

FOIA MARKER

This is not a textual record. This is used as an administrative marker by the William J. Clinton Presidential Library Staff.

Collection/Record Group: Clinton Presidential Records
Subgroup/Office of Origin: Council on Environmental Quality
Series/Staff Member: Kathleen (Katie) McGinty
Subseries:

OA/ID Number: 2899
FolderID:

Folder Title:
EPA [Environmental Protection Agency] - Vehicle Emissions Enhanced I/M [Inspection and Maintenance] Costs and Benefits Draft December 1991

Stack:	Row:	Section:	Shelf:	Position:
S	61	6	2	2

December
1991

Air

2.0

3.0



**New York State
Department of
Environmental Conservation**



ROBERT A. WHITBY, Ph.D., P.E.
Automotive Emissions Laboratory
Division of Air Resources

50 Wolf Road
Albany, NY 12233-3259

Lab (518) 453-1800
Office (518) 457-3200

Draf

* 100% PIRAN
 * 100% PENGAWASAN - SECURE

Table of Contents

	Page
List of Appendices	ii
List of Tables	iii
1.0 INTRODUCTION	1
2.0 EMISSION REDUCTIONS FROM I/M PROGRAMS	3
2.1 Recent I/M Test Programs (Maryland and Indiana)	3
2.2 FTP Correlation Comparison Between the IM240 and the Second-chance 2500 rpm/Idle Test	7
2.2.1 I/M Test Assessment Criteria Overview	10
2.2.2 Detailed Discussion of Correlation and Test Assessment	13
2.2.3 Avoiding Errors of Commission	14
2.3 Estimating I/M Testing Credits for MOBILE4.1	22
2.3.1 Tech4.1 Background and Assumptions	22
2.3.2 Evaporative and Running Loss Modeling, and the Effectiveness of Purge/Pressure Testing	26
2.3.3 Benefits of IM240 NOx Inspections	27
3.0 COST AND ESTIMATING COST EFFECTIVENESS	36
3.1 Cost of Conventional I/M Testing	36
3.1.1 Inspection and Administration Costs	36
3.2 Estimated Cost of High-Tech I/M Testing	38
3.2.1 General Methodology	38
3.2.2 Equipment Needs and Costs	39
3.2.3 Cost to Upgrade Centralized Networks	41
3.2.4 Cost to Upgrade Decentralized Programs	47
3.3 Repair Costs	49
3.3.1 HC and CO Exhaust Repair Costs and Methodology	49
3.3.2 NOx Repair Costs and Methodology	51
3.3.3 Evaporative System Repair Costs and Methodology	53

Draft

12/18/91

-i-

Handwritten notes:
 10/18/91
 Planning
 *KIM PENG - summary

Handwritten notes:
 DONE TRANSPORT ZONE
 DONE EQUIPMENT
 DONE INSPECTION
 DONE REPAIR
 DONE COST
 DONE IMPLEMENTATION

3.4	Fuel Economy Benefits	55
3.4.1	Fuel Economy Benefits of Evaporative System Repairs	55
3.4.2	Fuel Economy Benefits of IM240 Repairs	56
3.4.3	Fuel Economy Benefit for the 2500 rpm/Idle Test	57
3.5	Recurring Failure and Repair Rates	59
3.6	Method for Estimating Cost Effectiveness of I/M Programs	62
3.6.1	Inspection Costs	62
3.6.2	Repair Costs	63
3.6.3	Fuel Economy Cost Benefits	64
4.0	COST AND BENEFITS OF ENHANCED I/M OPTIONS	64
4.1	Emission Reduction Benefits	64
4.2	Cost Effectiveness Estimates	66
4.2.1	Assumptions and Inputs for the Program Options	66
4.2.3	Cost-Effectiveness Calculations	67
4.2.4	National Cost of Choosing Low Option I/M	69
5.0	ONBOARD DIAGNOSTICS AND ON-ROAD TESTING	70

List of Appendices

Appendix

- A Cost Effectiveness Model Version 4.1 Source Code Listing
- B Tech4 Model Version 4.1 Source Code Listing
- C Evaporative Emissions and Running Loss Emission Factor Derivation
- D Purge and Pressure Test Figures and Spreadsheet
- E Regression Analyses for Fuel Injected 1983 and Later Vehicles
- F MOBILE4.1 Technology Distribution and Emission Group Rates and Emission Levels
- G FTP Correlation Comparison Between IM240 and Second-chance 2500 rpm/Idle Test
- H Data Analyses for Fuel Injected 1983 and Later Vehicles
- I Evaporative System Purge and Pressure Diagrams
- J Evaporative System Repairs and Repairs

