 3 percent grade at the same speeds. All ten of the vehicles which participated in this part of the RSD test program had been recruited to the ATL laboratory for other emission testing programs and were simply selected for the RSD testing based on availability. As a result of participating in the other programs, these vehicles underwent FTP testing and repairs. However, none of the vehicles received an RSD test after repair.

RSD testing at roadside sites of in-use vehicles, which had received a transient dynamometer test, was the major effort of this study. This RSD testing was conducted at two expressway ramp sites, and a secondary street with two-way traffic. The majority of this on-road testing was conducted at the expressway sites, and employed the first design RSD unit (RSD #1). The second design unit (RSD #2) was used at the second test site, a fairly lightly traveled, two-lane expressway service drive with two-way traffic. Both RSD test sites were located less than one mile from the specially-modified centralized I/M facility in Hammond, Indiana, which administered the transient IM240 dynamometer test.

The IM240 is a new two bag mass emission test conducted on a dynamometer over a transient driving schedule. The driving schedule for the IM240 test consists of the first two "hills" of the new car certification test, the Federal Test Procedure (FTP), with some modifications to include more transient operation. However, the driving schedule does not include a vehicle engine-start. The dynamometer inertia weights and horsepower settings were selected based on a consolidated list of the new car certification settings for the vehicle model. The emissions were measured using a CVS-CFV system with laboratory grade emissions analyzers. For further information on the IM240 consult EPA technical report number EPA-AA-TSS-91-1 [8].

The vehicles which participated in the RSD testing were a subset of vehicles selected for a larger program designed to monitor the emission performance of in-use vehicles using the IM240 dynamometer test. These vehicles were selected for IM240 testing as they entered

the Hammond I/M facility based on the availability of the dynamometer, and the owner's willingness to participate. If the vehicle owner declined to participate, that car went through the normal Indiana I/M procedure (idle and 2500 RPM no load), and the next car in line was chosen to receive an IM240. Only after the vehicle had completed the IM240 test was the owner approached about participating in the RSD drive-by test. Drivers were asked to drive by the RSD site and were given a monetary incentive if they indicated that they would participate (cars were not stopped at the RSD test site itself). This additional recruitment procedure for the RSD testing was needed only for the expressway sites, in that the secondary street site was located so that owner participation was blind.

After receiving the IM240 test, the car was inspected for catalyst tampering and misfueling. It then received a pressure test of its evaporative emission control system. This procedure took only a few minutes. However, during this period the vehicles were turned-off to conduct the evaporative pressure test. The effect of this vehicle shutdown on subsequent RSD emissions is unknown. However, since the shutdown was brief, it is expected to be minimal.

The two expressway test sites were on the northeast cloverleaf of the Cline Avenue and I-94 Interchange in Hammond, Indiana. The cloverleaf was an entrance ramp leading onto Westbound I-94 from Northbound Cline Avenue. The geometry of the ramp was circular with a slightly upward grade throughout.

Two different test sites on the expressway ramp were used. The first site was about 50 yards from the ramp entrance. The road grade at this point was about 2.75 degrees. Also, because the ground surrounding the roadway was relatively level, this site was convenient for setting up the equipment and parking a supporting van. However, it proved to be unsatisfactory because it allowed curious vehicles owners to slow down while passing through the RSD beam. Where it was estimated that typical average speeds on that section of the ramp were around 15 to 25 MPH, most of the test vehicles were found to be travelling at speeds of 5 to 15 MPH.

On the third day of testing at this site, the problem of vehicles slowing down was solved by moving to a second site on the ramp about 25 yards from the ramp exit. The road grade at this point was also 2.75 degrees. Because the vehicles were about to enter the freeway, it was more difficult for the the vehicle owners to slow down to look at the equipment while passing through the RSD beam. As a result, the average vehicle speed was more than 25 MPH and vehicle operation was believed to be fairly representative of ordinary expressway ramp driving.

After receiving the new RSD unit (RSD #2), it was decided to move to a test site on a secondary road with two-way traffic, about one-quarter of mile from the I/M lane. The site was a straight, flat road with a posted speed limit of 35 MPH. It was situated such that somewhat more than half of the cars exiting the I/M lane would pass through the test section. Thus, it was possible to conduct the RSD tests at this site without involving the vehicle owner. The RSD device was set up so that the beam crossed both lanes of traffic.

## OPERATIONAL EXPERIENCE

The original goal of this test program was to conduct RSD tests on all the vehicles which received IM240 tests. However, for various reasons not all the test vehicles received the RSD test. As shown in Tables 1 and 2, described more fully in the following sections, there were several reasons for vehicles not receiving the RSD test, including recruitment problems, RSD equipment problems, and inclement weather.

**VEHICLE RECRUITMENT** - As noted earlier, the vehicle recruitment procedures differed between test sites. At the expressway site it was necessary to inform the owner of the RSD test and offer a monetary incentive for participation. In some cases, the owners declined to participate, or in some instances, agreed to participate (accepted the monetary incentive), but never showed up for the RSD test. In other cases, they showed up, but were missed, because of communication problems from the IM240 lane to the roadside RSD operator, alerting the operator that a test vehicle was on its way.

Table 1
Vehicle Recruitment

| Site | IM240 | Owner Declined /Vehicle Missed | Actual RSD Participation |
|---|---|---|---|
| X-way | 407 | 71 | 336 (83%) |
| 2-lane | 266 | 120 | 146(55%) |
| Combined | 673 | 191 | 482 (72%) |

Most of these RSD refusals to participate were due to the vehicle owner citing time constraints or other reasons. Many of these refusals occurred at the end of the day when the I/M lane was backed-up. Unfortunately, it was noticed that a few of the owners of vehicles with very high IM240 emissions, or with signs of tampering (fuel inlet restrictor disabled) also tended to decline. In addition, several vehicle owners declined because they did not want to drive on an expressway.

As a result of owner refusals and operator misses, only 336 vehicles out of 407 vehicles actually drove by the expressway site where an RSD measurement was attempted (see Table 1).

The second site was partially chosen so as to avoid the need to inform the vehicle owners about the RSD test. Thus, direct recruitment was not necessary, and vehicle owner involvement was minimized. This helped insure that vehicle owners would not change their driving patterns in the RSD test section, and avoided the issue of some owners with high emitting vehicles declining to participate in the RSD test. The other reason for choosing a second site was to obtain results at a location that would be expected to have different vehicle operation.

Unfortunately, as shown in Table 1, a high RSD test rate was not achieved at this site either. This was due to the fact that the location of the second site allowed IM240 vehicles to exit the I/M test lane in two directions. Only one of these directions took the vehicle by the RSD site. Therefore, as indicated in Table 1, only 146 vehicles out of 266 (55%) participated in the RSD testing. The other 120 vehicles were not involved because they exited from I/M lane in the opposite direction from the RSD test site, or they missed the RSD test because of lack of communication between the lane and the RSD operator.

**RSD EQUIPMENT OPERATION** - Operation of both RSD systems was fairly straightforward with the set-up and operating procedures being nearly identical for both systems. The only differences were due to software upgrades, and the absence of cryogenic cooling for the RSD #2 (two-lane testing) system. Most of the basic set-up and operating problems were addressed during the first few days at the first on-road site (the initial expressway location). These problems involved the typical learning curve, experienced when operating unfamiliar equipment. Beyond that, testing was reasonably routine, interrupted only by occasional equipment problems, and inclement weather.

Severe equipment problems with either RSD units were infrequent. However, one major problem did occur with the RSD #1. The problem was the failure of a computer board which controlled the video acquisition and storage, and it resulted in a few days of down time. Once diagnosed, the board was replaced with a new one (provided by the supplier of the RSD equipment). The second equipment problem which resulted in a couple days downtime was the theft of the roadside power generating equipment. This occurred at the two-lane site while RSD #2 was operating. It illustrates a potential practical problem with this type of emission testing. Other more minor equipment problems which were resolved by the equipment operator included: (1) the heating element used to produce the collimated RSD beam burned out several times, (2) rain entered the detector and had to be dried out using a heat gun, (3) high winds potentially causing the instrument to erroneously make a reading were present at times.

The number of vehicles lost to RSD testing due to equipment problems with each of the RSD units is shown in Table 2. Overall, approximately 16 percent of the RSD tests were missed. However, many of these problems were related to the emerging nature of this technology, and as it matures, the number of RSD tests lost to equipment problems would be expected to decline drastically.

**WEATHER EFFECTS** - One of the objectives of this study was to determine if the RSD could operate in inclement weather such as rain or

snow. Track testing was excluded from this requirement. However, the on-road RSD testing was attempted when inclement weather was present during the expressway testing in August, November, and December. Testing in inclement weather led to some missed RSD tests. At the expressway site, 27 out of the 336 participating vehicles (8 percent) were clearly missed due to rain or snow (see Table 2). Also, as indicated in the instrument description, the RSD unit has a built-in quality control algorithm that flags illogical results as 'invalid readings'. Some of the RSD results discussed in the next section, and labelled 'invalid' may have been tested on a rainy day. However, it was not possible to segregate the recorded data in a manner that would allow an answer to that question. Therefore, the actual loss due to weather conditions could have been higher than indicated.

Table 2
Vehicle Capture Rates

| Site | Actual RSD Participation | Equip Malfunction | Weather Losses | True RSD Sample | Percent of Participation | w/o Equip Malfunct. |
|---|---|---|---|---|---|---|
| X-way | 336 | 28 | 27 | 281 | (84%) | (91%) |
| 2-lane | 146 | 24 | --- | 122 | (84%) | (100%) |
| Combined | 482 | 52 | 27 | 403 | (84%) | (89%) |

Testing of the RSD #2 unit at the two-lane site was done in late March. During this period no inclement weather testing was done due to the generally fair weather conditions on all but two days. During these two days, RSD testing was not attempted because of hailstorms, and the vehicles which received IM240 tests on those days are not included in Table 2 under weather losses.

In addition to lost test time, inclement weather also resulted in many of the equipment problems which were mentioned above. Nevertheless, it was found that testing could occur when very light rain was present, although the number of non-linear CO/CO2 errors increased if the pavement was wet and a large water "rooster tail" was created behind the car that interfered with the IR beam. In addition, the intermittent rain became a nuisance since all the equipment had to be covered and uncovered.

RSD SAMPLE - The true RSD sample, shown in Table 3, was computed by removing the number of vehicles that were not tested because of recruitment problems, equipment problems, or inclement weather. This true sample (403 vehicles overall) contains all the vehicles which were attempted to be tested by the RSD under, as best we could determine, reasonable conditions. The table includes both the valid and 'invalid' readings based on these measurement attempts. Invalid reading being those flagged by the unit's internal quality control algorithm.

Subsequent analysis of the RSD's capability to identify High Emitters used only the valid readings because traditionally, only valid I/M and IM240 tests are used for such analyses. If necessary, invalid I/M or IM240 tests can be repeated. However, unlike I/M or IM240 tests which can be easily repeated, RSD tests might not be conveniently repeated. A RSD second chance test would require the vehicle to drive past the instrument again under as nearly as identical conditions as possible. Since repeat RSD testing was not in the program plan, it was not done. Therefore, in assessing the RSD's capability to identify High Emitters, an argument could be made that the entire 'True RSD Sample' (in Table 3) should be used, since the 'invalid' sample may include some High Emitters.

Based on consistency with past practices, only the valid RSD readings in Table 3 were used for subsequent analyses. However, this decision should be reviewed in any future programs relative to the type of vehicle sampling planned, since the effect of using the 'True RSD Sample' (as opposed to only 'valid RSD tests') would have the effect of reducing the effectiveness of the RSD unit in identifying High Emitters.

Table 3
RSD Sample

| Site | True RSD Sample | Valid CO RSD | Invalid CO RSD | Valid HC RSD | Invalid HC RSD |
|---|---|---|---|---|---|
| X-way | 281 | 257 | 24(9%) | --- | --- |
| 2-lane | 122 | 99 | 23(23%) | 53 | 69(57%) |
| Combined | 403 | 356 | 47(12%) | 53 | 69 |

To clarify, an invalid test result as tabulated in Table 3, could have resulted for two reasons. First, if the standard deviation of the CO/CO2 ratio, which is measured more than one hundred times per second, was greater than 20 percent, a flag would be set. This prevents rapidly changing CO/CO2 ratios from being recorded as valid. Second, if the instrument could not detect a CO plume, a flag would be set. This prevents pedestrians, multiple axle trucks, and other accidental beam blockages from being recorded as valid. Wet conditions could cause both these RSD errors to occur, however, as indicated, this potential source for 'invalid results' could not be separated from other causes in the recorded data.

The number and percentage of valid and invalid RSD CO results for each site suggest different levels of performance between the two instruments. For example in Table 3, RSD #1 shows a fairly low rate of invalid readings. Whereas, RSD #2 at the two-lane site shows a high rate of invalid readings (approximately 25 percent). This higher rate of invalid readings suggests that RSD #1 is more efficient and sensitive to low CO concentrations than RSD #2, possibly due to the cryogenic cooling of RSD #1. However, the longer RSD beam length at the two-lane road (greater than 30 feet) versus the expressway site (19 feet) may also have contributed to the higher rate of invalid readings.

The rate of RSD HC invalid readings made by RSD #2 (56 percent in Table 3) is unacceptably high, and suggests that the HC capability of the RSD in its current state of evolution needs much improvement. Potentially one of the problems with the RSD HC channel is the very tight instrument sensitivity required to measure relatively dilute HC concentrations. According to the manufacturer of the RSD unit, a difference of 100 ppm HC produces a difference of only 1 mV by the detector. In addition, the fairly long RSD beam length at the two-way road site made the already weak signal even weaker, and the detection more difficult. Based on the experience in this program with an admittedly early design unit, the performance and the results from the HC RSD channel should be viewed with caution.

## TEST RESULTS

A description of each vehicle tested along with its test scores from the IM240, RSD, and the Indiana I/M tests can be found in reference [9].

