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I/M Costs, Benefits, and Impacts

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1.0 INTRODUCTION

Despite having the best vehicle control program in the world, many areas in the United States continue to measure unhealthful levels of air pollution, approximately half of which can be attributed to motor vehicles. As a result, in addition to tighter standards on new vehicles and their fuels, the Clean Air Act Amendments of 1990 (Act) require the implementation of vehicle Inspection and Maintenance (I/M) programs in areas that have been designated as nonattainment for ozone or carbon monoxide (CO). A total of 181 such areas currently exist in the United States, 56 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 CO areas registering levels greater than 12.7 parts per million (ppm)). Eighty-three of the 181 nonattainment areas currently designated will require the implementation of an enhanced I/M program.

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

Much has also been learned since 1974 about the many ways vehicles contribute to the problem of air pollution. Previously, it was thought that the majority of the air pollution problem attributable to mobile sources was the result of exhaust emissions; it is now understood that emissions in the form of evaporative and running losses are also major contributors. The gasoline evaporating in the tank of a vehicle and escaping into the environment is as much a source of volatile organic compound (VOC) emissions as are the exhaust gases emitted from the tailpipe. Vapor recovery and recirculation mechanisms have been installed on vehicles since 1971, but these systems can deteriorate with time and are often rendered useless as a result of wear, tampering, and design defects. Cost effective tests have been developed to detect evaporative system failures of this sort, including the evaporative system purge test and the evaporative system pressure test.

Under the terms of the Clean Air Act Amendments of 1990, EPA is required to establish minimum performance standards for I/M programs. The Act further specifies that the standard for enhanced I/M shall be based upon a program that employs an annual cycle of automated emissions analysis, performed at a centralized test-only site, and enforced through the denial of registration. EPA has developed these standards and has formalized them as part of the I/M rulemaking.

In the past, the model program used to establish the performance standard assumed a model program along the lines of the original New Jersey program - a standard which remains essentially unchanged for basic I/M programs. For the enhanced I/M performance standard, however, EPA has developed a model program 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 that included in the enhanced I/M performance standard is expected to achieve emission reductions from mobile sources on the order of approximately 31% for ozone-forming hydrocarbons (HC) and 34% for CO (compared to 5% HC and 16% CO emission reductions from the basic I/M performance standard program design).

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

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

It should be noted that in finalizing this document, EPA continues to base its estimates on the MOBILE4.1 emission factor model, primarily because the latest model - MOBILE5 - is still in the process of development and revision and is not ready for final release.

2.0 GLOSSARY OF KEY TERMINOLOGY

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

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

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

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

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

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

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

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

IM240 Exhaust Test[1]: A mass emissions (as opposed to concentration), transient short test run on an inertial and power-absorbing dynamometer using a 240 second driving cycle loosely based upon the LA4 cycle used in the FTP. EPA originally divided the driving cycle into 2 parts or "bags" with separate emissions determinations, but recently has begun integrated analysis of emissions on a second-by-second basis. Unlike the idle test which is conducted at a single speed and expresses emissions in terms of percentages and ppm, the IM240 is conducted at a range of accelerations and decelerations and provides emissions measurements in terms of grams per mile (gpm). The IM240 has proved particularly effective in accurately identifying high emitting, newer technology vehicles.

Preconditioning: Operation of a vehicle at a specific speed, load (including no load), and time to ensure that a vehicle is properly warmed up prior to testing. For the purpose of transient testing, a period of operation prior to testing to avoid errors of commission as a result of evaporative system purging into the sample. Under the two-ways-to-pass criteria (see section 4.2.3 for a more detailed discussion) this goal is achieved by establishing two sets of cutpoints, a set of cutpoints for the composite results, as well as cutpoints for Bag-2 results (with the first 93 seconds - or Bag-1 - being used as the preconditioning mode).

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

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

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

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

3.0 I/M PERFORMANCE STANDARDS

3.1 Enhanced I/M Performance Standard

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

EPA's enhanced I/M performance standard is based on centralized, annual testing of light-duty vehicles (LDVs) and light-duty trucks (LDTs) rated to 8,500 pounds Gross Vehicle Weight Rating (GVWR) using the transient IM240 exhaust test incorporating NO_x cutpoints, and purge testing of the evaporative control system of 1986 and later vehicles (using cutpoints of 0.8 to 0.7 gpm HC, 20 gpm CO, and 1.4 to 3.0 gpm NO_x, depending upon the age and weight rating of the vehicle). Two-speed testing is to be performed on 1981-1985 model year vehicles (using cutpoints of 1.2% CO, 6% CO_2, and 220 ppm HC) while idle testing is to be used on pre-1981 vehicles. Idle test cutpoints for older vehicles must yield a 20% failure rate. The performance standard also includes visual inspection of the catalyst and fuel inlet restrictor on all 1984 and later vehicles and evaporative system integrity (pressure) testing of 1983 and later vehicles. Using EPA's mobile source emission model, MOBILE4.1, this performance standard is estimated to yield a 28% reduction in VOCs, a 31% reduction in CO, and a 9% reduction in NO_x by the year 2000 over a non-I/M scenario.

3.2 Recommended Enhanced I/M Program Design

The Act requires EPA to establish a performance standard based on an annual test program. States, however, are free to implement alternative program designs, including a biennial program, provided the emission reductions achieved meet or exceed those achieved by the model program. This demonstration is made using EPA's mobile source emission model which includes biennial and annual program credits. Given the added convenience and cost-effectiveness of a biennial program, EPA recommends that states adopt a biennial program that can meet the performance standard, through, for example, increased vehicle coverage.

3.3 Basic I/M Performance Standard

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

4.0 EMISSION REDUCTIONS FROM I/M PROGRAMS

4.1 Recent I/M Test Programs

The data used by EPA to assess the benefits of high-tech I/M testing concepts, including the IM240 , 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. More extensive programs are currently being run in Indiana and Arizona, although data from Arizona is still too new for incorporation in this report. The Maryland pilot study began testing in August 1989, and continued through December of that year, testing a total of approximately 600 vehicles for an average of approximately 120 vehicles per month. The larger-scale Indiana program began testing in February 1990. As of November 1, 1991, approximately 8,300 vehicles had been tested as part of the Indiana program, with an average of approximately 120 vehicles per week. As such, the database produced by this test program is the largest of its kind ever assembled to assess I/M testing. The Arizona program began testing vehicles on June 8, 1992 and has tested over 1,500 vehicles so far. EPA has not had time to quality assure the Arizona data, however, and it therefore has not been used in compiling the figures in this report.

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

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

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

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

Table 4-1

IM240 Selection Standards for Stratified FTP Recruitment

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

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

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

Table 4-2

Weighting Factors for Correcting Recruitment Biases

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

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

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

At the Hammond I/M station, in addition to the IM240, technicians perform the official Indiana I/M test (2500 rpm/Idle) and an additional second-chance 2500 rpm/Idle test for those that fail the first chance test. Vehicles that require a second-chance test first receive 3 minutes of preconditioning. The combination of this “enhanced” steady-state testing, along with the IM240 and purge/pressure tests allows for direct comparison of these alternative I/M procedures. Section 4.2 of this report provides a more detailed discussion of the results of comparing the degree to which the IM240 and the second-chance 2500 rpm/Idle test correlate with the FTP.

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

The evidence displayed in Section 4.2 (see below) and Appendices C and E of this report graphically and quantitatively shows the advantage of the high-tech IM240 test for the sample of vehicles tested in Indiana in 1990 and 1991. The actual calculations of the exhaust emission reductions of the several short tests are more detailed in order to best reflect the actual characteristics of the fleet as it ages and changes in technology mix. A computer model called Tech4.1 is used to calculate technology- and age-specific adjustment factors that represent the effect of I/M programs of different types (the so-called "I/M credit"), and these factors are built into the mobile source emissions model MOBILE4.1. Section 4.6.1 of this document contains details on the Tech4.1 model.