List of Tables

	<u>Page</u>
2-1 IM240 Selection Standards for Stratified FTP Recruitment	4
2-2 Weighting Factors for Correcting Recruitment Biases	5
2-3 FTP, Lane IM240, and "Tank Fuel" IM240 Results	15
2-4 Vehicle 1674 NOx, FE Results Versus Dynamometer Settings	16
2-5 Two-Mode Criteria Applied to Lane IM240 Error-of-Commission Vehicles	19
2-6 Variables Affecting CO Emissions	20
2-7 Short Test Identification Rates	25
2-8 Short Test Repair Effectiveness	26
2-9 Lane IM240 Based Emission Factor Levels with IM240 NOx Cutpoints	30
2-10 Side Effects of I/M on NOx Emissions	32
2-11 Lane IM240 Based Emission Factors with IM240 Cutpoints	34
3-1 I/M Program Inspection Fees	37
3-2 Equipment Costs for New Tests	40
3-3 Expendables for New Tests	40
3-4 Peak Period Throughput Rates in Independent I/M Programs	41
3-5 Current Program Costs	44
3-6 Costs to Add Pressure Testing to Centralized Programs	45
3-7 Costs to Add Proposed Tests to Centralized Programs	46
3-8 Inspection Volumes in Licensed Inspection Stations	47
3-9 Costs to Conduct Pressure, Purge, and Transient Testing in Decentralized Programs	49
3-10 Average Cost of Repairing Emission Control Components	51
3-11 Average Repair Costs	53
3-12 Average Repair Costs and Fuel Economy Benefits	54
3-13 Zero Improvement Vehicle Sample Size Adjustments	57
3-14 Adjusted Zero FE Benefit Vehicle Sample Size	58
3-15 Exhaust Test Failure Rates	60
3-16 Default Inspection Costs in CEM4.1	63
3-17 Default Repair Cost in CEM4.1	63
3-18 Fuel Economy Benefits in CEM4.1	64
4-1 MOBILE4.1 Inputs for Enhanced I/M Performance Standard Options	65
4-2 Benefits of I/M Programs Options	66
4-3 Total Annual Program Cost	67
4-4 Cost per Ton Allocating All Costs to VOC	68
4-5 VOC Cost per Ton Accounting for NOx and CO Benefit	69
4-6 Total Cost and Benefits of I/M Options	69
4-7 Excess Cost of Choosing Low Option I/M	70

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 pollutants 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 an 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 enhanced I/M programs, however, EPA is considering a performance standard which would be based on loaded, transient testing, in conjunction with evaporative system purge and pressure tests. Using EPA's MOBILE4.1 computer model, a high-tech I/M program such as the one depicted above is expected to achieve emission reductions from mobile sources on the order of approximately 30% (compared to a 5% emission reduction 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 EMISSION REDUCTIONS FROM I/M PROGRAMS

2.1 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 IM240¹, 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 have 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. Injection is rapidly replacing carburetion as the preferred fuel-metering method for new

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

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. To avoid this, 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 Federal Test Procedure (FTP)² 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 2-1. 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 2-1

IM240 Selection Standards for Stratified FTP Recruitment

Model Years	Selection Standards (grams per mile)	
	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, error-of-commission rates and failure rates (all important criteria for assessing the overall effectiveness of

2 The Federal Test Procedure (FTP) is an 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 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.

I/M testing strategies). The database was corrected using the weighting factors presented in Table 2-2.

Table 2-2

Weighting Factors for Correcting Recruitment Biases

Fuel Metering System	Lane IM240 Results	Lane Count	Lab Sample Count	Weighting Factor	# Lab Veh Passing FTP	# Marginals Failing FTP
PFI	Clean	1505	65	23.15	25	32
	Dirty	97	22	4.41	1	2
	Total	1602	87		26	34
TBI	Clean	1555	90	17.28	29	40
	Dirty	166	40	4.15	4	6
	Total	1721	130		33	46

Weighting factors are used as follows: If the 22 dirty vehicles that received FTP tests in the Port Fuel Injected (PFI) vehicle sample had excess HC emissions which totaled 100 grams per mile (gpm), the database would be corrected in this case by multiplying 100 by the 4.41 weighting factor, resulting in a corrected excess emission rate of 441 gpm for the dirty vehicles (excess emissions are those FTP-measured emissions that exceed the certification emission standards for the vehicle under consideration). In comparison, the excess emissions of the IM240 clean vehicles have to be multiplied by 23.15 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 65 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 excess

emission identification rates, I/M failure rates, error-of-commission 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 2.2 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 I/M tests. Additionally, one of the IM240s being performed at the lab is restricted to inertia weight settings of 2,500 pounds or 3,500 pounds. This restriction allows EPA to evaluate the FTP correlation effect of a more economical dynamometer (with only two inertia weights).