## HIGH EMITTER IDENTIFICATION

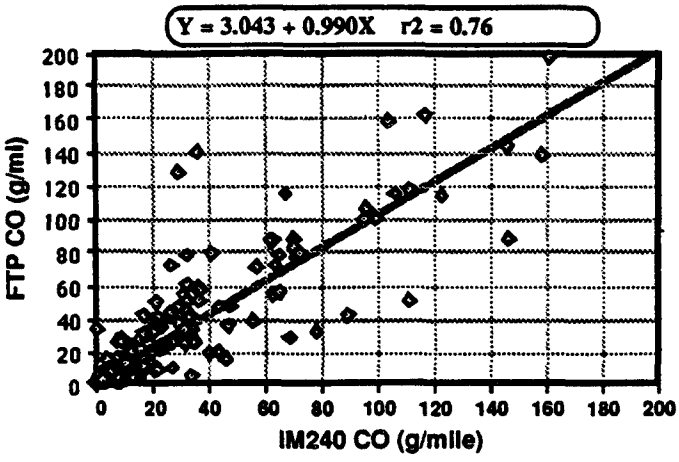
The primary goal of this project was to evaluate the ability of the RSD concept to consistently identify vehicles with excessive CO emissions as determined by transient dynamometer testing. In other words, could the RSD properly categorize vehicles (i.e., pass or fail) based on their IM240 mass emission test scores. RSD hydrocarbon measurements were added later in the program, and were similarly, but less extensively, analyzed.

To achieve this goal, the analysis focused on several areas. The first addresses a brief comparison and correlation of the IM240 with the Federal Test Procedure (FTP) results. Logically, the next would be to address the ability of the RSD to categorically identify vehicles as gross or high emitters versus normal emitters. However, before the categorical analysis can take place, it is necessary to define the ground rules for High Emitters, and from this, identify the number of High Emitters in the valid RSD sample. Only then can the ability of the RSD to properly categorize vehicles be assessed.

**IM240 VERSUS FTP** - In order to better understand the usefulness of the IM240 as a vehicle to evaluate the RSD results, a brief comparison of the IM240 to the Federal Test Procedure (FTP) is appropriate. All of the testing to compare the IM240 to the FTP was conducted in a separate test program, and a more extensive evaluation of those results will be the subject of some future report. However, for the purposes of this RSD report, a simple regression of the data available should be sufficient to make the point.

A regression of the available IM240 and FTP data from the 300 vehicles in Figure 2 indicates reasonably good correlation, as demonstrated by the correlation coefficient ($r^2 = 0.76$) and the slope ($b = 0.99$). More importantly, a review of the specific vehicle data indicates that the IM240 is excellent at identifying vehicles with high excess FTP emissions. In

Figure 2
**FTP Versus IM240**




fact, for virtually all vehicles tested, where the model year ranged between 1976 and 1989, there were zero errors of commission by the IM240 relative to the new car standards on the FTP (i.e., all cars that failed the IM240 at the new car standards for HC, CO, or NOx, also failed the FTP for the same pollutant). The almost perfect categorical relationship between the IM240 and the FTP was a little surprising because the IM240 does not include the cold start operation found in the FTP. Only warmed-up operation occurs on the IM240, and the results do not reflect the contribution of any engine-start emissions (cold or hot). The lack of cold operation on the IM240 should, however, not pose a significant problem, since all RSD measurements and all I/M test results in this study were made on warmed up cars. Therefore, based on the good linear correlation of the IM240 to the FTP, and its success at identifying gross CO and HC emitters, it can be viewed as a representative substitute by which to judge the RSD results and base the effectiveness of the RSD systems.

**DEFINITION OF A HIGH EMITTER** - A necessary part of the analysis needed to identify High Emitters was to determine the appropriate level with which to ascertain that a vehicle was a High Emitter. Historically, the specific levels have been related to a vehicle's FTP emission levels, and EPA's modeling programs for in-use fleets (MOBILE4) [10] have used a factor of the mean plus two times the standard deviation of the mean fleet emissions as the High Emitter level. To determine High Emitter cutpoints for the IM240, this same procedure was applied to 135 vehicles which received before and after repair IM240 tests in another EPA test program. The resulting cutpoints are shown in Table 4. As in previous analyses of FTP results, this testing showed that many vehicles whose before-repair emissions exceeded these cutpoints usually achieved substantial reductions in emissions from repair. Vehicles whose emissions were less than the cutpoints in Table 4, often had no reductions or a very small percentage reduction in emissions from repair. In short, our practical experience has been that vehicles with mass emissions above such cutpoints can usually be repaired to a value under the cutpoint quite effectively, while those below the cutpoint have been very difficult to repair in a cost effective manner.

Our focus in this analysis was to evaluate the ability of the RSD to find High Emitters (HE) which could realistically be expected to yield substantial emission reductions from repair. A vehicle is defined as a HE if its IM240 emissions exceed the cutpoints shown in Table 4. The potential emission reductions from the repair of these vehicles was defined as the emissions in excess of the Table 4 standards (i.e. greater than 10 g/mile CO for 1983+ Model Year vehicles), and such reductions were termed Repairable Excess Emissions (RPEE).

**HIGH EMITTERS IN THE SAMPLE** - The cutpoints in Table 4 were used to identify High Emitters (HE's) in the sample of valid RSD tests. For instance, at the two sites there were a total of 356 valid RSD CO tests conducted. Of that total, 97 vehicles, or 27 percent, exceeded the IM240 cutpoints in Table 4. Whereas, only 53 valid HC test were conducted at the two-lane site. The analyses in the following sections use the number of valid RSD test in Table 5 as the base value to compute certain RSD effectiveness rates.

Table 4
**IM240 High Emitter# Cutpoints**

| Model Year Grp | CO | HC |
|---|---|---|
| 1976 - 1980 | 30 g/mile | 2.0 g/mile |
| 1981 - 1982 | 20 g/mile | 1.0 g/mile |
| 1983 and Later | 10 g/mile | 1.0 g/mile |

# Includes vehicles termed both "HIGH" and"SUPER" Emitters in MOBILE4

Table 5
High Emitters

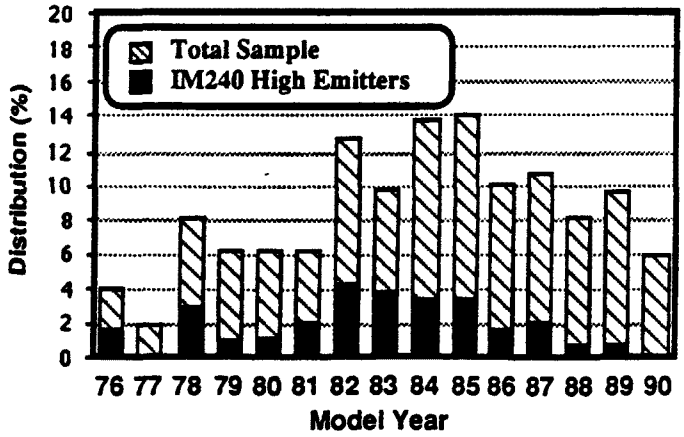
| | Valid RSD CO Sample | IM240 CO Highs | Valid RSD HC Sample | IM240 HC Highs |
|---|---|---|---|---|
| X-way | 257 | 72 (28%) | - | --- |
| 2-lane | 99 | 25 (25%) | 53 | 8 |
| Comb | 356 | 97 (27%) | 53 | 8 |

The model year distribution of the vehicles in the 'combined sample' of valid CO tests in Table 5 is shown in Figure 3. This figure provides a finer breakdown of the overall distribution and of the distribution of High CO Emitters (HE). It also shows several interesting points. First, the 1982 through 1985 model years comprise almost 50 percent of the sample, and they also include a large portion of the HE vehicles. Second, the HEs make up a discernible portion of most model year samples, even some late model years. For example, for the 1978 through 1985 model years, typically 25 to 35 percent of the model year sample are HE vehicles. For the 1989 model year, the percentage is between 5 and 10 percent.

To further simplify subsequent analyses, the three model year groups in Table 4 were combined into two groups -- a 1976 to 1982 group, and a 1983 and later group. However, the cutpoints in Table 4 were still used to define High Emitters within even the consolidated groups.

By grouping the 97 HE CO vehicles (combined sample in Table 5) into these two model year groups, it can be shown that the older 1976-82 sample contributes less than half (45 percent) of the total HEs for CO. This older vehicle group also only contributes 46 percent of the vehicles to the overall sample. The closeness of the fraction of HE's to that for the overall sample distribution indicates that the older vehicles did not contribute a disproportionate share of the HE vehicles in this program.

Figure 3
**Model Year Distribution**




**RSD IDENTIFICATION OF HIGH EMITTERS** - The analysis of the RSD's ability to properly identify High Emitters focused primarily on CO emissions, since a combined total of 356 valid RSD CO tests were conducted at the two sites. A lesser emphasis was placed on HC emissions, because only 53 valid HC measurements were obtained at the one site. These analyses in most instances evaluated the CO sample in the two distinct model year groups (i.e., 1976 - 1982 model years, and 1983 and later model years). However, due to the small size of the HC sample, all model years were grouped together.

The primary data set used in the analysis was formed by combining the expressway (X-way) and two-way street (2-lane) data sets together. This combination was done in order to produce a larger, and potentially more representative database. However, limited separate analyzes were conducted on the results from the two principal roadside sites to illustrate any potential differences, and to determine if combining the data masked any important results.

RAW DATA - The first analysis was to scatter plot the RSD concentration data versus the IM240 mass emission data. Figures 4(a) and 4(b) show the combined sites CO results for each model year group. Figure 4(c) shows the HC results for all model years. In viewing these scatter plots, there appears to be more of a relation between the RSD CO data and the IM240 values for the older 1976 - 1982 model year group than for the 1983 and later group. In any case, the regression correlation coefficient is marginal in the case of CO, and extremely poor in the case of HC. Scatter plots, of course, provide only an overall relationship, and Figure 4 does not provide any information on the ability of the RSD to properly categorize a vehicle as a High Emitter on the IM240, or as a Normal Emitter.

Figure 4
**RSD - IM240 Scatter Plots**
(Combined Sites)

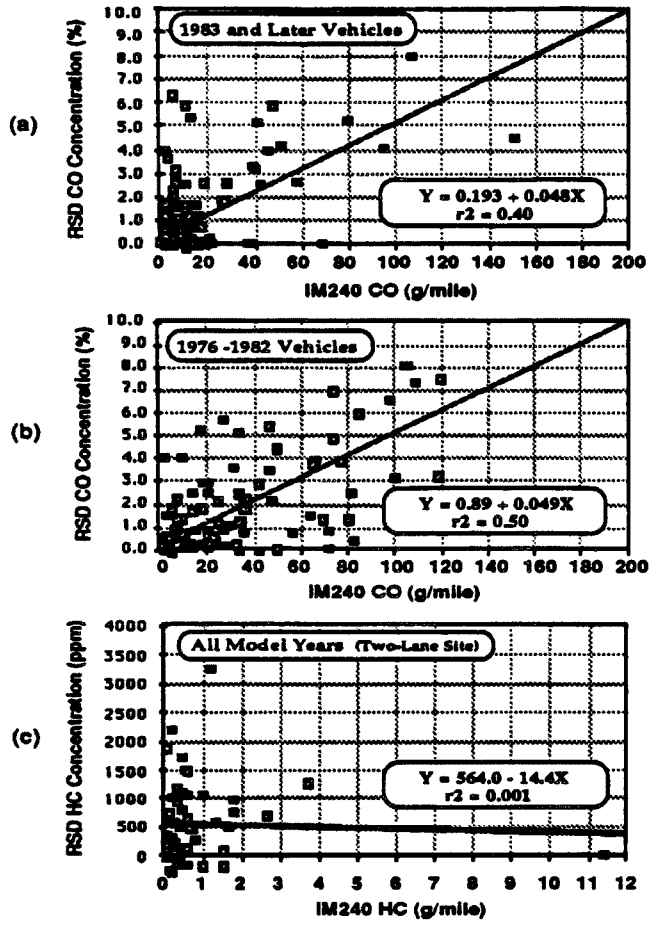
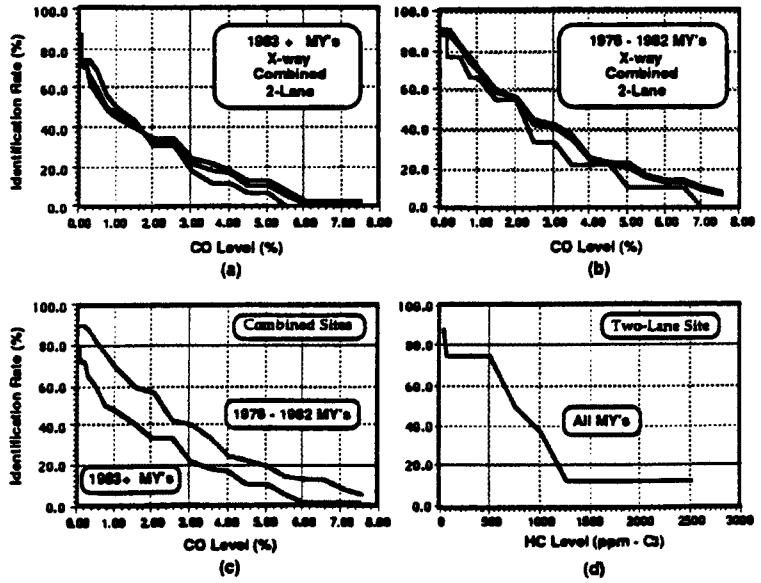



Figure 5
**RSD Identification Rate**




RSD HIGH EMITTER IDENTIFICATION RATE - The ability of the RSD to correctly identify vehicles with high IM240 mass emissions as High Emitters is a central issue in the evaluation of the performance of the RSD concept. The ability of the RSD to identify such vehicles is shown in Figure 5 as a function of RSD CO level. A detailed table of these values can be found in reference [9]. The identification rate in Figure 5 is defined as the ratio of the number of IM240 High Emitting vehicles identified by the RSD to the total number of High Emitting vehicles identified by the IM240. If the RSD were to identify all of the High Emitters identified by the IM240, the identification rate would be 100 percent.