Finally, the Indiana testing program has revealed the true seriousness of evaporative emission control system malfunctions that develop during real world operation. Previous EPA testing programs (i.e., those conducted during the last 10 years or so) that did not make use of an operating I/M lane to screen and recruit vehicles for more thorough laboratory testing have focused mostly on vehicles that were about 5 years old or younger, in order to most quickly obtain information on the latest generation of new technology vehicles. When special efforts were made to recruit high mileage vehicles, they tended to be vehicles that had accumulated unusually high mileage for their age, for example vehicles from owners with long commutes or who used their vehicles for business during the day. EPA staff have been concerned for some time that testing such vehicles was not giving a true picture of evaporative emission problems, which may develop more as a function of passing time than of miles driven; for example, deterioration of rubber and plastic components would be more time-than mileage-based. Also, the recruitment practices in the test programs prior to the Indiana I/M lane program relied on owner response to letters and phone calls. There has been concern that this resulted in a different sample of vehicles, probably a sample biased towards better maintenance condition than would be found if owners could be solicited face-to-face, as they are in the Hammond study (where the level of motorist participation has been sufficiently high to ameliorate these concerns). These differences in study design explain why the Indiana program has produced results very different from previous estimates of in-use evaporative emissions. EPA's interest in the high-tech evaporative purge and pressure tests has been in response to these findings.

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

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

This section focuses on the comparison of the IM 240 transient test (using cutpoints of 0.8 gpm HC and 15 gpm CO for the results over the full 240 seconds, with a provision that a vehicle also may pass by having emissions during the last 147 seconds of the test less than or equal to 0.5 gpm HC and 12 gpm CO - see Section 4.2.3 for a more detailed explanation of the two-ways-to-pass criteria) to EPA's currently recommended second-chance 2500 rpm/Idle test procedure [2], and details the evaluation criteria upon which the comparison is based. This comparison shows how an I/M program based on one of the better currently used (non-dynamometer) I/M tests (second-chance 2500 rpm/Idle) can be

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

improved upon by changing to the IM240 test, which has a much better classical correlation with the FTP than the idle or 2500 rpm/Idle test for matched pollutants (see the regression analyses including R-squared values and scatter plots in Appendix E for an illustration of this better correlation).

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

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

Comparing lab FTP and lane IM240 results is problematic for several reasons, but still shows good correlation. Since the lab tests are performed at a different time from the lane IM240s, intervening factors, such as intermittent problems or changes in the vehicle, may affect the results. For example, exhaust systems are often repaired, when needed, prior to the lab tests. Another major problem making lab and lane comparisons difficult is the

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

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

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

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

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

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

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

fleet). Also, the short test should pass vehicles that are not malfunctioning, in order to avoid impacting owners of vehicles which have emissions low enough to not merit repair. The figures in Appendix C, which are discussed in the following sections, graphically demonstrate the differences between the second-chance 2500 rpm/Idle test and IM240 in regard to these objectives.

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

4.2.1 I/M Test Assessment Criteria Overview

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

4.2.1.1 Excess Emission Identification Rate (IDR)

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

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

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

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

4.2.1.2 Failure Rate

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

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

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

4.2.1.3 Error-of-Commission (Ec) Rate

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

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

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

*Error-of-commission

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

4.2.1.4 Failure Rate Among FTP-Passing Vehicles

The risk of failing an I/M test with a clean vehicle is not expressed very clearly, however, by stating fleet error-of-commission rates. Fleet rates tend to be very low, but the impact on any individual motorist can be very significant. A more informative statistic than error-of-commission rate is the failure rate among all inspected vehicles which still pass their FTP standard. This indicates the risk to the owner of having a clean vehicle failed. For the IM240 using the two-ways-to-pass criteria, only one vehicle out of 274 (i.e., 0.4%) failed the IM240 while passing the FTP (see Appendix C, as well as the discussion under Section 4.2.3 "Errors of Commission Under the Two-Ways-To-Pass Criteria"). While the false failure rate for the second-chance two-speed test is initially comparable to the IM240 using the two-speed cutpoints in current use, tightening these cutpoints to improve IDR has the effect of increasing the false failure rate for the steady-state test. For example, as illustrated in Figures 1 through 3 of Appendix C, for 1983 and newer PFI vehicles, tightening the steady-state cutpoints from 220 ppm HC and 1.2% CO (the cutpoints most commonly used in current I/M programs) to 100 ppm HC and 0.5% CO has the effect of increasing the test's false failure rate from 0% to 13% - this, even though the two-speed test's IDRs for both HC and CO still fall appreciably below that of the IM240. For 1983 and newer TBI vehicles, the same tightening of cutpoints achieves HC and CO IDRs for the steady-state test that actually exceed those of the IM240 by a percentage point or two, but this at the cost of a false failure rate of 20% compared to one, debatably "false" failure for the IM240 (Figures 4 - 6, Appendix C).

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

4.2.1.5 "Normal Emitter" Failure Rate

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

4.2.2 Detailed Discussion of Correlation and Test Assessment

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

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

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

- The FTP excess emissions identification rates are 19% higher for HC and 13% higher for CO with the IM240 as compared to the second-chance 2500 rpm/Idle test using the 1.2%/220 ppm standards.
- Neither test failed FTP-passing vehicles.
- The IM240 increases the failure rate to 13% from 10% for the preconditioned, second-chance 2500 rpm/Idle test.

Figure 2 in Appendix C illustrates the power of the IM240 test compared to the 2500 rpm/Idle test using the 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 C for both figures). Note the following:

- The IDRs are still 8% higher for HC and 5% 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 29% compared to only 13% for the

IM240. So even with the IM240's higher IDRs, significantly fewer vehicles will need to be repaired.

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

- The normal emitter failure rate is only 2.5% for the IM240 versus 22% for the second-chance 2500 rpm/Idle test. This means that the vehicles identified for repairs by the IM240 are more likely to achieve significant emission reductions.

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

4.2.3 Two-Ways-To-Pass Criteria

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

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

Catalyst temperature can also effect test outcome. Emissions are generally highest after a cold start, before the catalyst has had a chance to warm up. If a vehicle is standing in line for a prolonged period of time, or was not sufficiently warmed up before arriving at the test lane, this can cause the vehicle to register as a failure, when, in fact, it should be passed. It is this problem of catalyst cool down that has lead EPA to recommend preconditioning as a means for avoiding false failures. Under the two-ways-to-pass criteria, Bag-1 acts as a preconditioning mode, thus providing insurance against this particular variety of false failure.

4.2.3.1 Errors of Commission Under the Two-Ways-To-Pass Criteria

I/M test procedures and standards that cause low emitting vehicles to fail an I/M test are obviously undesirable. Because the emissions of properly functioning vehicles are known to vary in a predictable manner with changing test conditions, the FTP controls variables such as test temperature, vehicle temperature, humidity, vehicle prior operation, and fuel characteristics (by using a special test fuel), as well as other variables to help achieve repeatable results on a given vehicle. Since many of the variables known to affect vehicle emissions cannot be controlled in an I/M program, EPA is forced to relax the stringency of its pass/fail standards to allow properly functioning vehicles to pass, even when such variables "stack up" or otherwise conspire to produce seemingly high emissions readings. EPA is also constrained by cost-effectiveness disbenefits that attend relaxed standards. As the standards are loosened, the percentage of high emitting malfunctioning vehicles not identified for repairs increases. On the other hand, forcing properly functioning cars to be diagnosed by a mechanic also hurts cost-effectiveness along with other obvious undesirable effects.

The model program uses IM240 two-ways-to-pass standards of 0.8/15.0/2.0 composite results and 0.5/15.0 for Bag-2. The Appendix F cutpoint tables show that the error-of-commission rate is zero for PFI and carbureted vehicles, but is 1.2% for TBI vehicles. The purpose of this section is to discuss whether the error-of-commission rate of 1.2% indicates that the IM240 standards are too stringent.

A false failure resulted on only one [5] of the 274 1983 and newer vehicles that received FTP tests. It is surprising that any FTP-passing cars failed the IM240 two-ways-to-pass standards, however, since the IM240 driving schedule is taken from the FTP and is a hot start test at the Indiana lane.

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[5] This vehicle was actually tested at the laboratory. As explained in Section 4 1, the database was corrected to accurately represent the in-use fleet distribution, so the error of commission vehicles discussed in previous sections were from the corrected database. This section only discusses the vehicles that were actually tested, so the single error of commission PFI vehicle becomes 4 vehicles after the weighting factor discussed in Section 4.1 is used. Similarly, the three actually-tested TBI error of commission vehicles become 17 vehicles in the corrected database. This section is unique in discussing only the actually-tested vehicles.