The evidence displayed in Section 2.2 (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 2.3 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 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.

2.2 FTP Correlation Comparison Between the IM240 and the Second-chance 2500 rpm/Idle Test

This section focuses on the comparison of the IM240 transient test to EPA's currently recommended second-chance 2500 rpm/Idle test procedure³, and details the evaluation criteria upon which the

3 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.

comparison is based. This comparison shows how 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 and scatter plots in Appendix E for an illustration of this better correlation).

For the sake of this comparison, only 1983 and newer vehicles equipped with fuel injection were considered. (Emission benefits presented in Section 4 do reflect the application of the IM240 to carbureted vehicles also). This vehicle 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. This report calls for an immediate second-chance test for vehicles that initially fail the emission standards. Prior to the second test, vehicles are preconditioned at 2500 rpm, no-load for 3 minutes. 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.

Y1	982
R ²	
Y2	986
Y3	986

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 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 while lane tests are done on the fuel in the tank of the vehicle as received. Also, the equipment used in the lane tests is of a lower maximum emission

value than the lab equipment; for example, a car would have pegged the lane instrument 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 NO_x is not 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 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, and to avoid possible increases in the emissions of such vehicles from mechanics' attempts to solve a problem which does not actually exist. The figures in Appendix E, 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.

2.2.1 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 excess emissions identification rate, 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 2.2.2 provides a more detailed discussion of the same topics.

2.2.1.1 Excess Emission Identification Rate

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:

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

As can be seen in Figures 1 and 4 in Appendix G, the IM240 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.

2.2.1.2 Failure Rate

As the excess emissions identification rate increases, the opportunity to identify vehicles for emission repairs also increases. However, this measure is not sufficient for determining which is the more effective 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:

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

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 identification rate in conjunction with a low failure rate (as a result of identifying fewer vehicles passing or close to the standard) efficiently utilizes resources. Figures 1 and 4 in Appendix G show that the IM240 achieves its higher identification rate without a large increase in failure rate. Figures 2 and 5 show that applying the more stringent California idle mode standards to achieve excess emission identification rates similar to those of the IM240 causes the failure rate to greatly exceed the IM240's failure rate (34% vs. 13% for PFI), despite second-chance testing. Even with the 34% failure rate, the stringent second-chance 2500 rpm/Idle test identifies 6% less excess HC emissions and 3% less CO emissions than the IM240 does with a 13% failure rate for PFI vehicles. Applying more stringent standards to both Idle and 2500 modes as shown in Appendix G, Figures 3 and 6, makes the problem even worse.

2.2.1.3 Error-of-Commission 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 as 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:

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

*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 excess emissions identification rate by making the I/M test standards more stringent, this "improvement" comes at the cost of potential increases in the error-of-commission rate.

2.2.1.4 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. Figures 1 through 6 of Appendix G graphically illustrate this point. As can be seen, the IM240 failure rate for vehicles that pass their FTP standards was lower than the failure rate from second-chance 2500 rpm/Idle standards that achieve comparable excess emissions identification rates. Section 2.2.3 discusses in depth the vehicles that are shown in Figures 1 through 6 to be failures at the lane.

2.2.1.5 "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 (note that a different definition of "normal" is used in classifying vehicles in MOBILE4.1, see section 2.3). Normal emitters include those vehicles that pass the FTP. Such vehicles are difficult to

properly repair (at least short of catalyst replacement, which EPA generally avoids in its emission repair evaluations due to cost and because new catalysts often mask other defects), their emissions are sometimes increased by inept repairs, and they account for little of the total excess emissions (less than 14%; see Appendix H, pages 7 and 16). Therefore, normal emitters are not particularly cost effective to identify for repairs. These vehicles probably lack overt defects. Those that fall above one of the FTP standards obviously have some problem, but likely have suffered catalyst deterioration (which is difficult to diagnose) or were either poorly designed or built in the first place. Thus, the marginal costs of identifying and effectively repairing these vehicles may not be worth the marginal benefits that could be expected.

2.2.2 Detailed Discussion of Correlation and Test Assessment

The following analysis shows that the IM240 test is considerably more powerful as an I/M test than the second-chance 2500 rpm/Idle test for both TBI and PFI vehicles. The analysis presumes that the IM240 is implemented to achieve higher excess emission identification rates. Given that rationale, IM240 standards of 0.8 gpm HC and 15 gpm CO were selected for this analysis. These IM240 standards achieve excess emission identification rates that are significantly higher than for the present second-chance 2500 rpm/Idle standards, while limiting the error-of-commission rate to less than 1%.

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 for TBI vehicles, they are not formally discussed. Carbureted vehicles are not considered because they are disappearing from the market, and for the purposes of testing older technology vehicles, the steady-state tests are still adequate.