The CO High Emitter rates are separated by site to show any differences that might be apparent between the results. Differences were possible because a different RSD instrument was used at each site, and both sites had different traffic characteristics, (e.g., vehicle speeds and accelerations). Nevertheless, a comparison of the RSD CO High Emitter identification curves from both sites (Figures 5a and 5b) illustrates that roughly the same results at both sites were obtained over a complete range of RSD CO levels. This is especially true in the case of the 1983 and later vehicles, where the difference in identification rates between sites is typically only 5 or 10 percent (Figure 5a). The site effect in Figure 5(b) for the 1976 through 1982 model years shows a slightly larger difference between sites. However, because the results from both sites were rather consistent for each model year group, the RSD data from both sites were combined for most of the analyses throughout the remainder of the paper.

Combining the RSD results by site produced a larger data set for analysis. A further combining of the database across the two model year groups would produce a still larger data set. Based on the proportional distribution of High Emitters by model year in Figure 3, such combination would seem appropriate, except possibly for some late model years. However, Figure 5(c) shows that the RSD, at all CO levels, systematically identifies a higher proportion of 1976 though 1982 High Emitters than 1983 and later High Emitters. Typically, the difference is

around 10 or 20 percent. This is evidence that although the distribution of High Emitters is similar for most individual model years, the ability of the RSD to find a High Emitter is not the same, and is a function of model year, or model year group. Thus, combining the two model year groups for subsequent analysis is probably not appropriate.

Unlike the CO results, no sample stratification was done for the HC results because the RSD HC sample was relatively small (only 53 valid readings), and because there were very few High HC Emitting vehicles in the 1976 through 1982 model year range. For example, only one vehicle in the 1976 through 1982 model year group was found to be a High Emitter. Instead, the High Emitter identification rate as a function of HC level was computed using an 'all' model year sample. This information is shown in Figure 5(d).

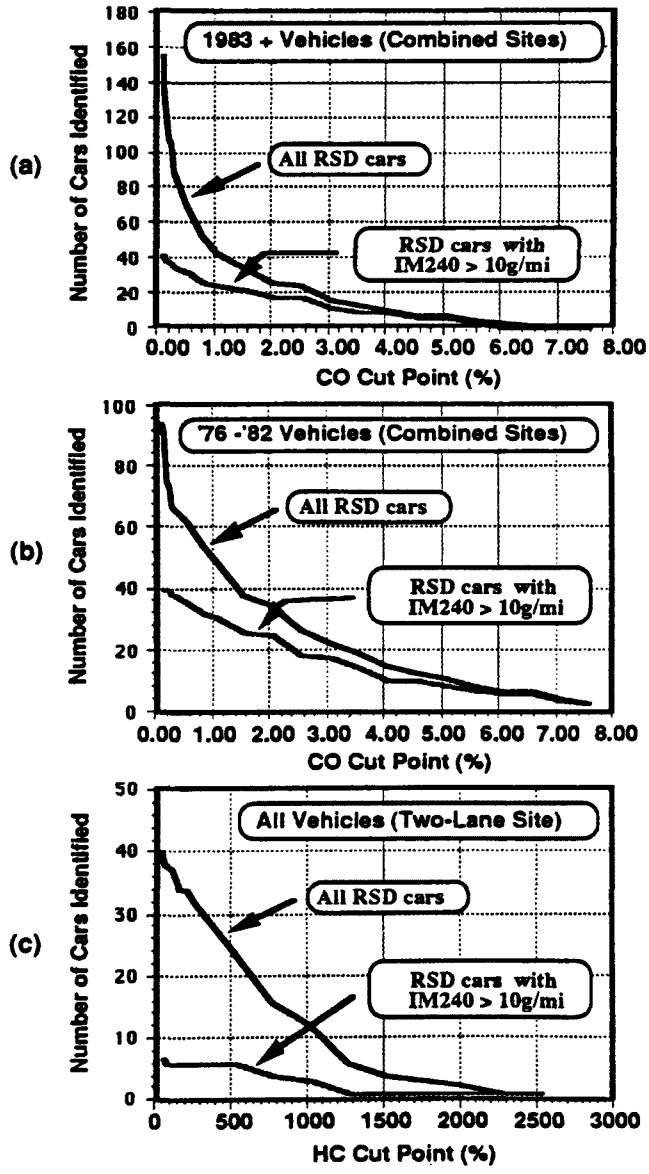
RSD CUTPOINT ANALYSIS - The RSD CO and HC levels shown in Figure 5 can also be used as a standard to pass or fail vehicles. The exact CO or HC values (called cutpoints) which are chosen, would reflect the desired severity of the test, and would determine the number of High Emitting vehicles which would fail. The selected values are usually chosen based on the results of a cutpoint analysis designed to maximize the number of High Emitters found, and minimize the number of Normal Emitters (i.e., not High Emitters) which might be falsely failed. For this cutpoint analysis, the RSD CO cutpoints range from the very tight 0.05% RSD CO cutpoint to the loose 7.50% RSD CO cutpoint. For RSD HC, the cutpoints ranged from 50 ppm HC to 2500 ppm HC (Hexane equivalent).

The first part of this cutpoint analysis simply compares the number of IM240 High Emitting vehicles identified by the RSD to the total number of vehicles with an RSD CO level above a given cutpoint. As seen in Figure 6, the RSD in all cases identifies more cars than are truly High Emitters on the IM240.

At cutpoints above 3% CO in Figure 6(a) for late model cars, there appears to be reasonably close agreement in identifying High Emitters between the RSD and the IM240. However, at the higher cutpoints fewer cars were identified. As the CO cutpoints are tightened, the the RSD and IM240 curves begin to diverge dramatically, indicating that a great percentage of these new vehicles captured by the lower RSD cutpoints are, in fact, low IM240 emitters which should not be failed. For example, at the extremely tight 0.10% RSD CO cutpoint the number of 1983 and later RSD failures was more than 140 vehicles, while the number of truly High Emitting vehicles was only about 35.

Similar comments can be made for the 1976 - 1982 model year group, except that the divergence between the RSD identification and the IM240 occurs at a higher RSD cutpoint, in this case 5% CO (see Figure 6b).

Figure 6
**Failures versus High Emitters**



The ability of the RSD to identify HC High Emitters is extremely poor. The curves in Figure 6(c) do not have similar shapes, and tend to diverge even at high HC cutpoints. Furthermore, the number of High HC Emitter Identified is extremely low at all cutpoints above 1000 ppm.

As seen in Figure 6, the RSD can falsely identify vehicles that are not High Emitters. Not shown in Figure 6 is the opposite issue of High Emitting vehicles NOT identified by the RSD. Such errors, generally referred to as errors of commission (Ec) or False Failures, and as errors of omission (Eo) or False Passes, are inherent in the selection of a cutpoint to maximize the number of High Emitters found, while minimizing the number of Normal Emitters falsely failed.

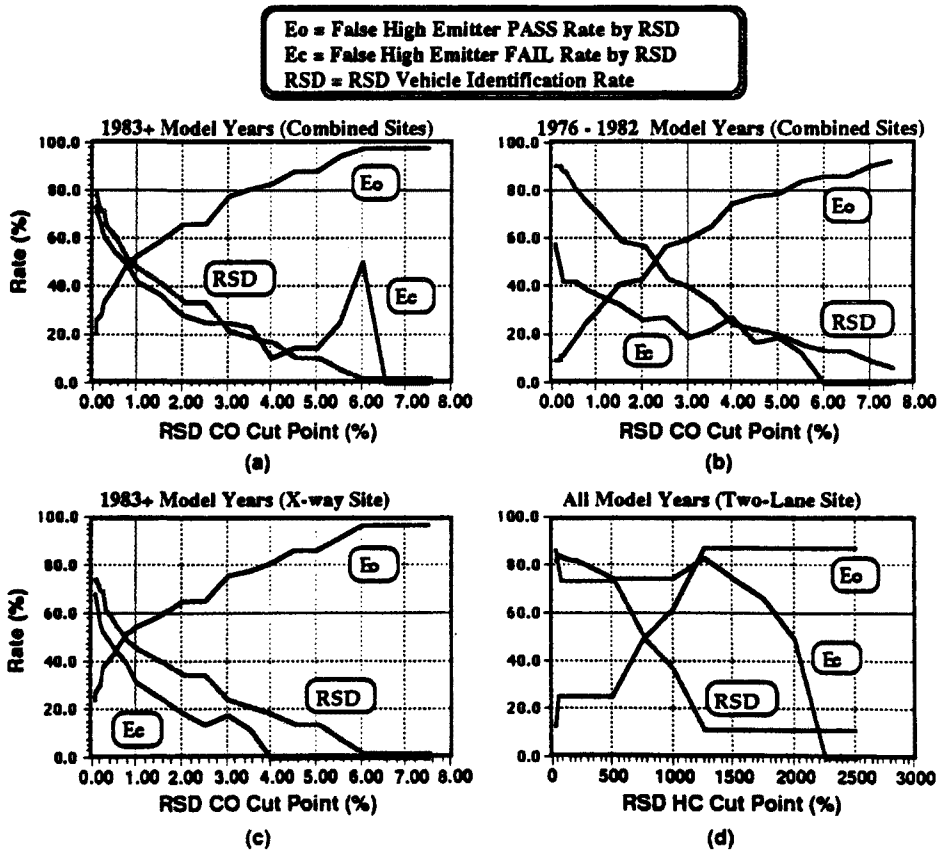
False Failures were determined by subtracting the number of IM240 High Emitting vehicles that were identified by the RSD from the total number of vehicles identified by the RSD, and then the sum was divided by the total number of vehicles identified by the RSD. In essence, this calculation is a measure of the fraction of cars identified by the RSD that are NOT High Emitters. A large value would indicate that many of the vehicles identified are not High Emitters, and should not have been identified.

False Passes were determined subtracting the number of IM240 High Emitting vehicles that were identified by the RSD from the total number of High Emitters identified by the IM240, and then the sum was divided by the total number of High Emitters identified by the IM240. This calculation is a measure of the fraction of High Emitters NOT identified by the RSD. A large value, in this instance, would indicate that many High Emitting vehicles that should be identified would be missed.

The effectiveness of the RSD test in terms of High Emitter Identification (RSD), False Failures (Ec), and False Passes (Eo) is shown in Figure 7 for both model year groups. A detailed table of combined site results for each model year group can be found in reference [9].

As indicated in Figure 7(a) relatively few 1983 and later High Emitters were identified by the RSD system (less than 30 percent) at high to moderate cutpoints (7.5% RSD CO to 2.0% RSD CO), while the False Pass rate was extremely high (greater than 70 percent). However, on the plus side, the False Failure rate was generally quite low, with the exception of the high rate around 6.0% RSD CO. This exception occurred because the sample of vehicles with very high RSD CO scores was so small that one False Failure dominated the results. A probably more representative False Failure rate pattern can be seen in Figure 7(c),

Figure 7
**RSD Identification Accuracy**



constructed only from the RSD results at the express way site. It shows that the false failure rate for High Emitting vehicles is virtually zero at the higher cutpoints.

Despite the exceptions, the overall results from the 1983 and later vehicles suggest that the RSD will not identify the majority of the High Emitting late model vehicles. However, in the instances when a vehicle is identified as a High Emitter by the RSD (at the higher cutpoints), it is usually correctly identified. For example, at the frequently cited cutpoint of 4.5% RSD CO, less than 15 percent of the 1983 and later High Emitters were identified. This means that 85 percent of the High Emitters were missed by the RSD at 4.5% RSD CO causing a False Pass rate of 85 percent. However, the False Failure rate was only 10 percent of the RSD failure rate, suggesting that virtually all the late model RSD failures at 4.5% will be High Emitters.

The 1976 through 1982 model years show results in Figure 7(b) generally similar to the 1983 and later vehicles. However, they typically had higher identification rates of High Emitters, lower rates of False Passes, but higher rates of False Failures at identical cutpoints (to the 1983 and later model years). These somewhat different results are likely due to the inherently higher emission levels of the older vehicles (because they were certified to higher new car standards), and a longer period of normal deterioration due to age. They suggest that in order to be fair to all model year vehicles, RSD cutpoints should be based on model year or technology type, instead of one single value such as 4.5% RSD CO.

Like the HC RSD results shown in Figures 5(d) and 7(d), the High Emitter Identification, and the False Failure and False Pass rates shown in Figure 7(d) were quite negative. They indicate that at present, the RSD HC channel cannot be used to accurately and repeatedly identify High HC Emitters without simultaneously falsely identifying many low emitting vehicles. For example, even at the extremely tight cutpoint of 25 ppm HC (Hexane equivalent) the RSD identified about 80 percent of the HC High Emitters. At higher and more reasonable cutpoints, the HC High Emitter Identification rate dropped to around 10 percent. Despite this low rate, the False Failure rate was extremely high.

The results also show that at virtually all reasonable HC cutpoints the false failure rate exceeded 70 percent of the total failure rate. In fact, no cutpoint was identified which could reduce the false failure rate below 70 percent and still produce a High Emitter identification rate of more than 20 percent. In addition, during the test program one vehicle had IM240 HC emissions exceeding 11 g/mile, but recorded an RSD HC score of 0 ppm HC. Therefore, based on these findings in conjunction with the fact that more than half of the RSD HC measurements were invalid, strongly suggests that at the present time, the RSD HC system cannot make repeatable or accurate measurements of in-use vehicle hydrocarbon emissions.

Viewing the cutpoint analysis for CO on an overall basis would indicate that the percentage of High Emitters identified versus the overall number of failures is fairly high at cutpoints greater than 3.0% RSD CO. This suggests that typically if a vehicle tests above 3.0% RSD CO it is likely to be a High Emitter. Overall this is a positive sign, since it suggests that a moderate RSD CO cutpoint can be found that will identify at least some High Emitters without falsely failing a large percentage of the fleet. On the negative side, however such a cutpoint would also likely miss a large portion of the true High Emitters. More High Emitting vehicles could be identified by using lower cutpoints, but that would increase the numbers of False Failures to possibly unacceptable levels. Such trade-offs could seriously affect the use of the RSD as a screening tool for High Emitters. One can only speculate, but it may be that requiring a high RSD reading to have been observed on several different days, or at several different sites, before a vehicle was classified as a failure would improve the balance between proper and improper failures.