Vehicle number 1724 failed the IM240 HC standard in its Hammond lane test, with a score of 0.96 gpm, but passed the FTP with a score of 0.31 gpm. Vehicles that pass the FTP are normally considered properly functioning vehicles, but the mechanic's inspection identified the following problems:

Checklist Comments

- Idle Mixture: Rich
- Fuel Injection Components: Meters excessive fuel
- Distributor Assembly: Cap and rotor dirty
- Initial Timing: Specification = 8 ° BTDC, actual = 3° Retarded
- Spark Plugs and Wires: Plugs worn, wires arcing
- Catalyst: Poor performance

Narrative Comments

Injection meters excessive fuel.
Cap & Rotor dirty.
Wires Arcing
Plugs worn
Timing -5° [Slight disagreement with checklist which indicated -3°.]

These are hardly results that would be expected of a properly functioning vehicle, so the question is not: "Why did this vehicle fail the IM240?" The more appropriate question is: "Why did this car, considering these problems, pass the FTP?" The answer seems to be that the car passed the FTP due to several interactive variables. High HC emissions are frequently caused by ignition system problems which cause a vehicle to misfire. If misfiring is only an intermittent problem, it is possible that a vehicle that fails one test, will register as a pass when tested later.

The worn spark plugs, arcing spark plug wires, and dirty cap and rotor all can contribute to intermittent misfire. If bad enough, any of these problems can lead to steady misfiring, but since the vehicle passed the FTP, the presumption is that the engine was misfiring more during the IM240 at the inspection station than during its FTP test at the lab. Additionally, the dynamometer inertia weight setting at the lane was 3,000 pounds, whereas it was only 2,875 pounds for the FTP. While not a large difference, the voltage required to fire the spark plugs increases with increasing load. With a marginal ignition system, the voltage available at the spark plug may be less than the voltage required to fire the spark plug, so logically, more misfire should be expected with the higher loading this vehicle was subjected to during the IM240. Also, the vehicle received its IM240 test on July 30, 1991, but ATL did not receive the vehicle from the owner until August 12, 1991 and it did not receive its FTP test until August 15, 1991. The fact that the owner retained possession of the vehicle for nearly two weeks between the lane IM240 test, and the FTP test is important because spark plugs that are misfiring one day, usually due to carbon deposits, can clean themselves under high temperature operation, and have less or no apparent misfire on a different day. Also, given the proverbial problem of malfunctions that do not exhibit themselves when the mechanic is in the car, only to reappear during the trip home, most people can easily relate to such intermittent problems. This vehicle's passing FTP score is probably because the intermittent misfire that occurred during the IM240, occurred to a lesser degree during the FTP. This brings us back to the question; "Should the IM240 standards be relaxed to avoid false failures?" The evidence suggests that this car was correctly identified as needing repairs by the 0.8/15.0/2.0 and 0.5/15.0 two-ways-to-pass standard, and only passed the FTP by a fluke. Therefore, EPA's judgement is that the debatably "false" failure of this vehicle is insufficient justification for relaxing the standard.

4.3 Evaporative Test Errors of Commission

In its submission to the I/M docket, Toyota commented that some vehicles that failed the purge or pressure test appeared to be passing the current certification evaporative SHED test with combined diurnal and hot soak emissions of less than 2 grams. Toyota expressed concern that the existence of false evaporative failures would make them responsible for a more stringent, post-certification regulatory requirement that denies them "due process." EPA is also concerned about the possibility of evaporative test false failures, and has identified five vehicles which were potential evaporative test false failures from a list of 20 failing vehicles. The test results from these five vehicles are shown in Table 4-3.

The majority of the apparent false failures had serious mechanical problems, or evaporative system leaks. In addition, these apparent evaporative false failures can be categorized into those that may have occurred due to errors in performing the test, and those that were due to an intermittent malfunction of the vehicle.

Table 4-3

Evaporative Test Results

Veh	Pres	Purg	Malfunction	Diurnal (g/tst)	Hot Soak (g/tst)	As Recv Running Losses* (g/tst)	Aft Rep Running Losses* (g/tst)
1596	F	P	Loose Gas Cap	0.10	0.39	-----	-----
1689	P	F	Purge TVS	0.74	0.68	78.6	4.4
1704	F	P	Gas Cap Seal	0.96	0.73	-----	-----
1712	F	P	Vent Line Leak	0.53	0.45	190.9	175.0
1714	F	P	Gas Cap Seal	1.09	0.46	-----	-----

*Running loss emissions are based on the Modified LA4 Running Loss Test at 95 °F. The test consists of three consecutive LA4 driving schedules conducted in an enclosed SHED.

4.3.1 Vehicle 1689

This vehicle, a 1985 Mercury Marquis, was the only apparent false purge failure. It received two purge tests. The first test was at the lane, and a second confirmatory test was done at the contractor's lab. As Table 4-3 notes, the vehicle was shown to have zero purge during the purge test. Diagnosis of the vehicle identified a stuck thermal vacuum switch controlling the evaporative purge. Six subsequent running loss tests showed this vehicle to be a gross emitter. However, during two of the six running loss tests (each test was three consecutive LA4 cycles), the vehicle's purge system operated intermittently, and provided a total purge of 38 liters during one test, and 28 liters during the other test (these are low levels of purge for a running loss test). During the remaining four running loss tests the purge flow was zero. Therefore, this vehicle demonstrated that it could purge occasionally, but that in general it was not operating as designed and should be considered a failure. In addition, after repair of the thermal vacuum switch which controls purge flow, this vehicle showed a dramatic reduction in running loss emissions from 78.6 grams HC/test to 4.4 grams HC/test while its purge flow was increased to a relatively consistent 85 liters per running loss test.

Because the failure mode of this vehicle was of an intermittent nature, it is possible that sufficient purge occurred randomly on this vehicle. Thus, adequate purge may have occurred prior to the hot soak and diurnal enabling the vehicle to pass these tests. In any case, the data supports the fact that a critical emission control component malfunctioned on this vehicle.

4.3.2 Vehicles 1596, 1714 and 1704

Vehicle 1596, a 1990 Chevrolet, was initially found to be a pressure failure at the lane when the system would not hold any pressure. This type of failure requires a substantial leak which is usually readily apparent. Nevertheless, the technician could not identify the source of the leak even after attempting two pressure retests, both of which the vehicle passed. As a result of the lane pressure initial test failure, the vehicle was recruited to the lab for running loss testing and repair. Here, it was again retested and found to clearly pass the pressure test. Although, the actual reason for the initial failure is unknown, it is believed to be the result of improper testing technique or equipment malfunction which was apparently recognized by the inspector (thus explaining why the vehicle was retested at the lane). Thus, based on the retest results in the lane, this vehicle should never have been recorded as a failure.

Vehicle 1714, a 1986 Chevrolet, was also diagnosed as a pressure failure at the lane. The lane inspector identified a leak near the gas cap or filler neck. This vehicle was then retested at the contractor's lab, and passed. However, the final passing pressure was just over the standard of 8 inches of water after two minutes (below 8 inches of water is a failure). Thus, a very small leak might have been present depending on the tightness of the gas cap, and the quality of the seal between the gas cap and filler neck. At the time, the lane pressure test procedure did not call for tightening the gas cap prior to the test. However, the lane procedure did call for removing the gas cap at the end of the test to check for pressure in the tank. Following removal, the inspector would then reinstate and properly tighten the gas cap.

At the laboratory, gas caps have always been tightened prior to conducting the pressure test. In addition, the lane procedure has been changed so that gas caps are tightened prior to the pressure test.

Vehicle 1704, a 1983 Toyota, was also diagnosed as a pressure failure at the lane due to a leak identified near the gas cap. However, after recruitment to the lab, the vehicle marginally passed two pressure tests, and was not recruited for running loss testing. Like vehicle 1714, it is probable that this vehicle had a very small leak due to the condition of the gas-cap/filler-neck seal. The test procedure changes are expected to eliminate failures such as these.