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. Note the following:

- The FTP excess emissions identification rates are 15% 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.
- No FTP passing vehicles failed the second-chance 2500 rpm/Idle test in this sample. Four FTP-passing PFI vehicles failed the IM240 yielding an error-of-commission rate of 0.8%. These vehicles are discussed in Section 2.2.3. Note

that these Ecs can be prevented through the use of modal analysis and Bag 2 results.

- The IM240 increases the failure rate to 13% from 11% 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 13% for the IM240. So even with the IM240's higher IDRs, significantly fewer vehicles are identified for repairs.
- Eleven percent more FTP-passing vehicles fail the second-chance 2500 rpm/Idle test than fail the IM240. Sending this many more cars for repair, while also identifying less excess emissions wastes resources.
- The normal emitter failure rate is only 1% for the IM240 versus 28% 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 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.

2.2.3 Avoiding Errors of Commission

I/M test procedures and standards that cause low emitting vehicles to fail I/M tests are obviously undesirable. Using the standards of 0.8 gpm HC and 15 gpm CO, false failures resulted on five of the 220 vehicles that received FTP tests (1983 and newer with fuel injection). It is surprising 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. Also, discussed are EPA's ongoing efforts to develop strategies that will prevent false failures while maintaining high IDRs. 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 in previous sections. Of the 87 PFI equipped 1983 and newer vehicles receiving FTPs, 26 passed the FTP, while one of these 26 failed the IM240 standards of 0.8/15. Of the 130 TBI 1983 and newer vehicles receiving FTPs, 33 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 2-3.

Table 2-3

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.

2.2.3.1 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 enriches 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 2-4 provides fuel economy and NO_x results for vehicle 1674 for the various tests conducted.

Table 2-4

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 2-3) 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). While 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.

2.2.3.2 Interactions of Vehicle Design, Fuel Properties, and Test Conditions

Three techniques have been 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 two-mode test, use the second mode with the composite result to determine pass/fail. For example, consider a vehicle with a composite result of 0.7 gpm HC and 16 gpm CO, with mode 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 look at the emissions in mode 2 of the test and apply pass/fail criteria for just that portion of the test. Assuming mode 2 standards 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 modes.

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 IDA,

as shown in the tables in Appendix H. For example, page H-10 lists a variety of potential cutpoints of varying stringency, the most 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 84% to 59% and the CO IDR from 84% to 72%. 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-mode criteria are better ways of avoiding false failures. The theory behind this is as follows. Assuming that the test were 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 properly functioning.

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, mode 2 results should be lower than the composite results, on a gram per mile basis, and second chance tests after preconditioning, as shown for current short tests, should be less influenced by canister purge.

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

? — OK, but how many valid failures would become errors of omission via the 2-mode criteria?

Table 2-5

Two-Mode Criteria Applied to Lane IM240 Error-of-Commission Vehicles

(grams per mile)

Vehicle Number	Lane IM240 Mode-1		Lane IM240 Mode-2		Lane IM240 Composite	
	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 mode 2 standards has the added benefit of reducing the normal emitter failure rate for TBI vehicles from 4.4% to 3.5%. At the same time, the overall TBI failure rate decreases from 20.7% to 19.7% without a perceptible reduction in the IDRs which remain at 84.1% and 77.2% for HC and CO respectively. Analogous benefits were observed for the PFI sample, where the normal emitter failure rate for PFI vehicles decreases from 2.3% to 2.0%, and the overall PFI failure rate decreases from 13.3% to 13.0% without a perceptible reduction in the IDRs which remain at 84.1% and 83.6% for HC and CO respectively.

All of the TBI error-of-commission vehicles passed 0.8/15 gpm standards on the tank fuel IM240, indicating 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 mode 2 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 would 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 mode-2 criteria indicates that second-chance testing will not be necessary. This discussion explains why this additional alternative can be useful and shows that these 4 TBI FC vehicles were tested under rather unique conditions.

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 2-6).

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 intense vapor generation in their fuel tanks.

Table 2-6

Variables Affecting CO Emissions

<u>Vehicle Number</u>	<u>Canister Purge Volume liters</u>	<u>Engine Displacement liters</u>	<u>I/M Lane Temperature ° F</u>	<u>Lane Test Date</u>
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, high CO readings are likely as purge flow increases. 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 could have caused high canister loading. High canister loading combined with the high purge rate probably caused the high emissions. Table 2-5 shows that the mode-1 emissions were more than 5 times higher than the mode-2 emissions, further indicating that a highly loaded canister was sufficiently purged during the first mode to achieve relatively clean mode-2 results.