REPAIRABLE EXCESS EMISSIONS IDENTIFIED BY RSD - The previous section on cutpoint analysis described the effectiveness of the RSD system in terms of the number of High Emitting vehicles identified by the RSD at particular CO or HC cutpoints. An equally important consideration is the amount of excess emissions represented by the vehicles

identified by the RSD (i.e., which High Emitters are failed). As indicated, this paper addresses excess emissions as emissions above the levels defined in Table 4. Defined here as Repairable Excess Emissions, or RPEE, these excess emissions represent the potential emission reductions from those vehicles identified by the RSD, if they were properly repaired.

The RPEE was calculated for each cutpoint as the sum of the excess IM240 emissions from all High Emitting vehicles identified by the RSD (i.e., those above the levels in Table 4), divided by the sum of the excess IM240 emissions from all of the High Emitting vehicles. In short, it is the fraction of excess emissions from all cars with mass emissions above the levels in Table 4 that were identified by the RSD.

The effectiveness of the RSD was analyzed in terms of RPEE because the RPEE identification rate reflects the actual emission level of each High Emitter, whereas the High Emitter identification rate accounts only for the number of High Emitters without regard for emission level. The difference between the two effectiveness parameters arises because of the effect that vehicles with very high mass emissions can have on the total emissions of all the vehicles in a given sample. Typically, these vehicles (called Super Emitters in MOBILE4) comprise a large share of the excess emissions in a test sample (or fleet), although they are usually few in number. Further, such vehicles can be readily repaired to moderate emission levels. For these reasons, their correct identification is of prime importance in the control of repairable excess emissions, and in the evaluation of the RSD system's ability to identify vehicles with repairable excess emissions.

The first order of analysis was to evaluate the RPEE identification rate of the RSD. The difference in model year groups can be seen in Figure 8. The results show that at cutpoints greater than 4.0% CO, the model year differences are pronounced, with a greater amount of RPEE identified for 1976 through 1982 vehicles than for 1983 and later vehicles. The trend of identifying more from the old cars than the newer cars was previously noted in the rate comparisons of High Emitter identification shown in Figure 5(c). However, this trend occurred at all CO cutpoints relative to the number of vehicles identified. This previous analysis suggested that the RSD was more effective at finding 1976 through 1982 High Emitters than 1983 and later ones. In contrast to this previous analysis, Figure 8 shows similar RPEE rates for both groups at tighter cutpoints, suggesting that if appropriate cutpoints are chosen, the RSD can be equally effective at identifying the excess emissions from new cars as well as old cars.

To better understand the true relationship between the number of High Emitters identified by the RSD, and the Repairable Excess Emissions from those vehicles, the data were plotted in Figure 9. A careful examination shows that for the 1983 and later vehicles, at cutpoints between 1% to 4% CO, the RSD identified less than half of the High Emitters. However, those few vehicles which were identified contribute significantly to the total repairable excess CO emissions. At relatively tight cutpoints, the RSD seems to find the worst of the 1983 and later High Emitters, although, not all of them, since even at extremely tight cutpoints, the RPEE rate was only around 80 percent.

For the 1976 through 1982 vehicles (Figure 9b), the story is a little different, and possibly a little more positive. For this model year group, the RPEE and High Emitter identification rates appear to proportionally track each other better. In addition, for these vehicles, the RPEE rate seems to be a more linear function of CO cutpoint, suggesting a stronger relationship between number of vehicles identified by RSD emissions and repairable excess emissions.

Figure 8
**Repairable Excess CO Emissions**
**(Model Year Effect)**

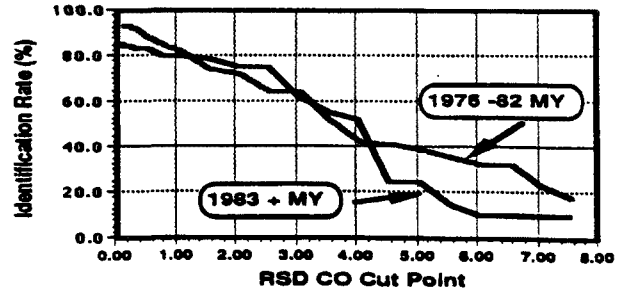
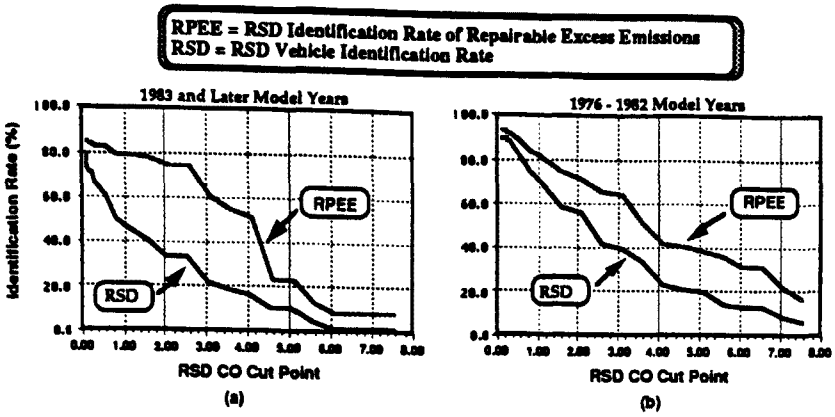


Figure 9
**Vehicle vs Excess CO Emissions**

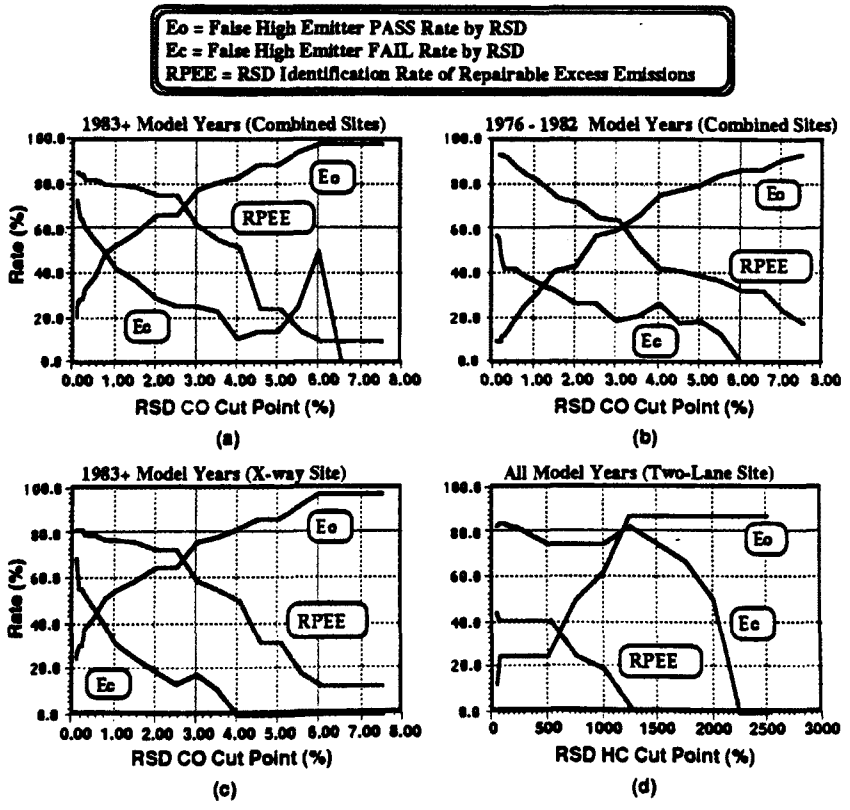



Like the High Emitter identification rate shown in Figure 7, the RPEE rates also need to be compared with the False Failure and False Pass rates. This is done to see if a potential balance between high RPEE rates and low False Failure rates exists for RSD. To make the comparison easier, the False Failure and False Pass rates from Figures 7 were plotted along with the RPEE rate as a function of CO and HC cutpoint. The results of this effort are shown in Figure 10, stratified by model year group, site, and pollutant in an analogous arrangement to Figure 7.

For 1983 and later vehicles (Figure 10a), the RPEE rate (indicated as RPEE in the figure) ranged from 10 percent at very loose cutpoints to 70 percent at about 2.0% RSD CO. Further tightening of the RSD cutpoint produced little additional RPEE, but dramatically increased the False Failure rate (Ec). This increased False Failure rate suggests that the 2.0% RSD CO cutpoint may be the lowest practical RSD cutpoint that should be considered for the later model year vehicles (assuming that the False Failure rate of 20 to 25 percent is acceptable at the 2% cutpoint). In contrast, the widely reported 4.5% RSD CO cutpoint had a RPEE rate of about 25 percent, meaning that at this cutpoint, 75 percent of the RPEE would be missed by the RSD. Also, as mentioned previously, the False Failure rate (Ec) in identifying the number of High Emitters was around 10 percent of the identification rate, and the False Pass rate (Eo) was more than 85 percent of all of the High Emitters in the model year group. This means that 10 percent of the RSD failures identified contribute nothing to the RPEE. However, 85 percent of the High Emitters which do contribute something to the RPEE were not identified.

An optimal balance between a high RPEE and a low False Failure rate is more difficult to find in the 1976 through 1982 sample. Here, both the RPEE rate and False Failure rate seem to be linear functions of RSD CO cutpoint. However, if the goal is to hold False Failures to less than 20 percent then a 3.0% RSD CO cutpoint which identifies 60% of the RPEE seems reasonable. If False Failures need to be almost zero, then a 6.0%

Figure 10
**Repairable Excess Emissions Identification**



RSD CO cutpoint is more appropriate. For comparison, the 4.5% RSD CO cutpoint identified about 40 percent of the RPEE, and surprisingly had a False Failure rate of about 20 percent.

Like the HC High Emitter identification rates, the HC RPEE rates were extremely poor. In fact they seemed to be worse in the sense that the maximum HC RPEE rate was less than 50 percent of the total HC RPEE. However, this was principally due to the 11 g/mile IM240 HC emitter which had an RSD HC test result of 0 ppm. Nevertheless, the HC RPEE identification was very low for most cutpoints, yet the False Failures were nearly 80 percent of the total failures. In all, coupling these results with all the other low High Emitter identification rates, and high False Failure and False Pass rates, leads to the conclusion that the HC RSD in its current state will not accurately measure the HC concentration in a vehicle's tailpipe with sufficient accuracy to be able to determine if a vehicle is truly a High Emitter and in need of repair.

## RSD and I/M

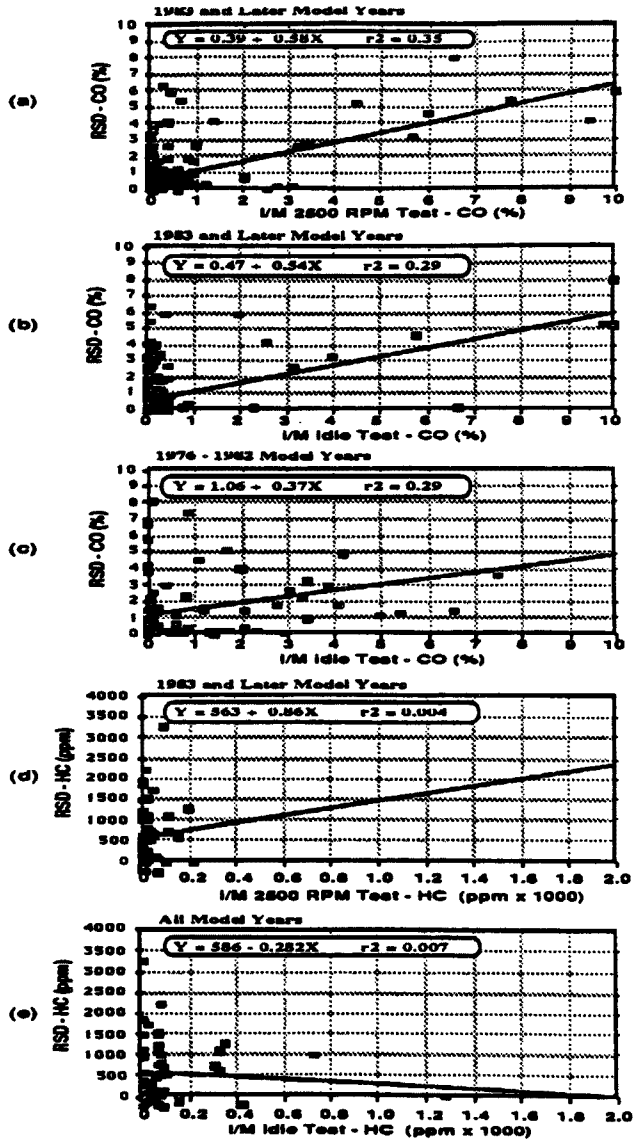
As indicated, the primary goal of this study was to evaluate the ability of the RSD to properly categorize High Emitters. However, because the IM240 vehicles had also received an official Indiana I/M test, the unique opportunity to compare the RSD results with I/M scores on the same vehicles was exercised.

The Indiana I/M test is a centralized biennial contractor run I/M program [11]. A two-speed idle test (2500 RPM and idle) is used for 1981 and later vehicles. The 207(b) cutpoint of 1.2% CO is used for the idle portion of the test, and a 1% CO value is used for 2500 RPM. The 207(b) HC standard of 220 ppm is employed at both speeds. Only the idle test is used for 1976 through 1980 vehicles. The 1980 vehicles are tested against a 2% CO cutpoint, while the 1976 through 1979 model years use a 3.5% CO cutpoint.

Because the Hammond, Indiana I/M site was also used to evaluate second chance tests and preconditioning cycles as part of a previously completed program, all of the vehicles were tested consistent with the recently published EPA guidelines for short test procedures (12).

**RAW DATA** - Similar to the evaluation of High Emitter identification by the RSD, the first analysis here was to scatter plot the data. Figures 11(a) and 11(b) address the I/M CO test for the late model cars, while Figures 11(d) and 11(e) provide an HC comparison on these same vehicles. The idle test for the older cars is in Figure 11(c). About the best that can be said about these data is that the relation between RSD and I/M scores is poor for CO, and nonexistent for HC. However, it must be remembered that the relationship of short tests to the certification test is not based on a relationship of scores, but a relationship of pass/fail categories.