4.3.3 Vehicle 1712

Vehicle 1712, a 1987 Chevrolet, was found to have a leak in the vent line at the connection between the rubber hose and the steel line between the canister and the fuel tank. This leak was found after several pressure test failures at the lane and the lab. Modified LA4 running loss tests (three consecutive LA4 cycles at 95 $^{\circ}$ F) produced evaporative emission levels of more than 190 grams over the 22 mile test. Likewise, modified high temperature (95 °F) diurnals produced emission levels of 44 grams (hot soak) and 10 grams (diurnal). An after-repair running loss test was also conducted resulting in running loss emissions of 175 grams per test.

EPA views I/M false failures as a significant problem, and is committed to investigating and implementing strategies to prevent their occurrence. For the evaporative system tests, such strategies include tightening gas caps prior to the pressure test, automation and computerized control of the test, test algorithms that insure all sequence are properly performed, and refined procedures to eliminate the possibility of technician testing errors. It is not advantageous to falsely fail, and attempt repairs on vehicles which are passing the certification standards and operating as designed. However, EPA also feels that malfunctions that cause excessive evaporative emissions from vehicles in-use such as leaking gas caps, leaking fuel tanks, broken fuel tank vent lines, and malfunctioning purge controllers should be identified and repaired. It has been shown that both the pressure and purge tests are effective at identifying vehicles with these problems, while minimizing the identification of the vehicles without such problems.

4.4 Approval of Alternative Tests

Although the IM240, purge, and pressure tests represent EPA's current trio of recommended high-tech tests, we do not rule out the possibility of future, valid alternatives to these tests, including fast-pass and fast-fail transient testing strategies (see Section 4.5, "Transient Testing Fast-Pass/Fast-Fail Strategies"). States may seek approval of such strategies, contingent upon the state's demonstrating to EPA's satisfaction that such strategies are at least as effective as EPA's recommended tests at identifying excess emissions while maintaining a comparably low error-of-commission rate. As the sheer number of analyses contained in this report can attest, EPA does not promulgate new testing strategies capriciously. Before proposing the IM240, purge, and pressure tests, EPA amassed a compelling body of data on each through pilot programs conducted in Maryland and Indiana (see Section 4.1) for further discussion of these pilot studies). Rigorous evaluations of each were conducted to determine their effectiveness at identifying excess emissions while maintaining low error-of-commission rates. Economic analyses were also conducted to assess the cost-effectiveness of the tests, as no degree of technical excellence will justify a testing strategy that is exorbitant in its overall cost. For example, the FTP is the hallmark against which I/M testing strategies are measured, but cannot itself be used as an I/M test, given its cost.

A more detailed discussion of several currently proposed high-tech testing alternatives is included in Section 9.0 of this report.

4.5 Transient Testing Fast-Pass/Fast-Fail Strategies

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

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

Table 4-4

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

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

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

Another area that EPA is investigating is the possibility that the overall test time may be reduced. The IM240 is itself an FTP-like short test based upon a modified and condensed driving cycle that takes as its reference the LA4 cycle used in the FTP. EPA is currently investigating the possibility of further abbreviating the test by comparing how well data from either of the two hills of the IM240 driving cycle (i.e., Bag-1 and Bag-2) taken separately correlate with the current two-mode IM240. Preliminary results based upon a sample of 188 1983 and newer fuel-injected vehicles which were recruited at the Indiana I/M lane and subsequently retested under lab conditions (which included each vehicle receiving an FTP) suggest that analysis of Bag-2 (i.e., emissions sampled during the second hill of the IM240 driving cycle) may be about as good as the full IM240 when it comes to identifying vehicles that would pass or fail on the basis of the full test. Using Bag-2 cutpoints of 0.60/12 for HC and CO respectively, and looking at Bag-2 results only, 90% of the excess HC emissions and 84% of the excess CO emissions were identified, with an Ec rate of 0.7%, as compared to the full IM240 using the 0.8/15 cutpoints only (i.e., no Bag-2 cutpoints), which identified 82% and 85% of the excess HC and CO emissions, respectively, with an Ec rate of 0.8%. These findings come with the caveat that they are based upon a Bag-2 sample which followed the Bag-1 portion of the driving cycle, meaning that Bag-2's high degree of correlation with the IM240 may be the result of preconditioning occuring during the Bag-1 phase. Even if such is, in fact, the case, the prospect of a shorter overall test time still seems good since adequate preconditioning for Bag-2 could probably be obtained in less than 93 seconds by modifying Bag-1 to use a higher speed over less time.

To determine whether or not preconditioning is a factor, EPA has begun testing a sample of vehicles using what is, in effect, a three bag test, beginning with the second hill of the IM240 driving cycle up front (hence no possibility for "Bag-1" preconditioning) followed by a regular IM240. Once this data is analyzed, it should help EPA determine (1) whether or not preconditioning is a factor in Bag-2's high degree of correlation with the full test and (2) whether preconditioning would improve the correlation between Bag-1 and the full test. In addition, as mentioned above, EPA has also begun collecting second-by-second data, which will allow us to determine whether or not there is some point in the testing cycle by which time if vehicle X is emitting at a rate Y, it will clearly pass or fail.

4.6 Estimating I/M Testing Credits for MOBILE4.1

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

4.6.1 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 D-1 in Appendix D provides details on national fleet averages for passenger vehicle distributions by model year and technology type; Tables D-2 and D-3 provide data on emitter groups by model year group, technology type, emission levels and rates, and mileage accumulation.

The model allows a separate IDR and repair effectiveness estimate for each of these divisions of the data by I/M test type, as illustrated in Table 4-5. It should be noted that the IDRs listed in Table 4-5 for the traditional I/M tests (i.e., the idle and 2500 rpm/Idle tests) are based upon historical emission factor data gathered at EPA's National Vehicle and Fuel Emissions Lab (NVFEL) in Ann Arbor, Michigan, as well as elsewhere, and not at the Hammond, Indiana test lane. The IDRs mentioned elsewhere in this report (Appendices C and F, for example) were derived as part of the Hammond study, and are not divided by emitter group, as is the case in Table 4-5.

In practice, because of small sample sizes, several of the divisions represented in Table 4-5 share information. In particular, the small amount of steady-state Loaded/Idle testing required that all vehicles without Loaded/Idle testing be assumed to have the same short test result for Loaded/Idle testing as they had for the 2500 rpm/Idle test for the purpose of determining the IDR for the Loaded/Idle test.

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

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

Repair effectiveness (Table 4-6) was determined by dividing the repaired sample by technology into PFI, TBI and Carb. Model year grouping was not used. To be eligible for the repair effectiveness analysis, a repaired vehicle must first fail the short test of interest before repairs, and then after repairs, must pass the same short test. Thus, different samples of repaired vehicles were used for each short test. The sample was then ranked by before repair emission level and divided into four equal-sized subgroups of increasingly more severe emissions failure. The before and after repair emission levels of each subgroup were then determined.

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

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

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

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

Assuming a 2500 rpm/Idle test is done, the HC IDR (see Table 4-5) for this group is 0.6187, or nearly 62% of the total emissions from these vehicles is identified by failing vehicles using the 2500 rpm/Idle test. Table 4-6 shows the results of a data analysis indicating the predicted average after repair levels given the before repair emission level. The series of points in the table are used to predict the after repair emission levels for all emitter groupings, only dependent on the average before repair emission level for that group. The before repair emission level falls between the two emission levels 1.9846 and 3.9314. The after repair levels for these emissions are 0.59231 and 1.0271 respectively. Interpolating, the after repair level for the 2.089 gpm before repair emission level is:

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

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

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

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

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

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

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

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

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

The average reduction in the rate of failure is calculated by determining the rate of failure at the midpoint between two vehicle ages. The effect of inspection can be visualized by plotting the non-program rate over age with the calculated before and after repairs failure rate estimates assuming inspection (see figure in Appendix B). At each age, vehicles due for inspection

4-5

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

Test Type	Model Years	PFI HC	PFI CO	TBI HC	TBI CO	Carb HC	Carb CO	Oplp HC	Oplp CO
Idle Test	81-82	0.2736	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

Test Type	Model Years	PFI HC	PFI CO	TBI HC	TBI CO	Carb HC	Carb CO	Oplp HC	Oplp CO
Idle Test	81-82	0.0506	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

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

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

Table 4-6

Short Test Repair Effectiveness

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

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

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 B with and without formulas. The spreadsheet originally contained errors which caused the benefits used in the MOBILE4.1 model to be smaller than the estimates reported in this document (which are based upon the corrected spreadsheet). The version of MOBILE4.1 released to the public does not yet reflect these changes, although they will be incorporated into the next MOBILE release.