2
open air
d-3-1-1-1
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, temperature deviations, and probable fuel RVP in determining whether to allow second-chance testing.

2.2.3.3 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 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 can be prevented by implementing pass/fail criteria that considers mode-2 results in addition to composite results. Under this strategy, vehicles fail only if their composite emissions exceed 0.8/15 and their mode-2 emissions exceed 0.5/12 gpm.
- Second-chance testing after preconditioning on marginally failing vehicles, especially those showing high purge rates, ----

could be used as a fail-safe mechanism to insure that no errors-of-commission occur.

In conclusion, there is evidence that indicates 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, mode 2 standards, and preconditioned second-chance tests on marginal failures.

2.3 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.

2.3.1 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 provide 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 emission identification rate (IDR) and repair effectiveness for each of these divisions of the data for each I/M test type, as illustrated in Table 2-7. In practice, because of small sample sizes, several of the divisions 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 2-8) 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 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:

$$2.019 + .0115 * 60.829 = 2.089 \text{ gpm}$$

Assuming a 2500 rpm/Idle test is done, the HC IDR (see Table 2-7) 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 2-8 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 .59231 and 1.0271 respectively. Interpolating, the after repair level for the 2.089 gpm before repair emission level is:

$$.59231 + ((2.089 - 1.9846) / (3.9314 - 1.9846)) * (1.0271 - .59231) = .6153$$

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

$$.6187 * .6153 + (1 - .6187) * 2.089 = 1.1772 \text{ gpm}$$

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 2-7

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 2-8

Short Test Repair Effectiveness

		<u>PFI/TBI</u>		<u>Carb/Opdp</u>	
		<u>Before</u>	<u>After</u>	<u>Before</u>	<u>After</u>
		<u>Repair</u>	<u>Repair</u>	<u>Repair</u>	<u>Repair</u>
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.

2.3.2 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, Indiana, 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 2400 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 smaller than estimated here. Since the benefits in MOBILE4.1 are less than the benefits we now estimate, they will not be corrected now. However, the entire issue of the potential benefits from pressure and purge checks will be revisited for the MOBILE5 model.

2.3.3 Benefits of IM240 NOx Inspections

None of the existing I/M program models or the MOBILE4.1 model itself are designed to estimate the effect of NOx emission inspection as part of an I/M program. Therefore, no estimate the

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

A sample of over 3200 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 NOx 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 NOx measurements and NOx measured on the Federal Test Procedure (FTP), an FTP NOx emission level was estimated for each vehicle in the sample. A linear least-square regression was run for estimated FTP NOx 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 NOx inspection first using the 10% failure rate cutpoints and then the 20% failure rate cutpoints. The exclusion of the higher NOx 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 NOx failures removed is assumed to be the benefit from the IM240 NOx emission test with only NOx related repairs performed. Results are shown in Table 2-9.

Since it is expected that most NOx emission testing will be done along with testing for HC and CO emissions, the side effect of HC and CO repairs on NOx emissions should also be accounted for. This effect is ignored in the standard MOBILE4.1 model. Typically NOx emissions will increase, on average, when HC and CO emission repairs are performed. The extent of this NOx emission disbenefit was determined by calculating average NOx 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 NOx emission levels of these vehicles after repairs were determined. These NOx emission levels are not the result of NOx related repairs, but a by-product of HC and CO emission repairs. Using the standard HC/CO 2500 rpm/Idle test identification rates along with the repair effects on NOx and the NOx emission rates by emitter group in the Tech4 model, the effect of NOx disbenefits was determined for each age of each model year. See Table 2-10.

The NOx disbenefits, as a percent change, are applied to the emission levels estimated from the regression equations at each age. The resulting NOx emission levels by age are regressed versus mileage for each model year to give the final emission factor equation for NOx. Comparing the emission factor results of the baseline case with the cases with 10% or 20% NOx emission testing failure rates was done to estimate the benefits, in tons, of the IM240 NOx emission test. Results are shown in Table 2-11. For example, at age 5 and mean mileage of 60,829 miles, the "20% fail" IM240 NOx cutpoints will reduce 1992 model year NOx 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 NOx emission benefit from use of IM240 NOx cutpoints. These benefits were used in applying the cost credit. It should be noted that since both the cases with and without the IM240 NOx inspection cutpoints should include the disbenefits of HC/CO repairs, the disbenefits do not effect the calculation of incremental NOx 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 2-9

Lane IM240 Based Emission Factor Levels with IM240 NOx 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 2-9

- continued -

13	14	15	16	17	18	19	20	21	22	23	24	25	Age	Regression	
12.9615	13.6257	14.1254	14.8463	15.4106	15.9421	16.4451	16.9209	17.3712	17.7999	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	1.163	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 2-10

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 2-10

- continued -

13	14	15	16	17	18	19	20	21	22	23	24	25	Model	Regression	
12.9613	13.4237	14.234	14.9483	15.4104	15.9421	16.4451	16.9209	17.3712	17.7949	18.1997	18.5808	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 2-11

Lane IM240 Based Emission Factors with IM240 Curpoints
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	2.6038	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 2-11

- continued -

13	14	15	16	17	18	19	20	21	22	23	24	25	Model	Regression	
12.9613	13.4237	14.234	14.8483	15.4104	15.9421	16.4451	16.9209	17.3712	17.7949	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

3.0 COST AND ESTIMATING COST EFFECTIVENESS

3.1 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.