FIGURE 11
RSD - I/M Scatter Plot

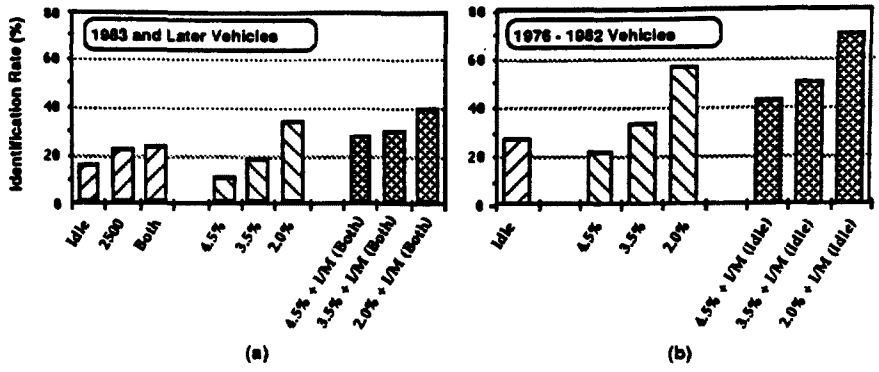


RSD VERSUS I/M - This analysis consisted of comparing the performance parameters previously used to evaluate the ability of the RSD to identify High Emitters and excess emissions with those same parameters calculated for the I/M tests. For simplicity, RSD results are shown for only three cutpoints, which include the frequently referenced 4.5% RSD CO cutpoint, a moderate 3.5% RSD CO cutpoint, and a more stringent 2.0% cutpoint. RSD HC results faired so poorly in the scatter plots that no attempt was made to compare them with the HC I/M results.

The effectiveness of the RSD and I/M tests in identifying High CO Emitters is shown in Figure 12 for both the 1983 and later vehicles and for the 1976 - 1982 vehicles. Examination of Figure 12(a) for late model cars shows that the RSD at moderate and high CO cutpoints is generally no better than the two-speed I/M test (i.e., 'Both' in Figure 12a) in identifying High Emitters. In the extreme case, the RSD found less than 15 percent of the High Emitters at the highly reported 4.5% CO cutpoint, while the two-speed I/M test identified almost 25 percent of the High Emitters. However, when the more stringent RSD cutpoint of 2% CO was used, about 35 percent of the High Emitters were found.

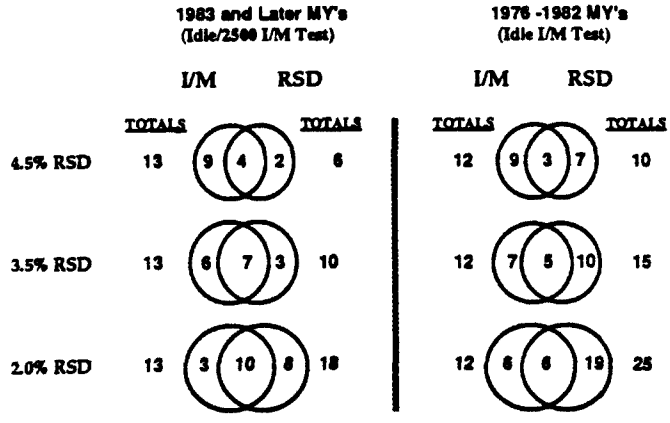
For the 1976 through 1982 vehicles in Figure 12(b), the I/M identification of High Emitters was marginally better than the RSD identification rate (at 4.5% CO). Relative to the I/M identification, the RSD identification improved substantially at tighter RSD cutpoints. For example, at the 4.5% RSD CO cutpoint, the identification rate of 1976 through 1982 High Emitters was only around 25 percent, slightly less than I/M rate, however, at the 2.0% RSD cutpoint, almost 60 percent of the High Emitters were found. (Note that the 2500 RPM test results are not shown for the 1981 and 1982 model years in the figure for the sake of consistency, although, they would boost the High Emitter identification rate of the I/M test somewhat for the 1976 - 1982 model year group.)

FIGURE 12
**High Emitter Identification Rate**
(CO, Combined Sites)




Mathematically, the RSD and I/M tests were combined to determine if the combination of tests would identify additional High Emitters. As seen in Figure 12, there is an increase in the identification rate, suggesting that the two tests identify different cars. This would seem reasonable since the tests are conducted under significantly different vehicle operating conditions, and would be expected to find problems which are particular to each operating mode. From the analysis shown in Figure 13, it is clear that a subset of different vehicles are identified by each test. For the 1983 and later group, the additional RSD identification is very marginal until the 2% RSD cutpoint is applied. However, for the older model year group, the additional RSD identification is substantial at all cutpoints. In fact, adding the I/M and 4.5% CO tests together nearly doubles the identification

Figure 13
**High Emitting Vehicle Identification Split**
(CO only)



rate of High Emitters, further attesting that different older vehicles fail each of the tests.

It should be pointed out, though, that the RSD test for the newer cars was compared against the two-speed idle test in Figure 13, whereas the older cars were compared to only the single speed idle test. The differences in I/M test type could possibly explain the improved identification of additional older cars by the RSD. In addition, the Indiana I/M CO cutpoint of 3.5% CO for the older cars (1976-1979 models) may not be as stringent as it should be. Tightening this I/M cutpoint for older cars would increase the number of High Emitters identified by I/M such that the identification improvements exhibited by the RSD in Figure 12(b) could possibly vanish.

Another important factor in any comparison of I/M with RSD are False Failure rates. False Failure rates were computed as a percentage of the failure rate, and they indicate the percentage of improper failures. Combined with the High Emitter identification rate, they are a measure of a test's ability to find High Emitters, yet avoid failing low and marginal Emitters.

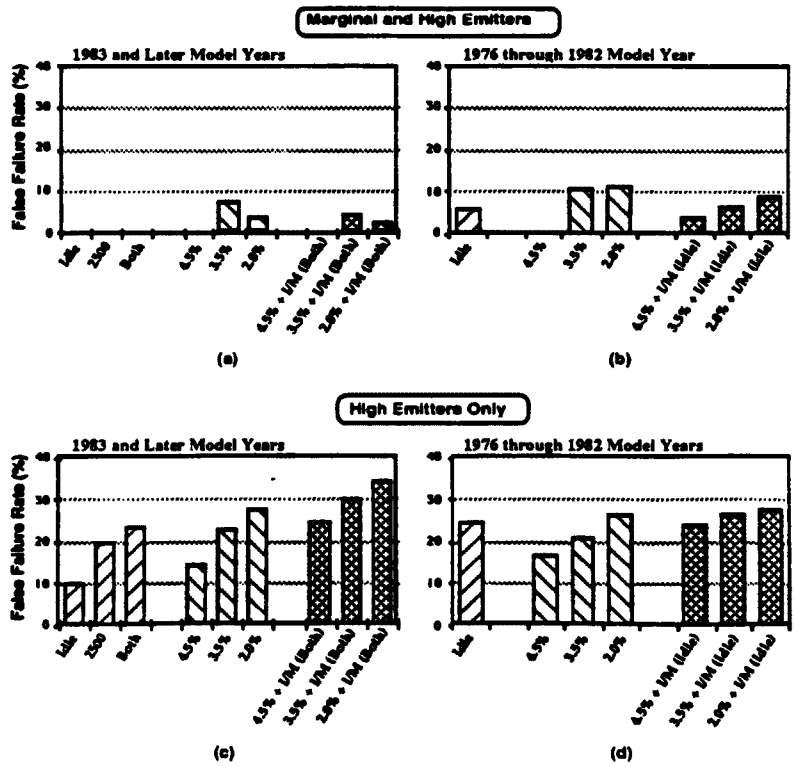
For the comparison of False Failures between RSD and I/M, two methods were used. The difference was in the level of IM240 score below which a failed car would be defined as a False Failure. The first method used new car certification standards applied to the IM240 results as the boundaries for False Failures. For example, if a 1983 and later vehicle failed either the RSD or the I/M test, and had an IM240 test score of less than 3.4 g/mile (1983 new car standard), it was considered a False Failure. This method of determining False Failures is similar to that used in MOBILE4, except that MOBILE4 uses FTP test scores (as opposed to IM240 test scores).

The second method used to compute the False Failure rate utilized the IM240 High Emitter cutpoints shown in Table 4 as the boundaries for False Failures. This method is identical to the method used in the previously described 'RSD CUTPOINT ANALYSIS.' With this method, a 1983 and later vehicle failing the RSD or I/M test, would only need an IM240 test score less than 10 g/mile, rather than 3.4 g/mile, to be considered a False Failure. Also, with this method, cars with IM240 scores between 3.4 and 10 g/mile (labeled Marginal Emitters) would be considered False Failures.

Both methods are shown in Figure 14, the first in (a) and (b),and the second in (c) and (d). The False Failure rates calculated in terms of only the High Emitters (second method) are substantially higher for both RSD and I/M relative to the False Failure rates calculated by method 1. However, the False Failure rate percentages for the two methods were based on different sample sizes. Therefore, a direct mathematical comparison can not be made.

Even so, a qualitative comparison can be made. In those cases where the the False Failure rates for method 1 (Figures 14a and b) are zero, it is probably safe to assume that all of the False Failures determined by method 2 (Figures 14c and d) were Marginal Emitters with IM240 scores between 3.4 and 10.0 g/mile.

Figure 14
**False Failure Rates**



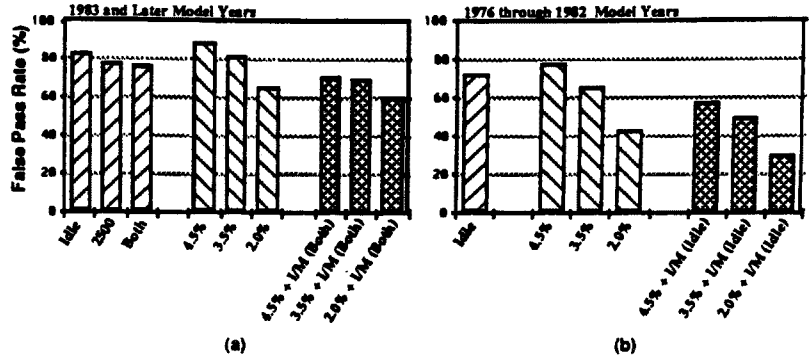
Given this assumption, it is likely that a majority of the False Failures identified by method 2, where the method 1 False Failure rate is greater than zero, were also Marginal Emitters. As implied previously, Marginal Emitters are more difficult to repair, and as a result, less likely to contribute to overall emission reductions.

Interestingly, the combination of the RSD and I/M tests shown in Figure 14(a) shows a lower False Failure rate than the RSD test alone. This apparent anomaly is a result of the sample size increasing, when combining the RSD and I/M samples, faster than the number of failures. In this particular case, the I/M-only False Failure rate was zero, therefore, the combined rates were the same as that for the RSD. Thus, the fraction of False Failures was lower for the combined sample than for the individual samples.

Another possible concern is the similarity in magnitude of the High Emitter identification rates in Figures 12(a) and 12(b) to the False Failure rates in Figures 14(c) and 14(d). The similarity might suggest that both tests tend to falsely identify a vehicle as a High Emitter almost as often as they correctly identify a High Emitter. However, it should be remembered that the calculations for the High Emitter identification rate were based on the total number of vehicles identified as High Emitters by the IM240, whereas the False Failure rate was based on the number of vehicles failing the RSD or I/M test. Because the number of IM240 High Emitters and the number of RSD or I/M failures were significantly different, any numerical similarity of identification rates and False Failure rates is merely coincidental.

A characteristic that must also be evaluated when comparing RSD to I/M are the False Passes or missed vehicles. The False Pass rate is the fraction of High Emitters not identified by the RSD or I/M test relative to the total number of High Emitters identified by the IM240 (also defined near Figure 7). An alternative calculation, in this case, would be to subtract the identification rates in Figure 12 from unity.

Figure 15
**False Pass Rates**
( High Emitters Only)



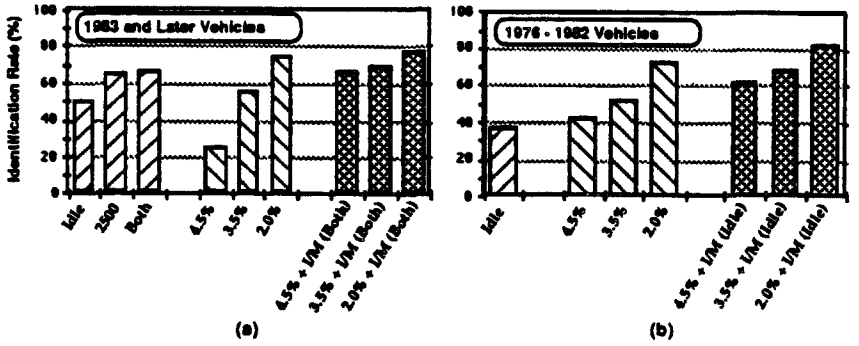

False Pass rates are shown in Figure 15, and as would be expected, more stringent tests (i.e., two-speed idle test), or tighter RSD cutpoints reduce the number of vehicles missed. In examining both model year groups in this figure, it is evident that the Indiana I/M test missed fewer vehicles than the RSD at a 4.5% cutpoint. Only at the most stringent cutpoints did the RSD substantially reduce the number of High Emitters missed by the I/M test.

Finally, as in the analysis of the RSD's ability to identify High Emitters, the comparison of RSD to I/M needs to look at the amount of repairable excess emissions (RPEE) identified by both tests. The RSD values in Figure 16 are the same as the individual RPEE values in Figure 10. The I/M RPEE values were calculated in a similar fashion, and are shown in Figure 16. Clearly, the Indiana I/M test for the newer vehicles identified more repairable excess emissions than the RSD test at a 4.5% CO cutpoint. However, at the most stringent cutpoint, the RSD did better.

For the older cars, the RSD consistently identified more excess emissions than the I/M test. In this case, though, it should be noted that the I/M test for these cars consists of only a single speed idle test, and it is likely that the identification rate of the I/M test would increase if a two-speed idle test were used.