4.6.3 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 NO_x emission inspection as part of an I/M program. Therefore, to estimate the effect of an IM240-based NO_x inspection, a simple model was developed.

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

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

Using the technology mix used in MOBILE4.1, the regressions were weighted together to produce emission factor zero mile levels and deterioration rates for each model year from 1983 through 1992. The difference in the emission levels between the cases with and without NO_x failures removed is assumed to be the benefit from the IM240 NO_x emission test with only NO_x-related repairs performed. Results are shown in Table 4-7.

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

Using the post-repair emission levels of the same vehicles used to calculate the after repair emission levels for HC and CO emissions, the NO_X emission levels of these vehicles after repairs were determined. These NO_X emission levels are not the result of NO_X-related repairs, but a by-product of HC and CO emission repairs. Using the standard HC/CO 2500 rpm/Idle test IDRs along with the repair effects on NO_X and the NO_X emission rates by emitter group in the Tech4 model, the effect of NO_X disbenefits was determined for each age of each model year (see Table 4-8).

The NO_X disbenefits, as a percent change, are applied to the emission levels estimated from the regression equations at each age. The resulting NO_X emission levels by age are regressed versus mileage for each model year to give the final emission factor equation for NO_X. Comparing the emission factor results of the baseline case with the cases with 10% or 20% NO_X emission testing failure rates was done to estimate the benefits, in tons, of the IM240 NO_X emission test. Results are shown in Table 4-9. For example, at age 5 and mean mileage of 60,829 miles, the “20% fail” IM240 NO_X cutpoints will reduce 1992 model year NO_X from 0.887 to 0.710 gpm, a reduction of 20%.

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

Table 4-7

Lane IM240 Based Emission Factor Levels with IM240 NO_x Cutpoints

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

Table 4-7

- continued -

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

Table 4-8

Side Effects of I/M on NOx Emissions

(Disbenefit of HC/CO repairs)

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

Table 4-8

- continued -

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

Table 4-9

Lane IM240 Based Emission Factors with IM240 Cutpoints with Disbenefits of HC/CO Repairs Included

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

Table 4-9

- continued -

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

5.0 REGULATORY IMPACT ANALYSIS - ESTIMATING COST AND COST EFFECTIVENESS

5.1 Cost of Conventional I/M Testing

EPA has collected and analyzed cost data from all operating I/M programs that could provide the information. EPA has analyzed per vehicle costs in I/M programs based upon four basic pieces of information: The I/M program agency budget, number of initial tests, the fee for each test, and the portion returned to the state or local government. This discussion will deal with three aspects of I/M cost: Inspection costs, oversight costs, and repair costs. Costs are analyzed for three different types of programs: conventional centralized and decentralized test-and-repair, and decentralized test-only.

5.1.1 Inspection and Administration Costs

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

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

The economies of scale and efficiency of operation in high volume test-only inspection networks enable motorists in these programs to enjoy lower average inspection fees than in low volume decentralized programs. Based upon 1989 I/M audits (which collected information from all I/M programs), and taking into account both inspection and oversight costs, decentralized programs using computerized analyzers have the highest costs, averaging about $17.70 per vehicle; centralized contractor-run programs average $8.42 per vehicle (recently gathered 1990 data show slightly different numbers, although these have not greatly affected the overall averages). Table 5-1 shows the estimated cost of the I/M program on a per vehicle basis, including inspection and oversight costs.

Table 5-1

I/M Program Inspection Fees

Decentralized Programs

Program	Cost Per Vehicle
Anchorage	$32.00
Fairbanks	$29.00
California	$48.39
Colorado	$11.20
Georgia	$10.68
Massachusetts	$17.18
Michigan	$10.87
Missouri	$9.00
North Carolina	$15.40
New Mexico	$16.00
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

Centralized Programs

Program	Cost Per Vehicle
Arizona	$6.00
Connecticut	$10.00
Florida	$10.00
Illinois	$8.07
Louisville	$6.00
Maryland	$8.53
Minnesota	$8.00
Nashville	$6.00
Washington	$9.00
Wisconsin	$8.73

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, conducting public information campaigns, as well as 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, and inspector training, which are performed by the contractor in a centralized program. 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.

5.1.2.1 Quality Assurance in Decentralized Programs

Costs of quality assurance (QA) measures vary among programs depending upon the comprehensiveness of the QA program and are not well documented in most state programs. The estimates in this section are based on EPA's proposed requirements for QA; i.e., they are more representative of costs that would be incurred in a good QA program than of QA programs as they currently exist. Cost information was obtained from the some I/M programs, principally California, and from various industry sources.

Performance audits are conducted to ensure that records are properly kept, that document security is adequate, that required inspection equipment is present and properly maintained, that inspectors have followed the rules, and to assess the general state of operations. There are two types of performance audits: overt and covert.

EPA's proposal requires overt audits of all test lanes or bays at least twice per year. For those stations where problems are discovered, either through administrative auditing or through covert auditing or other oversight functions, follow-up audits are needed to verify that the problems are resolved. Station visits would also have to be conducted to perform monthly record audits if such audits could not be performed via electronic link. In this analysis it is assumed, given all these factors, that an average of six station visits per year will be performed.

Based upon information from California and New York, EPA estimates that overt audits cost approximately $89 per audit. Staff time is estimated at $80.80 per audit based on the assumptions that an audit takes a total of three hours and that staff are paid $35,000 per year with overhead at 60 percent. Travel costs are estimated at $8.00 per audit based upon an average round trip distance of 25 miles and operating costs of 32¢ per mile based upon MVMA estimates. Hence, the annual cost per station is estimated at $534.

EPA's proposal requires at least one covert audit per year per inspector using vehicles set to fail the inspection. This requirement would establish a minimum level of activity, although it would not necessarily require that each inspector be covertly audited. Additionally, in test-and-repair programs, the proposal requires that each station receive one covert audit annually that includes the purchase of repairs. Follow-up audits would be performed at stations where problems are discovered.

California estimates that its covert auditing program costs about $1,000 per audit, on average. A number of different types of costs are incurred in performing covert audits. The vehicle has to be induced to fail the inspection and the inducement has to be documented so that the improper testing can be proven in court if necessary. The staff time and travel costs to perform and document the audit also contribute to the overall cost. In addition vehicles have to be acquired and should either be replaced or have their appearance altered through repainting in order to avoid recognition. The costs of pursuing a case through the administrative legal system in those instances where improper testing is discovered are also included in the overall $1,000 per audit figure. EPA's proposal also requires that repairs be purchased in at least one covert audit per station per year.

In this analysis the overall level of activity is estimated at three covert audits per station per year with repairs purchased in one. The estimated annual cost per station is therefore $3,250.

As indicated previously, station and inspector records are to be reviewed or screened at least once per month to assess station performance and identify problems that may indicate potential fraud or incompetence. The preferable way to do this would be for the state to obtain station records in a computerized format via a direct data link (required in enhanced I/M programs) to the inspection station and review and analyze them. Failing that, monthly visits would be made to any test stations not connected by the electronic data link and to review any records not recovered via this link. In addition, data analyses would be needed to track motorist compliance and to compile periodic reports.

California reportedly spends $1.8 million per year for data analysis staff. Its staffing level is estimated at about one FTE per 250 stations. As shown in Table 7-5 California has 8,752 stations, yielding an annual cost of $205.67 for data analysis activities. This figure does not include the cost of acquiring computer equipment for this purpose which some states may need to do.

Referee stations are needed to process waiver requests and to resolve consumer complaints of improper testing. In California the referee system costs $36 per vehicle for those vehicle that use it. (The California referee system is operated by a contractor, the State estimates the per vehicle cost would be roughly the same if the referee system were operated by the State.) The referee system is designed to accommodate three percent of the subject vehicle population. Tighter waiver limits to be imposed in enhanced I/M programs are likely to increase the pressure on referee stations. The cost estimates used here assume a five percent utilization rate for the referee stations.