3.1.1 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 3-1 shows the estimated cost of the I/M program on a per vehicle basis, including inspection and oversight costs.

Table 3-1

I/M Program Inspection Fees

<u>Decentralized Programs</u>		<u>Centralized Programs</u>	
<u>Program</u>	<u>Cost Per Vehicle</u>	<u>Program</u>	<u>Cost Per Vehicle</u>
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.

3.2 Estimated Cost of High-Tech I/M Testing

3.2.1 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.

3.2.2 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 (CO₂), 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 3-2 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 3-2

Equipment Costs for New Tests

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

The figures in Table 3-2 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 3-3. 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 3-3

Expendables for New Tests

<u>Test</u>	<u>Material</u>	<u>Cost</u>	<u>Replacement Interval</u>	
			<u>Centralized</u>	<u>Decentralized</u>
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.

3.2.3 Cost to Upgrade Centralized Networks

3.2.3.1 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 3-4.

Table 3-4

Peak Period Throughput Rates in Independent I/M Programs

<u>Program</u>	<u>Vehicles Tested per Hour</u>
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.

3.2.3.2 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 inspection 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 an 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 and other costs as shown in Table 3-5. 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 3-5

Current Program Costs

<u>Increments</u>	<u>Per Vehicle Cost</u>	<u>Total Cost Less Increments</u>
Current		\$8.50
Equipment	\$0.21	\$8.29
Staff	\$0.92	\$7.33
State Retainer	\$1.25	\$6.08

3.2.3.3 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 3-6. These are based upon the costs of equipment and expendables as shown in Tables 3-2 and 3-3 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 3-3, 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 3-6

Costs to Add Pressure Testing to Centralized Programs

<u>Increments</u>	<u>Per Vehicle Cost</u>	<u>Running Total Cost per Vehicle</u>
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

3.2.3.4 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. With the use of fast-pass and fast-fail algorithms, the total test time could be shortened for a significant number of vehicles. 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 3-5; 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. 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 3-2 and calculating the costs of five years worth of expendables using the figures in Table 3-3 and dividing by 117,000. The resulting costs estimates are shown in Table 3-7. Table 3-7 shows the result of factoring the figure of \$6.08, from Table 3-5, 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 3-7

Costs to Add Proposed Tests to Centralized Programs

<u>Increments</u>	<u>Per Vehicle Cost</u>	<u>Running Total Cost per Vehicle</u>
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.

3.2.4 Cost to Upgrade Decentralized Programs

3.2.4.1 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 only perform, on the average, about 1,025 inspections per year, as shown in Table 3-8 (note that this number is a station-weighted average).

Table 3-8

Inspection Volumes in Licensed Inspection Stations

<u>Program</u>	<u>Vehicles per Year</u>	<u>Vehicles per Station</u>
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

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.

Conversations with program personnel in decentralized programs indicated that inspectors (who have other duties as well) are paid about \$15 an hour. An overhead rate of 40% is assumed, for a total labor cost of \$21 an hour.

3.2.4.2 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 3-2 and 3-3 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.

3.2.4.3 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 3-2, 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 3-3 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 3-9.

Table 3-9

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

<u>Test Procedure</u>	<u>Incremental Cost</u>	<u>Total</u>
Pressure	\$0.23	\$17.93
Labor	\$1.75	\$19.68
Purge (Equipment only)	\$12.40	\$32.08
Transient (Equipment only)	\$24.97	\$57.05

3.3 Repair Costs

3.3.1 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")

3.3.1.1 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 included⁴. 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 vehicles⁵. 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.⁶

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.

3.3.1.2 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 3-10.

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 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

4 "1989 Annual Report Vehicle Exhaust Testing Program Jefferson County, Kentucky", April, 1990

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

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

visual inspection of the system. The PCV and gas cap repairs are the average cost of replacing these components.

Table 3-10

Average Cost of Repairing Emission Control Components

<u>Component</u>	<u>Pre-81</u>	<u>1981+</u>
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.