In reviewing the comparisons between RSD and I/M in Figures 12 though 16, it is difficult to see any substantial improvement over the I/M test with the RSD. At the 4.5% RSD cutpoint, the the I/M test for the new cars (i.e.,

Figure 16
**Repairable Excess Emissions**




the two-speed test) identified more High Emitters, had lower False Failures, had lower False Passes, and identified substantially more excess emissions. At the tightest cutpoint, the RSD did identify more cars and excess emissions, with a correspondingly lower False Pass rate, than the I/M test, however, it did so at the expense of an increase in False Failures. Lowering the cutpoint on the I/M test to achieve the same False Failure rate would be expected to produce similar increases in the identification of High Emitters and excess emissions with the I/M test.

For the older vehicle group, the RSD faired a little better. At the 4.5% cutpoint, the single speed I/M test and the RSD were roughly comparable in number of cars identified, false passes, and excess emissions. At this cutpoint, the RSD did have a measurably lower False Failure rate. At the lower cutpoints, the RSD performed better than the single speed idle test on the older cars with comparable False Failures.

In reviewing the fictitious combination of the I/M and RSD tests in these figures, some interesting observations can be made. For late model cars, the combination increased identification somewhat over the I/M test, but with the expected increase in False Failures. However, for the older model years, the combination drastically increased the identification (number of vehicles, and excess emissions) over the I/M test without a substantial increase in False Failures. In fact, the combined tests at the highest RSD cutpoint (4.5% CO) increased the identification over both the I/M and RSD tests while reducing the False Failure rate relative to the I/M test.

Clearly, the fictitious combination of I/M and RSD test did better with the older cars than than the newer cars, and was better than either test alone. However, even with the combination, only 30 to 40 percent of the late model High Emitters and 60 to 70 percent of the older ones were found. This, suggests that neither test is as effective as it should be in finding High Emitters. In the case of I/M, there are several possible methods to improve the capture of High Emitters. As previously indicated, tighter I/M cutpoints could be used, or, a single speed idle test could be replaced with a two-speed test - a two-speed test could be replaced with a loaded test, etc. The ultimate replacement, of course, would be the IM240. However, for RSD, the improvements in the identification of High Emitters are less obvious, and seem to be limited to decreasing the cutpoint, with a near exponential increase in False Failures (see Figures 6 and 7), or to reducing measurement variability (discussed next).

## REPEATABILITY ANALYSIS

A key requirement of any measurement system is that it provide consistent results to the same stimuli. In the case of RSD, Stephens and Cadle [4], and Lawson et.al. [5], have shown that under relatively normal conditions, the RSD can measure with reasonable accuracy, CO from a specially controlled vehicle. However, other elements in the measurement-consistency equation include the vehicle characteristics, its operation, and weather conditions.

A previous analysis of RSD data collected in Chicago [6] suggested that there could be considerable difference between RSD reading on the same car on different days (at about the same time of day). To further explore this area, several of these other elements that could cause variability in the RSD results, and the effect that these factors could have on the ability of the RSD to accurately identify gross emitters were analyzed. The track testing primarily addressed the vehicle and its operation. The analysis of the on-road data addresses vehicle operation, weather effects,

and a possible combination of the two on the exhaust plume behind a vehicle.

TRACK TESTING - The track testing was conducted over a three day period at the Bendix test track in New Carlisle, Indiana by Automotive Testing Laboratories (ATL). The track testing was the first opportunity for the ATL personnel to operate the RSD without the assistance of the developer.

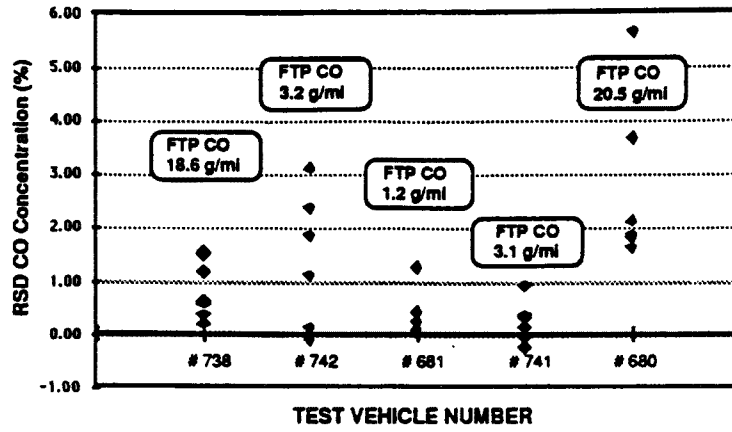
The track testing consisted of driving several vehicles by the RSD multiple times at the same speed to obtain replicate RSD readings. Several speeds were used at each of two sites - one a level road, and the other a 3 percent uphill grade. A total of 10 cars were tested, five at each site.

The speeds used during the RSD tests included 5, 10, 20, 30, and 40 MPH. The data were spotty at many of the these test speeds with numerous low voltage errors (i.e., no RSD readings). The lack of readings due to the automatic quality control feature was assumed to be partly due to the lack of experience with this equipment by the operator. As a result, only at 20 MPH was sufficient data collected to allow reasonable analysis of the reproducibility of the RSD measurements.

Figures 17 and 18 were plotted using the RSD data collected at 20 MPH and the as-received FTP from each vehicle. Figure 17 shows the repeatability of the RSD of tests done on the level road, and Figure 18 shows those from the 3 percent uphill grade. Both figures provide a visual indication of the variance among RSD scores on the same vehicle at a constant speed. The accompanying as-received FTP result provides a convenient qualitative comparison of the FTP mass emissions with RSD concentration emissions.

Examination of Figure 17 shows extremely high variability between RSD measurements made under very similar conditions on the level track. Based on these RSD results, it is likely that for some vehicles, the range of RSD results will fall on both sides of a likely cutpoint. For example, the RSD emissions of vehicle #742, which had a low FTP score, varied from a low reading of essentially zero

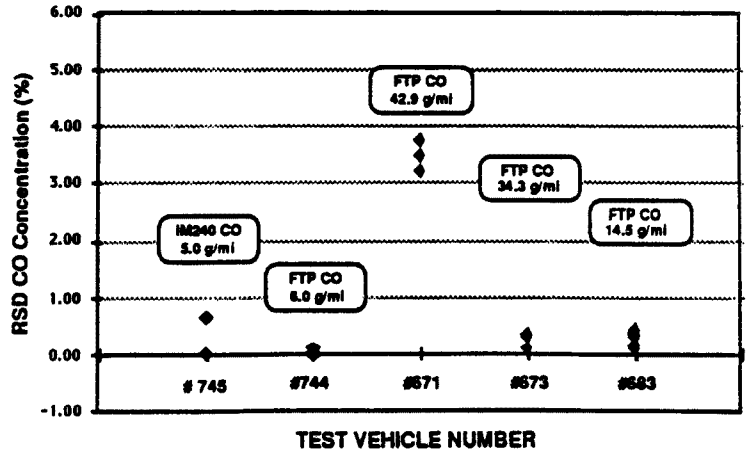
Figure 17
**RSD Reproducibility**
(Level Road, 20 MPH, ATL Test-Track)




percent CO all the way to 3% CO. This large variation in RSD readings could be a potential problem if a pass/fail cutpoint were to be selected that happened to be in the upper part of this range.

Conversely, vehicle #680, a very high FTP vehicle, had a similar spread in RSD readings, but the lower range of #680's readings overlapped the high end of #742's readings. Based only on this observation, it would be difficult to discriminate the dirty car from the clean car under these operating conditions with an RSD cutpoint in the 2% to 4% CO range. If a typical vehicle showed the kind of RSD emissions distribution evident in this example, the outcome of an RSD test could be based considerably on chance, or be a strong function of specific test conditions, instead of

Figure 18
**RSD Reproducibility**
(Uphill Road, 20 MPH, ATL Test-Trac



being based on the vehicle's FTP emissions or level of repair.

Examination of the uphill RSD results in Figure 18, show that they contrast very much with those from the level road testing in Figure 17. In terms of test variability the uphill results show a fairly high level of repeatability. For instance, the individual test results usually differed by less than 0.5% CO, with many showing much better repeatability than that. Whereas, the RSD readings from the level site frequently varied by as much 1.0 to 3.0% CO, none of uphill vehicles had RSD scores which varied to the extent that an individual vehicle's pass/fail status would likely change between tests.

The reasons for the inconsistency between the uphill and the level sites is not completely known. One possibility is that since the level road RSD testing was done on the first day of testing in this study, the lack of repeatability may have been due to the operator's lack of experience or some initial non-recurring start-up problem. If this were the case, then these results would not be representative of normal use. However, subsequent conversations with the operators, have ruled-out equipment problems a possible cause. Lack of experience could still have been a factor, though.

A second reason for the inconsistency may have been that cars can vary more on a level road. This could easily be the case, since the load on the engines is very light under these conditions. Any, even imperceptible change, in operating conditions during the split second that the RSD test was done could be a large percentage of the required load for the level road, possibly resulting in a large change in CO concentration level. If this were truly the case, then the results between tests, even on the same car, could be very different. On the other hand, the tests done at the uphill site placed a much heavier load on the engine. The higher load possibly led to less variability in the load demanded by the driver, since any small changes in load which did not cause a noticeable change from the specified test speed would be a considerably smaller portion of the higher uphill load. The smaller load variability may have resulted in more repeatable RSD data.

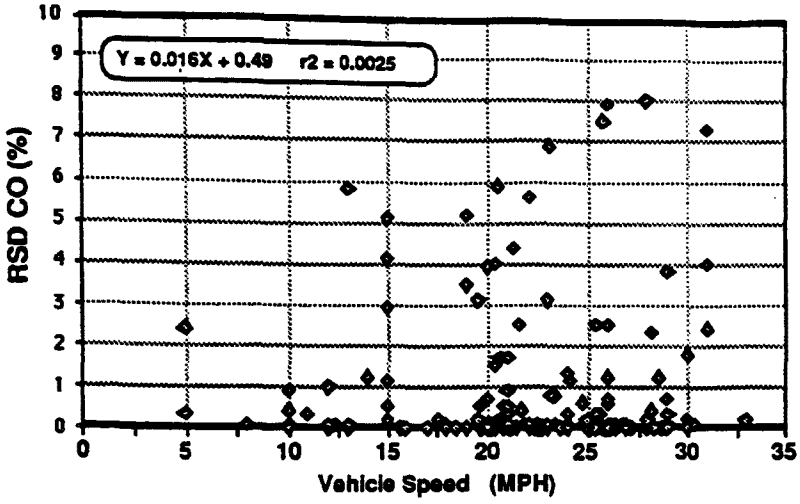
An obvious third reason is that different cars were used at each site, and the observed variability was simply a matter of coincidence. This possibility is somewhat discounted because of the consistency of the results within each road site. Furthermore, the difference in the False Failure rates in Figures 7(a) and 7(c) might also imply that the site selection can affect the variability of the RSD reading. Figure 7(a) included both level road operation and uphill operation (with acceleration), whereas Figure 7(c) included only uphill operation. As previously indicated, the False Failure rate of IM240 High Emitters for the combined site (Figure 7a) was higher than that for the uphill site. It is possible that some vehicles at the two-lane site exhibited the behavior demonstrated by vehicle #742, and were identified as High Emitters by the RSD, when in fact they were not. If this scenario truly occurred, it would suggest that only sites that impose some moderate load on the engine should be selected for future testing.

ON-ROAD DATA - RSD variability was also investigated using the on-road vehicle speed data collected at the expressway ramp site. Figure 19 shows a plot of the RSD CO concentration emissions versus vehicle speed at this site. No speed measurements were recorded at the two-lane site.

The vehicle speeds shown in this figure were measured manually by the RSD operator holding a radar gun. They reflect as closely as possible a vehicle's speed at the instant of the RSD test. The plot shows that the vehicle speeds ranged from 5 to 33 MPH with a mean of 23 MPH. The lower speeds (5 to 15 MPH) were generally recorded at the first site on the expressway ramp, and the higher speeds (20 to 35 MPH) at the second site on the expressway ramp.

The scatter and the linear regression results in Figure 19 indicate no relationship between speed and RSD CO concentration. The linear regression line is almost horizontal and the correlation coefficient is 0.0025. However, the lack of correlation between vehicle speed and RSD results is not surprizing. The more critical variables, as mentioned above, are likely to be vehicle acceleration and load. However, because of problems with the interface between the RSD system and the

Figure 19
On-Road Speed Effects




radar gun, acceleration could not be measured in this study.

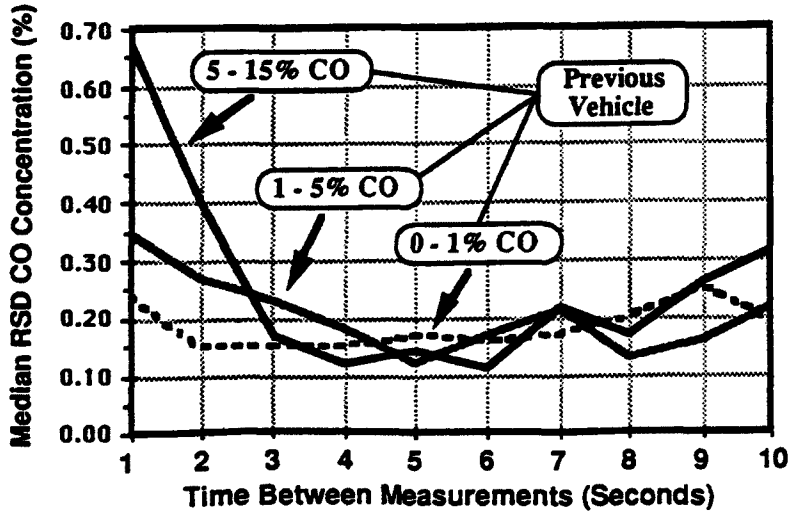
Considering these results, along with those from the test track, vehicle speed (at least over this range) does not appear to be useful as a site selection criteria. As suggested, other criteria are probably more useful, but possibly more difficult to measure or obtain.