In enhanced I/M programs where the regular tailpipe test is something other than the IM240, a facility to conduct transient tests on 0.1 percent of subject vehicles would be needed.

There are a number of different ways the state could obtain such a facility. Most likely a pre-existing garage or warehouse would be acquired that could be easily converted to a testing facility with only the addition of the necessary equipment. The equipment package to perform IM240, purge, and pressure testing costs an estimated $144,100. While building acquisition and operating expenses can vary considerably, in this analysis, these expenses are assumed to total $1 million over a five year period. Testing volume is conservatively estimated at four vehicles per day for a total of 1040 per year, and again, the total number of vehicles tested represent 0.1 percent of the subject fleet. Using these very general assumptions the cost of the state testing function is estimated at 22¢ per vehicle.

Inspector trainin g courses have to be continually updated in order to stay abreast of new developments. Inspector certification tests also have to be updated in order to keep them from becoming too easy. California spends approximately $65 per station per year on these efforts.

In states where I/M responsibilities are divided between the environmental agency and the motor vehicle agency there is a cost associated with transfer of data between the two agencies. While such costs are difficult to estimate, California estimates that it would cost 50¢ per vehicle per year

This analysis does not cover all costs that would be incurred in overseeing a decentralized I/M program. As mentioned previously, the cost of acquiring computer equipment is not considered here. Some states may not be able to use existing equipment. This analysis does not cover costs associated with enforcement activities against non-complying motorists, nor are estimates for conducting on-road testing provided. The costs of these functions would have to be priced out and divided by the number of subject vehicles. Table 5-2 details the per vehicle costs of a quality assurance program consisting of those functions analyzed here.

Table 5-2

Quality Assurance Functions and Costs in Decentralized Programs

Component	Cost per Station	Cost per Vehicle
Administrative Audits	$534.00	$0.52
Covert Audits	$3,250.00	$3.17
Referee Station	$1,845.00	$1.80
Data Staff	$205.67	$0.20
Training	$65.00	$0.06
Inter-agency Costs		$0.50
State Testing		$0.22
Total without State Testing		$6.25
Total with State Testing		$6.47

Per vehicle costs for most of these components are derived by dividing the per station costs by 1,025, the average number of vehicles tested per station in decentralized I/M programs. Programs with lower vehicle to station ratios will incur higher per vehicle costs. The per vehicle costs can be reduced by limiting the number of stations to maintain a high vehicle to station ratio.

5.1.2.2 Quality Assurance in Centralized Basic I/M Programs

The same activities needed in decentralized programs are performed to quality assure inspections in centralized programs with some differences. Referee stations may be replaced by a full time state referee at each facility. Auditing frequencies are assumed to be three times a year per lane for administrative audits and four times a year per lane for coverts (assuming one per inspector). Data analysis costs are estimated based on the assumption that the state's level of effort is tied to the number of vehicles. Hence, the vehicle per station figure used for decentralized programs is factored by the increased traffic at a centralized lane. The number of vehicles per lane is estimated to be 39,000 per year, based on a peak capacity of 25 vehicle per hour, and typical rate of 13 vehicles per hour (the derivation of these estimates is detailed in the next section).

Table 5-3

Quality Assurance Functions and Costs in Centralized Programs

Component	Cost per Lane	Cost per Vehicle
Administrative Audits	$267.00	$0.01
Covert Audits	$4,000.00	$0.10
Data Staff	$10,942.88	$0.28
State Referee	$14,040	$0.36
Inter-agency Costs		$0.50
Total		$1.25

5.2 Estimated Cost of High-Tech I/M Testing

5.2.1 General Methodology

EPA's estimates of the cos ts of high-tech test procedures are driven by a number of assumptions. Costs in conventional centralized and decentralized test-and-repair programs were derived using current inspection costs in I/M programs as they are reported to EPA as the starting point. For decentralized test-only networks costs are modelled in a manner similar to centralized programs, since all current test-only programs are centralized, however, costs are estimated using a range of test volumes and a higher level of state oversight is assumed since the network is composed of independent operators and may have a higher number of test sites than in centralized programs.

Another key 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. Construction costs in centralized programs are based on estimates supplied by centralized contractors. Other site costs and management overhead in centralized programs are back calculated from current inspection costs. For decentralized networks, it is assumed that longer test times could be absorbed with no increase in sites. The current average volume in decentralized stations is 1,025 vehicles per year (between 3 and 4 vehicles per day, depending upon the number of days per year the station is open). Consequently, increasing the length of the test, to the degree that the new procedures would, is not expected to impact the number of inspections that can be performed.

5.2.2 Equipment Needs and Costs

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

The analyzers us ed for the transient test are laboratory grade equipment. They are designed to higher accuracy and repeatability specifications than the NDIR analyzers used to perform the current I/M tests. Table 5-4 shows the estimated cost of equipment for conducting high-tech tests. This quality of technology is essential for accurate instantaneous measurements of low concentration mass emission levels.

Table 5-4

Equipment Costs for New Tests

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

The figures in Table 5-4 do not include the costs of expendable materials. Nitrogen gas is used up in performing the pressure test. Additionally, the FID burns hydrogen fuel. Calibration gases are needed for each of the analyzers used in the transient test. Because the analyzers used in the transient test are designed to more stringent specifications than the analyzers currently used in the field, bi-blends, gaseous mixtures composed of one interest gas in a diluent (usually nitrogen) are used to calibrate them. Multi-blend gases, such as are typically used to calibrate current I/M equipment, are not suitable. Current estimates for expendables are shown in Table 5-5. The replacement intervals are estimated based on the usage rates observed in the EPA Indiana pilot program and typical inspection volumes as presented later in this section. Calculations of per vehicle equipment costs presented throughout this report include per vehicle costs of these expendables as well.

Table 5-5

Expendables for New Tests

			Replacement Interval	
Test	Material	Cost	Centralized	Decentralized
Pressure	N2 Gas	$30	250 tests	250 tests
Transient	H2 Fuel	$60	2 months	1000 tests
	HC Cal Gas	$60	2 months	1000 tests
	CO Cal Gas	$60	2 months	1000 tests
	CO_2 Cal Gas	$60	2 months	1000 tests

Staff costs have been found to vary between centralized and decentralized programs, as does the effect on the number of sites in the network infrastructure. Therefore, the following sections are devoted to separate cost analyses for each network type.

5.2.3 Cost to Upgrade Centralized Networks

5.2.3.1 Basic Assumptions

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

Throughput refers to the number of vehicles per hour that can be tested in a lane. The higher the throughput rate, the greater the number of vehicles over which costs are spread, and the lower the per vehicle cost. EPA contacted program managers and consulted the contracts in a number of centralized programs to determine peak period throughput rates in the different systems. Rates were as reported in Table 5-6.

Table 5-6

Peak Period Throughput Rates in Centralized I/M Programs

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

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

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

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

5.2.3.2 The Effect of Changing Throughput

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

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

One way to estimate the cost would be to simulate a n actual network of stations and lanes in a given city. One could attempt to assess land costs, building costs, staff and equipment costs, costs for all necessary support systems, and other cost factors. However, this approach would be very time consuming and would rely on information which is proprietary to the private contractors that operate the programs and is, therefore, unavailable. Instead, the cost of the increased number of lanes and stations is derived by analyzing current costs and subtracting out equipment, direct personnel, construction, and state agency oversight costs. The remainder is adjusted by the change in throughput in the new system. Then, new estimates of equipment, personnel, construction, 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. Total average construction costs are estimated at $800,000 for a five lane station, yielding an average per vehicle cost of 82¢. In this analysis a figure of $1.25 is used to estimate the amount of the state retainer. This reflects EPA's best estimate of the per vehicle expense for a good state quality assurance program in a centralized network. Equipment, staff, construction, and state costs add up to $3.24 per vehicle. Subtracting this amount from the current average of $8.50 leaves $5.26 in infrastructure costs and other overhead expenses including employee benefits and employer taxes as shown in Table 5-7. This amount is then factored by the change in the throughput rate and the equipment, oversight, and staff costs for the new tests are then added.