3.3.2 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 vehicles⁷. 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 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

7 November 1991, EPA memorandum from E. Glover to C. Hawley, "Average Repair Costs and Benefits from Repairing High NO_x Vehicles."

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 3-11) 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 3-11. 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 3-11

NO_x Repair Costs

Yeh	MY	Make	Model	NO _x Repair Description	Labor Hours	Labor Cost	Parts Cost Retail	Diagnostic 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	CERY	NEW YORKER	Replaced EGR Valve	0.80	\$40	\$41	\$25	\$106
1095	89	PONT	GRAND PRIX	Clean EGR Passage					
				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	DOOG	W150	Replaced EGR Delay Valve	0.30	\$15	\$22	\$25	\$62
1657	83	CHEV	CELEBRITY	Replaced EGR Valve	0.70	\$35	\$63	\$25	\$123
				Clean EGR Passage					
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

3.3.3 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.⁸ Only 24 vehicles (vehicle 1667 was not available) were used to calculate the average fuel economy cost savings resulting from evaporative system repair. The results are shown in Table 3-12.

⁸ July 26, 1991, EPA memorandum from E. Glover to C. Harvey, "Average Repair Costs and Benefits from Repairing Purge and Pressure Failures."

Table 3-12

Average Repair Costs and Fuel Economy Benefits

<u>Test</u>	<u>Total Fuel</u>		<u>Economy Savings gal/mi</u>	<u>Average Parts Cost</u>	<u>Average Labor Hour</u>	<u>Average Total Cost*</u>
	<u>Total</u>	<u>Fuel Economy Improvement</u>				
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 pay rate 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.

3.4 Fuel Economy Benefits

3.4.1 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:

$$4.13 \text{ grams fuel/mile} / 128.3 \text{ grams fuel/mile} = 3.2\% \text{ Pressure failures}$$

$$4.05 \text{ grams fuel/mile} / 143.75 \text{ grams fuel/mile} = 2.8\% \text{ Purge failures}$$

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. Unfortunately, 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:

$$3.74 \text{ gpm running loss CH}_2.33 * \text{R Factor} = 3.74 \text{ gpm liquid fuel (CH}_{1.85})$$

$$3.74 \text{ g C/mi} * (1 \text{ cm}^3 / 0.745 \text{ g Fuel}) * (1 \text{ g Fuel} / 0.83 \text{ g C}) * \\ (2.0 \text{ liter} / 1000 \text{ cm}^3) * (1.0 \text{ gal} / 3.79 \text{ liter}) = 0.0016 \text{ gal/mi}$$

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.

$4.21 \text{ gpm running loss CH}_2.33 * \text{R Factor} = 4.21 \text{ gpm liquid fuel (CH1.85)}$

$4.21 \text{ g C/mi} * (1 \text{ cm}^3 / 0.745 \text{ g Fuel}) * (1 \text{ g Fuel} / 0.83 \text{ g C}) * (1.0 \text{ liter} / 1000 \text{ cm}^3) * (1.0 \text{ gal} / 3.79 \text{ liter}) = 0.0018 \text{ gal/mi}$

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%.

3.4.2 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 3-13 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 3-13

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

3.4.3 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 1/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 discovery that, on average, FTP fuel economy varies from IM240 measured fuel economy by 9.25%.

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 3-14 further details how these numbers were arrived at.

Table 3-14

Adjusted Zero FE Benefit Vehicle Sample Size

<u>Original # of Vehicles</u>	<u>Description of Data Used and Removed</u>	<u>Remaining Vehicles</u>
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.

3.5 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 3-15 shows the zero-mile and deterioration rates found in the BLOCK DATA section of the CEM program listing in Appendix A.

Table 3-15

Exhaust Test Failure Rates
(fraction)

<u>Test</u>	<u>Zero-Mile</u>	<u>Deterioration</u> (per 10K miles)	<u>Type</u>
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% 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 1. 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 3.4.

To determine purge and pressure repair costs, CEM requires recurring failure rates corresponding to an ongoing I/M program wherein the failure rates 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.

3.6 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 X \$/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

3.6.1 Inspection Costs

Inspection costs are determined by multiplying user-input inspection costs by 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 3-16.

Table 3-16

Default Inspection Costs in CEM4.1

<u>Test</u>	<u>Cost</u>	<u>Comments</u>
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 transient test
Transient Emission Test	67¢	Increment over purge cost

3.6.2 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 3-17

Default Repair Cost in CEM4.1

<u>Failure Triggering Repair</u>	<u>Pre-81</u>	<u>81+</u>
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.

3.6.3 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 3.5, 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 3-18

Fuel Economy Benefits in CEM4.1

<u>Test</u>	<u>FE Benefit</u>
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.