PLUME INTERFERENCE - A potential problem exists where the residual exhaust plume from a leading vehicle could possibly create an interference in the RSD reading of a closely following second vehicle. Such interference could cause erroneous results if the separation time between successive cars was short, and the difference in emission levels of the successive plumes was large. The potential problem of plume interference during the RSD measurements was anticipated by its developers. To minimize the effects of this problem, the researchers developed a criteria to detect and eliminate rapidly changing CO/CO2 ratios when two exhaust plumes mix together. Under such test conditions, the RSD discards readings when the standard deviation of the linear fit of CO and CO2 exceeds 20 percent.

Despite these precautions, Stephens and Cadle [4] found potential RSD measurement problems if the remnants of a previous vehicle's exhaust plume were present during the current RSD measurement. From their work they concluded that (1) a plume effect does occur, (2) the RSD test criteria identifies plume nonlinearity, (3) the residual plume effect seems to last on average at least one second and maybe longer, and (4) plume nonlinearity only occurs when sequential plumes are of greatly different concentrations.

In this study, a plume interference analysis, similar to one performed by Stephens and Cadle was conducted using a large sample of 21,000 vehicles. These vehicles were coincidentally measured by the RSD at the expressway site, in the process of measuring the 257 vehicles which received the both the IM240 test, and the RSD test. The results were similar to those obtained by Stephens and Cadle. For example, Figure 20 compares the median RSD emissions stratified into three levels based on the previous vehicle's RSD emissions. The figure shows a definite likelihood of measuring a higher RSD value if the time separation is two seconds or less and the previous RSD CO value was more than 5 percent. Based on the results in Figure 20, the RSD CO emissions of a typical vehicle will be about 0.5% CO higher if it is following (within one or two seconds) a High RSD Emitter (greater than 5%), than

Figure 20
Vehicle Separation Effect



if it is following a low RSD High (less than 1.0%). For separation times of three seconds or more, the CO medians show less relationship with the previous vehicle's CO, indicating the previous vehicle's plume has dispersed.

## IN-USE FLEET ANALYSIS

A second goal of this project was to evaluate the ability of the RSD units to predict average in-use emissions in a specified area. This evaluation consisted of three parts: (1) comparison of estimated average RSD CO mass emissions with IM240 mass emissions, (2) comparison of the median RSD and IM240 emissions collected in Indiana with RSD emissions collected in other states, and (3) use of the Indiana RSD emissions from the expressway site to simulate the collection of RSD emissions at a number of independent sites.

All three parts of this analysis required converting the RSD CO concentrations to CO mass emission estimates. This was done in a two step process following the method outlined by Stephens and Cadle [4]. First, the CO concentrations were converted to grams per gallon units using molar ratios from idealized fuel combustion equations, the EPA fuel economy equation, and other constants. The second step involved converting the grams per gallon units to grams per mile units using a fuel economy estimate. Two estimates for an individual vehicle's fuel economy were available. The first was the actual fuel economy measured during the IM240 test. It could be viewed as the best estimate available, since instantaneous fuel economies at the precise RSD test conditions would generally not be available. The second was an average by-model-year and by-manufacturer fuel economy estimate based on CAFE numbers [4].

ESTIMATED MASS EMISSIONS - RSD mass emission estimates in grams per mile were calculated using both of the above fuel economy estimation methods so that they could be compared directly with IM240 mass emission results. The individual model year results, and overall average results from the combined sample are shown in Table 6 along with the IM240 mass emissions. Also, shown for comparison are the average by-model-year RSD and I/M concentration measurements.

A comparison of the overall RSD mass estimates at the bottom of Table 6 with the IM240 mass CO emissions shows reasonably good agreement. The difference between IM240 based fuel economy RSD value of 15.51 g/mi is only 4 percent below the measured IM240 value. When the CAFE based fuel economy values were substituted, the difference between the RSD estimate and the IM240 increased to 16 percent. A likely reason for the larger difference when using the CAFE values is that the IM240 fuel economy is based on the actual performance of the in-use vehicles, whereas the CAFE is simply a rough model year and manufacturer average fuel economy based on new vehicles tested over the FTP. In any case, both estimating methods resulted in an average RSD value less than the IM240 value

In examining the individual model year results, however, the relationship between the estimated RSD emissions and the IM240 emissions was not as consistent, even though both measurement methods showed a generally

Table 6
Average Emissions by Model Year
(Combined Site)

| | | IM240 Test Results | | | Remote Sensing Results | | | Indiana I/M Results | |
|---|---|---|---|---|---|---|---|---|---|
| Model Year | Sample SIZE | CO (g/mile) | HC (g/mile) | NOx (g/mile) | CO* (g/mile) | CO** (g/mile) | CO (%) | Idle CO | 2500 CO |
| 1976 | 9 | 42.19 | 2.67 | 2.52 | 40.49 | 34.36 | 1.71 | 2.28 | |
| 1977 | 7 | 11.73 | 1.57 | 4.40 | 36.74 | 38.36 | 2.02 | 1.36 | |
| 1978 | 19 | 40.32 | 2.50 | 3.49 | 37.77 | 33.45 | 1.90 | 1.61 | |
| 1979 | 19 | 22.96 | 2.80 | 4.41 | 19.25 | 20.02 | 1.26 | 2.11 | |
| 1980 | 18 | 24.77 | 1.46 | 3.27 | 26.79 | 19.77 | 1.40 | 0.43 | |
| 1981 | 15 | 33.26 | 1.51 | 2.15 | 17.88 | 14.51 | 1.10 | 0.91 | 1.22 |
| 1982 | 30 | 28.17 | 1.72 | 2.65 | 25.17 | 21.87 | 1.66 | 0.75 | 1.49 |
| 1983 | 22 | 27.99 | 1.52 | 2.80 | 24.01 | 18.13 | 1.36 | 1.23 | 1.69 |
| 1984 | 37 | 10.60 | 0.68 | 1.79 | 16.34 | 14.55 | 1.14 | 0.30 | 0.66 |
| 1985 | 38 | 9.51 | 0.64 | 1.69 | 5.32 | 4.24 | 0.32 | 0.27 | 0.18 |
| 1986 | 31 | 10.77 | 0.62 | 1.33 | 11.64 | 10.05 | 0.81 | 0.77 | 0.67 |
| 1987 | 31 | 7.33 | 0.43 | 1.67 | 5.35 | 5.15 | 0.42 | 0.11 | 0.31 |
| 1988 | 27 | 5.81 | 0.41 | 0.89 | 4.54 | 4.49 | 0.39 | 0.16 | 0.13 |
| 1989 | 32 | 4.44 | 0.21 | 0.89 | 6.56 | 6.11 | 0.48 | 0.09 | 0.12 |
| 1990 | 20 | 3.13 | 0.15 | 0.61 | 5.62 | 5.51 | 0.44 | 0.11 | 0.13 |
| 1991 | 1 | 9.59 | 0.37 | 0.59 | 5.39 | 4.62 | 0.36 | 0.02 | 0.00 |
| 1976-82 | 117 | 29.52 | 2.02 | 3.20 | 27.44 | 24.13 | 1.54 | 1.24 | - |
| 1983 + | 239 | 9.63 | 0.57 | 1.47 | 9.67 | 8.37 | 0.66 | 0.36 | 0.45 |
| ALL | 356 | 16.17 | 1.05 | 2.04 | 15.51 | 13.55 | 0.95 | 0.65 | 0.45 |

* Grams per gallon RSD CO results were converted to estimated grams per mile using the individual vehicle fuel economies measured during the IM240 cycle.

** Grams per gallon RSD CO results were converted to estimated grams per mile using average CAFE fuel economy values.

decreasing pattern of emissions from older to newer model vehicles. For example, the RSD estimates for the 1984 model year with 37 vehicles were significantly higher than the IM240, while the 1985 RSD estimates with 38 cars were significantly lower than the IM240 value. This dramatic switch in RSD estimates, approximately a 70 percent decrease, occurred while the IM240 values changed only about 10 percent between the 1984 and 1985 model years. Although this example represents the most extreme case in Table 6, the change in RSD estimates from year to year, in general, seemed to vary more than the IM240 average emissions.

Relative to two methods of computing the RSD estimates, the similar results indicate that substituting the CAFE fuel economy estimates seems to be a reasonable approach. This is fortunate, since actually measured fuel economy values for individual in-use vehicles would probably never be available in any application of RSD to on-road measurements.

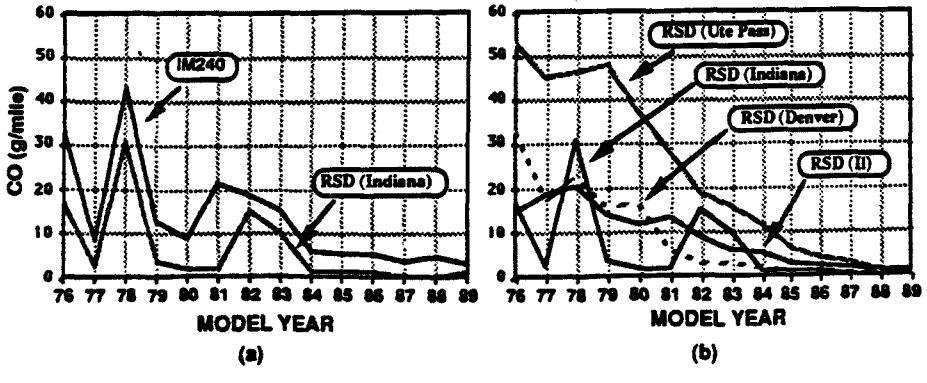
OTHER RSD TEST PROGRAMS - The CO concentration results from other RSD programs, which did not measure mass emissions, had previously been analyzed by the author [6] relative to their estimated fleet mass emissions. To put these other estimates in perspective, they were compared to the Indiana results.

Since the other results were analyzed in terms of the median values, the RSD and IM240 median values from the express way site were computed, and plotted in Figure 21(a). Excellent directional agreement between medians can be observed. For example, both curves seem to follow the same inconsistent emissions pattern for the older vehicles. Suggesting that the medians are similar, and that the same outliers and small sample sizes effect the RSD and the IM240 medians equally. This is a positive result, and suggests a good relationship between average RSD and IM240 results. However, total agreement between the two is not present, and the magnitude of both curves suggests that the RSD tends to under predict the IM240 over all model years.

The RSD data in Figure 21(a) were compared to the median data from the previous analysis [6] in Figure 21(b). This previous analysis included test data collected in Chicago, Illinois [1], Denver, Colorado, and Ute Pass Colorado by Dr. Stedman. Of the three sites, the vehicle operation and test site topography at the Denver location was probably the most similar to the Hammond, Indiana expressway on-ramp. The Ute Pass location at 8000 feet with a steep uphill grade and typically strong headwinds was probably the least similar. The Chicago express way ramp was marginally similar in that it likely included vehicle acceleration, but was a straight entrance ramp instead of a curvy one like Hammond and Denver.

Given the site differences, there is a general similarity in the model year pattern at all sites except Ute Pass. The difference between the general trend and a specific model year comparison may be due to the difference in sample size. The Denver and Illinois data included thousands of vehicles, where the Hammond data included only hundreds of vehicles. Nevertheless, the Hammond data is in the same ballpark as the Denver and Chicago data.

FIGURE 21
**Median By-Model-Year CO Emissions**




MULTIPLE FLEET SIMULATION - A serious shortcoming of previous RSD testing is that they did not include any mass emission data on matched vehicles. This test program addressed that need on an individual vehicle basis, but in evaluating fleet emissions, it is only one program with only one fleet average emission value (see Table 6). To determine how well the RSD fleet average in Table 6 might apply to on-road

easurements, many programs similar to this ne would need to be run.

In order to obtain a qualitative assessment ithout running many test programs, a omputer program was developed to simulate ie effect of many sites. Additionally, because ie analysis in this paper seems to suggest that SD may track broad trends in fleet averages asonably well, but does not do so well on ndividual vehicles, it would be useful to imulate many sites with different cars, but ith identical test conditions for each ndividual vehicle.

The correlated variables in this simulation program were FTP/IM240 mass emissions, IM240/RSD estimated mass emissions, and IM240/RSD vehicle speed. Only expressway data was used for this simulation. It was expected that the FTP/IM240 simulation would how good correlation as in Figure 2 earlier, nd that the IM240/RSD speed would show little orrelation.

The first step in the FTP/IM240 simulation vas to randomly partition the data in Figure 2 nto two equal sized samples, arbitrarily called ample 'A' and sample 'B'. Next, the average TP and IM240 CO mass emissions for each ample group were calculated. The difference etween the average FTP emissions of sample A nd sample B was then determined. Likewise he difference in the average IM240 emissions f sample A and B was calculated. This alculation process created a unique FTP missions difference between sample A and B, nd a unique IM240 emissions difference etween the samples. This unique data could hen be plotted on an x - y plot as a point.

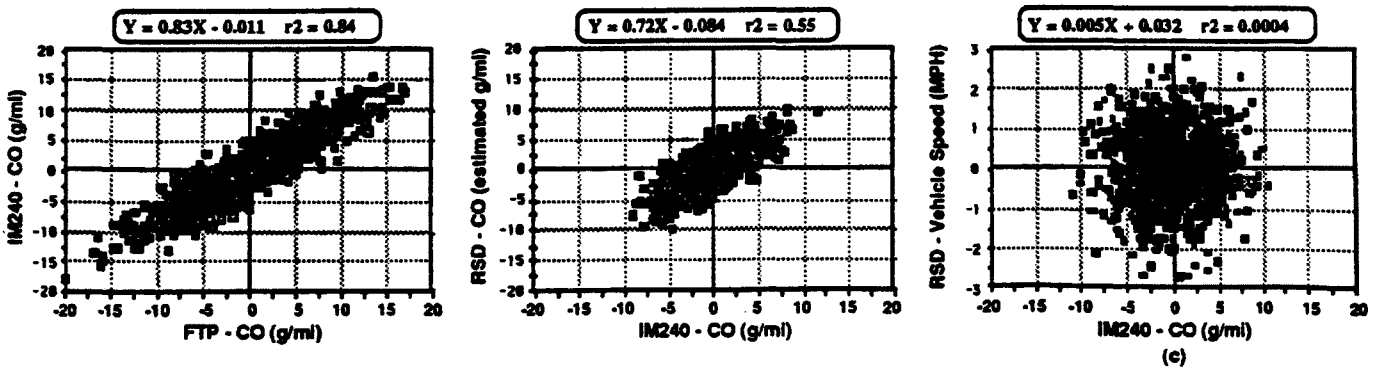
The process of randomly partitioning the data in Figure 2, and calculating the FTP and IM240 emission differences was repeated 1000 times, generating the 1000 paired FTP and IM240 data points in Figure 22(a). In this way, the mix of vehicles in each sample could be different, representing different fleets, but each vehicle would be tested under identical conditions. Therefore, only the effect on different fleet mixes would be evaluated.