Table 5-7

Current Program Costs

Increments	Per Vehicle Cost	Total Cost Less Increments
Current		$8.50
Equipment	$0.21	$8.29
Staff	$0.96	$7.33
Construction	$0.82	$6.51
State Retainer	$1.25	$5.26

5.2.3.2 Costs of New Tests

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. The new tests would likely be performed in a three position test queue, with one position dedicated to fee collection and other administrative functions, one to performing the pressure test, and the third to performing the transient and purge tests. 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. The pressure test would take approximately two minutes, and could be shortened through such potential strategies as computerized monitoring of the rate of pressure drop. EPA is in the process of looking at potential fast-pass and fast-fail strategies, and preliminary results suggest that roughly 33% of the vehicles tested could be fast passed or failed based upon analysis of data gathered during the first 93 seconds of the IM240 (i.e., Bag 1) using separate fast-pass and fast-fail cutpoints. Hence, EPA estimates that the average total test time could be shortened to at least four minutes per vehicle. This translates into a throughput capacity of 15 vehicles per hour. To accommodate peak demand periods and maintain short wait times, a design throughput rate of half of capacity is assumed, for a typical throughput rate of 7.5 vehicles per hour. Assuming the same number of hours of lane operation as previously, the total number of tests per lane in a transient lane is estimated to be 117,000 over the five year contract period.

State quality assurance program costs would increase given the complexity and diversity of the test system; an estimate of an additional 50¢ is used here but the amount could vary depending upon the intensity of the oversight function the state chooses. Staff costs per vehicle are calculated using the same assumptions for wages and hours of operation as shown in Table 5-7; 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. Three staff per lane are assumed to perform the tests. The additional tasks performed by inspectors in conducting the new tests - i.e., disconnecting vapor lines and connecting them to analytical equipment for the evaporative tests and driving the vehicle through the transient driving cycle - do not require that inspectors have higher levels of skill than they do presently. Rather, these tasks can be performed by comparably skilled individuals trained to these specific tasks. Total staff costs work out to $2.40 per vehicle. Equipment costs for each test procedure are derived by taking the equipment costs from Table 5-4 and calculating the costs of five years worth of expendables using the figures in Table 5-5 and dividing by 117,000. Construction costs for a five lane station are assumed to rise to $1,000,000. This is due to the fact that slightly longer lanes may be needed in order to accommodate test equipment and facilitate faster throughput. Dividing this figure by 117,000 vehicles per lane yields a per vehicle cost of $1.71. The resulting costs estimates are shown in Table 5-8. Table 5-8 shows the result of factoring the figure of $5.26, from Table 5-7, by the change in the throughput rate and adding in the equipment, staff, construction and state costs associated with the new test procedures. The figure of $5.26 is multiplied by 12.5/7.5, i.e., the ratio of the design throughput rate in the current program to the design throughput rate in a program conducting pressure purge and transient testing.

Table 5-8

Costs to Add Proposed Tests to Centralized Programs

Increments	Per Vehicle Cost	Running Total Cost per Vehicle
Adjust for Throughput	$5.26 * 12.5/7.5	$9.12
Staff	$2.40	$11.52
Construction	$1.71	$13.23
Oversight	$1.75	$14.98
Pressure Test	$0.13	$15.11
Purge Test	$0.41	$15.52
Transient Test	$0.87	$16.40

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 equipment costs of $144,000 per lane, and low throughput rates, the cost estimate presented here can be fairly viewed as a worst case assumption. As discussed earlier, the important issue is the quality of the test, not the frequency, so doing these tests on a biennial basis would offset the increased per test cost.

5.2.4 Cost to Upgrade Decentralized Programs

5.2.4.1 Basic Assumptions

The methodology used to estimate costs in decentralized programs is similar to that described above for centralized programs. Equipment and labor costs are key variables as they were in determining costs for centralized programs. However, estimates of costs for decentralized programs presented here do not include estimates of land costs and overhead. While inspections in decentralized programs are generally conducted in pre-existing facilities rather than newly built ones, there are nonetheless a variety of overhead expenses as well as opportunity costs associated with making space available for inspections in a facility that provides a number of other services as well. Data on these costs are not available and they cannot be deduced from reported inspection fees since, in most programs, fees are capped by law and, hence, do not reflect the actual cost of providing an inspection.

Total test volume rather than throughput and test time are the critical factors affecting cost in decentralized programs. Licensed inspection stations at present only perform, on the average, about 1,025 inspections per year, as shown in Table 5-9 (note that this number is a station-weighted average). Test volumes among stations in a single program can vary widely as shown in Section 7.0. It should also be noted that all decentralized programs in enhanced I/M areas, except for California, Virginia, and Colorado (which tests vehicles five years old and newer biennially, and vehicles older than five years annually) are annual programs. In this analysis the effect on per vehicle costs of switching from an annual inspection frequency to biennial, as well the effect of varying inspection volume, will be examined.

Table 5-9

Inspection Volumes in Licensed Inspection Stations

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

Annual tests of 1,025 vehicles per station is equivalent to between three and four inspections per day depending upon the number of days per week the facility is open and inspections are available. This is far below the 75 inspections per day projected in a multi-position high volume lane with three inspectors conducting high-tech tests, and significantly below the 16 inspections per day that could be done in a single position inspection bay with only one inspector (the derivation of this figure is detailed below). Two conclusions can be drawn from this. The first is that the additional time requirements of the new tests will not force a reduction in the total number of inspections that most stations can perform. The second is that, because costs are spread over a smaller number of vehicles than in the case of high-volume, centralized stations, the cost per vehicle for the new tests will be larger in this type of inspection network.

The higher costs for high-tech testing equipment have prompted questions of whether all current inspection stations would choose to stay in the inspection business with the implementation of an enhanced program, and how high a drop-out rate programs would experience if some did not. EPA knows of no data or reasonable assumptions by which a station drop-out rate could be reliably estimated. In this analysis inspection costs for high-tech testing are estimated for three scenarios: one where all stations remain in the inspection business, one where 50% of the stations drop out, and one where enough stations drop out such that those that remain are operating at maximum possible volume assuming that each has one inspection bay which has not been improved for high throughput and one inspector performing all parts of the inspection. In all three scenarios a biennial inspection frequency is assumed.

The current average test fee for 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 may charge. In many cases, the actual fee is likely to be below cost; stations presumably obtain sufficient revenue to stay in business by providing other services, which may include repair. It should also be noted that the intensity of the inspection and the sophistication and cost of the analyzer vary significantly among programs. Average inspection costs and revenues by program, taking these factors into account, are estimated in Section 7.4.1.

The costs for adding high-tech tests are derived by estimating the per vehicle costs of the key components: labor; equipment, including expendables; and support, i.e., service contracts and annual updates. Per vehicle costs are estimated by deriving total costs for each component and dividing by the number of vehicle inspections expected to be performed in a year, again, taking into account variations in inspection volumes and changes in frequency. 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, may be able to afford to purchase current analyzer equipment outright, the smaller gas stations and garages typically have to finance these purchases (although in some cases they may lease equipment). 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. Equipment costs are amortized over five years at 12% interest in the analysis in this report.

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

5.2.4.3 Cost Components and Scenarios

The full test, including data entry on the computer, preparing the vehicle for the different steps in the test procedure and conducting them, is estimated to take 30 minutes with only one inspector performing all tasks in a repair bay that is not configured specifically for inspection throughput. With labor costs at $21 per hour, as described above, this works out to $11.50 per vehicle. Equipment costs are taken from Table 5-4 and are amortized over a five year period at 12 percent annual interest (changing the assumed interest rate does not significantly affect the total per vehicle cost). This brings the total cost for the equipment package over the five year period to $192,325. These costs are divided by five years worth of inspections. The costs of expendables from Table 5-5 are added in according to the usage rates assumed for decentralized programs. Two other expenses typically encountered in decentralized programs are service contracts and software updates. Based on information from states, service contracts are estimated at $200 per month and annual software updates are assumed to cost $1,500.