4.0 COST AND BENEFITS OF ENHANCED I/M OPTIONS

4.1 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 4-1. 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. The high option includes underhood emission control device checks that

the low and medium options do not. Other inputs reflect national default values assumed in MOBILE4.1.

Table 4-1

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	1981-1983
Pressure	none	1971+	1971+
Purge	none	none	1984+
Transient	none	none	1984+
†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+	1975+
Catalyst	Yes	Yes	Yes
Fuel Inlet	Yes	Yes	Yes
Air Pump	No	No	Yes
Tailpipe Lead Test	No	No	Yes
Evap Disablement	No	No	Yes
PCV Disablement	No	No	Yes
Gas Cap	No	No	Yes
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 4-2. 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 a biennial high option program are also shown. Note 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 4-2

Benefits of I/M Programs Options*

<u>Scenario</u>	<u>VOC Emission Effects</u>		<u>CO Emission Effects</u>	
	<u>Emission Factor</u> (gpm)	<u>Percent Reduction</u>	<u>Emission Factor</u> (gpm)	<u>Percent Reduction</u>
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	1.662	20.2%	8.927	24.8%
Biennial High Option	1.499	28.1%	8.223	30.7%
Annual High Option	1.446	30.6%	7.835	34.0%

* Total Highway Mobile Source Emissions in 2000

The results shown in Table 4-2 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.

4.2 Cost Effectiveness Estimates

4.2.1 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 4.1. The assumed cost for an I/M inspection, including a visual check of emission control devices, is \$8.50. The 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. In addition, gasoline is assumed to cost \$1.25 per gallon. The average repair costs shown in Table 3-17 were assumed.

4.2.3 Cost-Effectiveness Calculations

Total annual program costs per million vehicles, as calculated by CEM4.1, are presented in Table 4-3, 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 4-3

Total Annual Program Cost

Scenario	Cost
Basic I/M	\$6,200,000
Low Option	\$9,100,000
Medium Option	\$11,000,000
High Option	\$11,000,000
Biennial High Option	\$5,100,000

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 4-3, and dividing them by the annual tons of hydrocarbon reductions. The results are shown in Table 4-4. Unlike the total costs in Table 4-3, 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 4-4

Cost per Ton Allocating All Costs to VOC

<u>Scenario</u>	<u>Costs per Ton</u>
Basic I/M	\$5,300
Low Option	\$4,100
Medium Option	\$2,500
High Option	\$1,700
Biennial High Option	\$800

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. 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 costs to CO yields a cost per ton of about \$100 for the 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 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 4-5. As expected the costs are lower in all cases, and the biennial high option program is about \$500 per ton.

Table 4-5

VOC Cost per Ton Accounting for NO_x and CO Benefit

<u>Scenario</u>	<u>Cost Per Ton</u>
Basic I/M	\$4,400
Low Option	\$3,300
Medium Option	\$2,100
High Option	\$1,300
Biennial High Option	\$500

4.2.4 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 4-6. 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 \$5000 per ton.

Table 4-6

Total Cost and Benefits of I/M Options

<u>Per Million Vehicles</u>	<u>Tons</u>	<u>Total Cost</u>
High Option	6,700	\$8,637,000
Centralized Low Option	2,200	\$7,467,000
Decentralized Low Option	2,200	\$16,325,000

To estimate the total cost of implementing a low option program it was assumed that of the 40 million vehicles subject to enhanced I/M 30 million vehicles would be in a decentralized system and 10 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 4-7. The extra direct cost of the low option would be about \$219 million while the indirect cost of the more expensive stationary source controls amounts to about \$890 million, for a total of about \$1.1 billion in excess cost.

Table 4-7

Excess Cost of Choosing Low Option I/M

	<u>Vehicles</u> millions	<u>Benefits</u> tons	<u>Cost</u> millions
High Option	40	268,000	\$345
Low Option Centralized	10	22,000	\$75
Low Option Decentralized	30	67,000	\$490
Total Low Option	40	90,000	\$564
High - Low		178,000	\$219
Stationary Cost @ \$5000/ton			\$890
Total Excess Cost			\$1,110

5.0 ONBOARD DIAGNOSTICS AND ON-ROAD TESTING

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.

Although SIP submittals for enhanced I/M programs must include provisions for on-road emissions testing, the extent of the role played by such testing is temporarily left to the State to decide, and, consequently, is difficult to project for the purpose of performance standard modeling. In addition, it is anticipated that such testing will function primarily as either an enforcement program quality assurance measure, or as a program evaluation tool. In either case, on-road testing is expected to contribute to the emission reductions achieved by the program; however, the extent to which it can or will is not yet determined. Hence, for the purposes this of cost-benefit analysis, the impact of on-road testing is not addressed.