An analogous procedure was repeated with the 256 vehicles tested at the expressway site which received both the RSD and the IM240 test. These CO differences were plotted in Figure 22(b). The same process was then used with IM240 CO data and the RSD speed data resulting in Figure 22(c).

The best agreement, as expected, of the three comparisons in Figure 22 is between the FTP and the IM240. This is noted by the high regression correlation coefficient, and the relative absence of data points in the upper left quadrant and the lower right quadrant. Points in these quadrants would occur if the difference between the FTP means of sample A and sample B were negative, and the difference between the IM240 means of sample A and sample B were positive, or vice versa. If this had occurred, it would have indicated there was little agreement between the paired FTP and IM240 results for that particular simulation.

In contrast to the FTP/IM240 simulation is the IM240 versus RSD speed simulation. As indicated, this simulation was only conducted as a control parameter of poor correlation, because theoretically, their should have been

**Figure 22**
**Fleet Simulations**
*(Emission or Speed Differences between Randomly Selected Sample*



no relationship between these variables since they came from non-overlapping, independent tests. The generally circular pattern shown in Figure 22(c) shows that this was the case. Note that the RSD speed parameter is the speed difference between sample A and B, not the average speed in either group.

Finally, comparison of the RSD and IM240 mass emission simulation showed fairly positive results, although not as positive as the FTP and IM240 results. As in the other figure, these positive results were evidenced by the reasonable correlation and the relative absence of the points in the two quadrants. In general, these results generally show that if the RSD and the IM240 were tested at many different test sites under IDENTICAL conditions, their mean emissions would typically be similar to one another.

As a final point, despite the good overall average and median emission agreement between IM240 and RSD, care must be taken as to not conclude that RSD estimates will consistently represent individual vehicle mass emissions over a complete driving cycle, or in-use operation over a wide range of conditions. This fact can be seen in the scatter plots of Figure 4, the repeatability plots of Figures 16 and 17, and in the individual model year emission results in Table 6. These results indicate that RSD measurements can vary considerably, for a number of different reasons which probably can never be completely accounted for in a one second test. Therefore, the utility of the RSD results in terms of fleet predictions is best if limited to a specific consistent test condition, and based on a large RSD sample.

## CONCLUSIONS

The primary goal of this test program was to evaluate the capability of the RSD to properly identify and categorize High Emitters as determined by the IM240. A spin-off analysis evaluated the performance of the RSD relative to a typical I/M test procedure, and the ability of the RSD to identify average fleet emission levels was investigated. Specific observations and conclusions from this test program are as follows.

1. The RSD did not, even at the most stringent cutpoints, identify all of the High CO Emitters. At the most commonly reported cutpoint of 4.5 percent CO, the RSD identified less than 15 percent of the late model High Emitters, which accounted for only about 25 percent of the repairable excess emissions, and only identified about 20 percent of the older model High Emitters. Approximately 85 percent of the late model High Emitters accounting for 75 percent of the repairable excess emissions were missed by the RSD in this test program.

2. Of the vehicles identified by the RSD as High CO Emitters, a moderate portion of them were, in fact, not High Emitters (i.e., False Failures). For cutpoints above 2 percent CO, RSD errors of commission ranged from zero to as high as 35 percent (combined site) for late model year cars, and from zero to approximately 25 percent for older cars. These ranges of False Failure rates, however, did confirm that at least 65 to 75 percent of the vehicles identified as High Emitters by the RSD truly are High Emitters.

3. The RSD was able to operate in mildly inclement weather conditions including light rain. Only about 10 percent of the CO tests were lost due to weather. Of this reduced total, about another 10 percent was lost due to improper RSD measurements detected by the RSD's internal quality control algorithm. Neglecting equipment malfunctions, slightly more than 15 percent of the sampled fleet was not measured.

4. The RSD CO performance looked more like a traditional I/M test than a loaded, transient, mass emission test. At the most reported cutpoint of 4.5 percent CO, the RSD was not nearly as effective in identifying High Emitters or repairable excess emissions as the two-speed idle I/M test for late model cars. Lowering the RSD cutpoint to 2 percent, increased the performance of the RSD to a level marginally better than the two-speed test, but at the expense of higher errors of commission (False Failures) relative to the the I/M test. Although the RSD identified fewer older model year cars than the single speed idle I/M test, it identified slightly more excess emissions with a measurably lower False Failure rate.

5. The RSD and the I/M CO tests identified different population groups. The RSD only

portion was generally smaller for the newer model group than for the older model year group.

6. Combining the RSD CO test and the I/M CO test improved identification of late model High Emitters, but at the expense of increased False Failures. For older cars, the combination substantially increased High Emitter identification with little change in False Failures relative to the I/M test. In combination with I/M, reasonable increases in identification of older vehicles were even observed at the 4.5 percent RSD cutpoint with a lower False Failure rate than with I/M alone.

7. Selecting an RSD cutpoint below 2 percent CO did not substantially improve the identification of repairable excess CO emissions from the late model vehicles. Selecting a cutpoint above 4 percent resulted in around 80 percent of all High Emitting vehicles falsely passing the RSD test. A recommended CO cutpoint range for future test programs would be from 2% to 3.5% CO, depending on the program objectives, and the acceptable False Failure rate.

8. Repeatability of the RSD CO emission measurements on track-tested vehicles was found to be extremely poor under steady-state conditions on a level road. However, much improved repeatability in RSD CO measurements were observed on vehicles operating on a 3% uphill grade. It is thought that the reasons for these variable results were due to individual vehicle differences, and its precise operating characteristics at the time of the RSD test, rather than the instrument itself. The reasons for the inconsistent measurement results are less important than the fact that they existed, and that they cannot currently be accounted for by the RSD system, since the current system measures neither vehicle speed nor acceleration accurately. With the current state of RSD development, it is recommended that future site selections lean toward those sites with light to moderate acceleration or uphill loads.

9. Improving the CO identification performance of the RSD may be difficult because reducing RSD variability and increasing identification performance appears to be influenced by vehicle operation, which is largely uncontrolled. Because of the likely uncontrolled vehicle operation, RSD identification improvements might only be achieved by lowering cutpoints, whereas I/M programs can lower cutpoints, add program features (e.g., functional checks), or change test type.

10. The RSD HC performance was abysmally poor. However, the unit used was one of the first prototypes developed, and future units would be expected to improve.

11. Reasonable agreement seemed to exist between the IM240 overall fleet-average emission levels and those estimated from the RSD measurements. However, substantial variations between the two measurement methods for individual model years was observed. Further analysis simulating multiple fleets, tends to imply that there is a rough relationship between the RSD fleet estimates and the IM240 when identical test conditions and very large samples are used.

12. The RSD plume interference analysis indicated that there is a definite likelihood of measuring a higher RSD value if the time separation between vehicles is two seconds or less, and the previous RSD CO value is more than 5 percent. However, even if these two conditions are met, the median effect is less than 0.5% CO.

As a final note, the inability of the RSD to identify even a significant fraction of the High Emitters was the most striking observation of this study. The cause for this inability to identify a large fraction of the High Emitters is probably more a reflection of the fact that an instantaneous RSD emission measurement is not likely to be completely representative of an overall driving cycle, rather than an inability of the RSD to accurately measure the instantaneous CO emissions in an exhaust plume. Compounding this problem is the current lack of ability of the RSD system to measure the exact operating mode of the vehicle during the test. Therefore, not only is the RSD system not capable of completely measuring the emissions from overall driving, the emission results which are measured are diminished in usefulness because there is no exact way to relate them to a vehicle driving mode.

Even so, this may not be a fatal handicap, since the RSD seems to have the ability to identify a portion of the High Emitters in a roadside environment quickly and non-obtrusively. As such, this is probably the RSD system's principle asset, and may be best used on a random basis in conjunction with a traditional I/M program. For example, identifying and repairing even a portion of the High Emitters in a CO 'hot spot' (outside of their periodic I/M cycle) may be sufficient to lower the ambient levels in the hot spot area.

## ACKNOWLEDGEMENTS

Recognition is given to Mr. Joe Patterson of Automotive Test Laboratories (ATL) for the many hours he spent alongside the expressway during the cold winter days in Hammond, Indiana. Recognition is also given to Mr. Pradeep Tripathi of ATL for his roadside efforts, and especially for the hours he spent processing RSD data and reading license plates from video tapes. Special acknowledgement also goes to Dr. Donald Stedman and Dr. Gary Bishop for all their valuable advice and support. Finally, thanks goes to Mr. Dennis McClement of ATL for his patience, and helpful suggestions throughout this process.

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# APPENDIX M

## MODEL YEAR FAILURE RATES BY TEST TYPE

# HAMMOND LANE I/M FAILURE RATES

| | | | | | |
|---|---|---|---|---|---|
| **HC 2500:** | --- | 220 ppm | 220 ppm | --- | --- |
| **CO 2500:** | --- | --- | 1.2 percent | --- | --- |
| **HC Idle:** | 220 ppm | 220 ppm | 220 ppm | 250 ppm | 350 ppm |
| **CO Idle:** | 1.2 percent | 1.2 percent | 1.2 percent | 2.0 percent | 3.5 percent |

**IM240**
**HC:** 0.8 g/mi
**CO:** 15 g/mi

| Model Year | Lane Sample | | | | | |
|---|---|---|---|---|---|---|
| 76 | 102 | 65 | N.A. | N.A. | 57 | 28 |
| 77 | 255 | 202 | N.A. | N.A. | 187 | 116 |
| 78 | 355 | 252 | N.A. | N.A. | 226 | 140 |
| 79 | 431 | 266 | N.A. | N.A. | 230 | 119 |
| 80 | 347 | 140 | N.A. | N.A. | 102 | 78 |
| 81 | 353 | 57 | 66 | 98 | 50 | 37 |
| 82 | 392 | 86 | 99 | 141 | 67 | 47 |
| 83 | 548 | 70 | 76 | 105 | 53 | 35 |
| 84 | 804 | 106 | 121 | 156 | 86 | 49 |
| 85 | 819 | 66 | 74 | 105 | 56 | 35 |
| 86 | 792 | 52 | 56 | 85 | 39 | 24 |
| 87 | 698 | 24 | 32 | 39 | 19 | 13 |
| 88 | 755 | 15 | 18 | 22 | 12 | 4 |
| 89 | 791 | 8 | 9 | 12 | 6 | 3 |
| 90 | 784 | 2 | 3 | 8 | 2 | 1 |
| 91 | 89 | 0 | 0 | 0 | 0 | 0 |
| 92 | 1 | 0 | 0 | 0 | 0 | 0 |

| Model Year | Lane Sample | |
|---|---|---|
| 76 | 121 | 104 |
| 77 | 281 | 255 |
| 78 | 385 | 338 |
| 79 | 456 | 354 |
| 80 | 351 | 239 |
| 81 | 366 | 219 |
| 82 | 403 | 243 |
| 83 | 467 | 199 |
| 84 | 677 | 263 |
| 85 | 658 | 194 |
| 86 | 643 | 121 |
| 87 | 548 | 59 |
| 88 | 632 | 37 |
| 89 | 632 | 27 |
| 90 | 604 | 14 |
| 91 | 36 | 0 |

Note: Shaded area indicates official Indiana I/M test

# HAMMOND LANE I/M FAILURE RATES

| | | | | | |
|---|---|---|---|---|---|
| **HC 2500:** | --- | 220 ppm | 220 ppm | --- | --- |
| **CO 2500:** | --- | --- | 1.2 percent | --- | --- |
| **HC Idle:** | 220 ppm | 220 ppm | 220 ppm | 250 ppm | 350 ppm |
| **CO Idle:** | 1.2 percent | 1.2 percent | 1.2 percent | 2.0 percent | 3.5 percent |

| Model Year | | | | | |
|---|---|---|---|---|---|
| 76 | 63.7% | N.A. | N.A. | 55.9% | 27.5% |
| 77 | 79.2% | N.A. | N.A. | 73.3% | 45.5% |
| 78 | 71.0% | N.A. | N.A. | 63.7% | 39.4% |
| 79 | 61.7% | N.A. | N.A. | 53.4% | 27.6% |
| 80 | 40.3% | N.A. | N.A. | 29.4% | 22.5% |
| 81 | 16.1% | 18.7% | 27.8% | 14.2% | 10.5% |
| 82 | 21.9% | 25.3% | 36.0% | 17.1% | 12.0% |
| 83 | 12.8% | 13.9% | 19.2% | 9.7% | 6.4% |
| 84 | 13.2% | 15.0% | 19.4% | 10.7% | 6.1% |
| 85 | 8.1% | 9.0% | 12.8% | 6.8% | 4.3% |
| 86 | 6.6% | 7.1% | 10.7% | 4.9% | 3.0% |
| 87 | 3.4% | 4.6% | 5.6% | 2.7% | 1.9% |
| 88 | 2.0% | 2.4% | 2.9% | 1.6% | 0.5% |
| 89 | 1.0% | 1.1% | 1.5% | 0.8% | 0.4% |
| 90 | 0.3% | 0.4% | 1.0% | 0.3% | 0.1% |
| 91 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 92 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |

**IM240**

**HC:** 0.8 g/mi

**CO:** 15 g/mi

| Model Year | |
|---|---|
| 76 | 86.0% |
| 77 | 90.7% |
| 78 | 87.8% |
| 79 | 77.6% |
| 80 | 68.1% |
| 81 | 59.8% |
| 82 | 60.3% |
| 83 | 42.6% |
| 84 | 38.8% |
| 85 | 29.5% |
| 86 | 18.8% |
| 87 | 10.8% |
| 88 | 5.9% |
| 89 | 4.3% |
| 90 | 2.3% |
| 91 | 0.0% |

Note: Shaded area indicates official Indiana I/M test