Per vehicle costs are estimated for three scenarios, biennial testing is assumed in all three. In the first, all stations remain in the inspection program. In the second, 50 percent of the stations drop out of the program, and in third there are only the minimum number of stations in the program to enable each to inspect at full volume with one inspector performing all parts of the inspection and a service station bay that has not been improved for high throughput.

In the first scenario, the switch to biennial would mean that annual volume is cut in half, or 513 vehicles per year. In the second scenario the 50 percent reduction in the number of stations brings the annual inspection volume back to 1,025. In the fourth scenario, it is assumed that each station inspects at maximum capacity, i.e., one vehicle every thirty minutes, and that an inspector is available 50 hours per week. This results in an annual volume of 5,200 vehicles.

Table 5-10

Costs to Conduct High-Tech Testing in Decentralized Programs

Scenario	Annual Volume	Cost per Vehicle
No Drop-out	513	$106
50% Drop-out	1,025	$58
72% Drop-out (Maximum volume)	5,200	$32

Note that while reducing inspection frequency to biennial cuts motorists' costs in centralized programs, in decentralized programs such cost reductions are only achieved by reducing opportunities for stations to participate. In the scenario in which 50 percent of the stations drop out and testing is biennial, annual station volume is the same as if testing were annual and no stations dropped out. Hence, the estimated per vehicle cost in a biennial program with a 50 percent station drop-out rate is the same as would be derived for an annual program with no stations dropping out. Reducing inspection frequency to biennial, while maintaining the same number of stations, has the effect of almost doubling the per vehicle cost since operating costs are spread over half as many vehicles. Note also that the per vehicle cost far exceeds the per vehicle cost in centralized programs except in the scenario where 72 percent of the stations drop-out.

5.3 Costs of Four-Mode, Purge and Pressure Testing

It has been proposed that a series of simpler, loaded mode and other steady-state tests would provide equivalent emission reductions to the IM240 at a lower cost. The emission reduction potential of this approach is currently being evaluated at EPA's test lane in Phoenix, Arizona. The information needed to do a cost analysis can be approximated at this time based upon the test process.

The test procedure being evaluated is a series of emission tests referred to as the four-mode test: A 40 second 5015 mode (15 mph at xxx load), a 40 second 2525 mode (25 mph at xxx load), a 40 second mode at 50 mph and normal road load, and a 40 second idle mode. EPA anticipates a 30-60 second preconditioning mode would be needed to insure proper warm-up and canister purge down. Allowing also for necessary time to transition between test modes (5-10 seconds), the four-mode test would require a total of approximately four minutes. As with the IM240-based test scenario, purge testing is assumed to occur simultaneously with the tailpipe test and pressure testing would be done separately. It should be noted, however, that some vehicles may not purge during this test and may require a short transient retest to activate purge.

5.3.1 Equipment and Expendables

The equipment used for the four-mode test is simpler than for the IM240 test. The dynamometer may not need inertia weights, and a raw gas analyzer, like the ones used in the current I/M tests, is upgraded with a NOx analyzer and an anamometer, to enable mass concentration calculations, for this test. The equipment for the purge and pressure test are the same as described previously. The estimated costs are shown in Table 5-11.

Table 5-11

Equipment and Costs for the ASM Test

Pressure System	$600
Flow Sensor	$500
Dynamometer	$20,000
Anamometer	$2,000
BAR90 w/NOx Analyzer	$16,900
Total	$40,000

Expendables for this test are nitrogen gas for the pressure test and calibration gases for the analyzer. The cost of nitrogen gas is the same as in the previous analysis on IM240 costs (the pressure test procedure is the same regardless of the type of tailpipe test used). Current calibration gases are multi-blends consisting of propane, CO, and CO2. A cost of $45 per bottle is used here. In this analysis, it is assumed that multi-blend gases that include NO will be available at the same cost. Alternatively, one could assume that two bottles of calibration gas, one current standard multi-blend and a bottle of NO will be needed, however, the additional cost per test is insignificant (less than 5¢, even in a low volume situation).

5.3.2 Centralized Programs

The total test time per vehicle would be about 11 minutes, including administrative processing in an efficiently run testing lane. In a multi-position lane the throughput would be governed by test time at the longest position, which would be four minutes. This translates into a peak throughput rate of 15 vehicles per hour and, using the standard design criteria for centralized programs described earlier, an average throughput of 7.5 vehicles per hour. Using the lane operation assumptions detailed earlier, this translates into 23,400 vehicles per lane per year and 117,000 vehicles over an assumed five year contract period. Three staff per lane would be needed to perform the entire test sequence including inputting vehicle identification information, conducting the tests and presenting and explaining the results to the motorist.

The per vehicle cost of the four-mode test in centralized programs is estimated by the same methodology as was used to estimate IM240 costs. Current costs for test equipment, staff, state oversight, and construction are subtracted from the current average per vehicle cost, this amount is factored by the change in throughput, and estimated costs for equipment, staff, construction, and state oversight in a four-mode test program are added to obtain an estimated total cost.

Table 5-12

Costs to Add Proposed Tests to Centralized Programs

Increments	Per Vehicle Cost	Running Total Cost per Vehicle
Adjust for Throughput	$5.26 * 12.5/7.5	$9.12
Staff	$2.40	$11.52
Construction	$1.71	$13.23
Oversight	$1.75	$14.98
Pressure Test	$0.13	$15.11
Purge Test	$0.18	$15.29
Four-mode Test	$0.35	$15.64

5.3.3 Decentralized Programs

The same methodology used to estimate costs of IM240 testing is used here. Most assumptions are unchanged. Total test time is thirty minutes, equipment is amortized over a five year period. Two parameters are changed in this analysis: equipment costs total $40,000 instead of $144,100, and state costs include a cost for state mass emission testing.

Table 5-13

Costs to Conduct Four-Mode Testing in Decentralized Programs

Scenario	Annual Volume	Cost per Vehicle
No Drop-out	513	$51
50% Drop-out	1,025	$31
72% Drop-out	5,200	$25

5.4 Repair Costs

5.4.1 HC and CO Exhaust Repair Costs and Methodology

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

5.4.1.1 Tailpipe Emission Test Failures

Based on current information from I/M programs which collect repair cost information, the average cost to repair a 1981 or newer vehicle failing the 2500 rpm/Idle test is approximately $75, including parts and labor. For example, 1989 repair data from the Louisville, Kentucky I/M program shows the average cost to be $54 for all model year vehicles if only commercial repairs are included. The overall average cost drops to $42 per repaired vehicle if the cost of self repairs (repairs performed by the individual vehicle owner) are also included [6]. In addition, the $75 average repair cost figure is further supported by the findings from an I/M repair study conducted in California which showed the average repair cost to be $72 for 1980 and later model year vehicles [7]. 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. [8]

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

5.4.1.2 Emission Control Inspection Failures

The average cost (separated by model year group) to repair emission control components identified as needing repair or replacement by a visual inspection are shown in Table 5-14.

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

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[6] "1989 Annual Report Vehicle Exhaust Testing Program Jefferson County, Kentucky", April, 1990

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

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

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

Table 5-14

Average Cost of Repairing Emission Control Components

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

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

5.4.2 NO_x Repair Costs and Methodology

Repair costs for NO_x reduction, and the supporting analysis are discussed separately from the HC and CO repair cost analysis because repairs targeted to reduce HC and CO emissions often have no effect on NO_x emissions. Moreover, the Indiana data showed that the HC/CO failures and the NO_x failures were essentially separate sets of vehicles[9]. 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.

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

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 National Vehicle and Fuels Emissions Lab (NVFEL) in Ann Arbor, Michigan, as well as at the ATL facility in South Bend, Indiana. In this program, large numbers of in-use vehicles were recruited for testing and repair to better characterize the emissions of the fleet. However, for the analysis of NO_x costs, the overall database was restricted to 1983 and later model year vehicles which had received an FTP test both before and after repair, and had been tested in the last few years. As a result, data from 169 1983+ model year vehicles with repair data were obtained.

Most of the 169 vehicles were high emitters of HC or CO, and had repairs aimed at those pollutants, since EPA had given the testing contractor instructions to focus on HC and CO emissions. In order to more accurately characterize the cost of effective NO_x repairs, criteria were used to further select vehicles which clearly had high NO_x emissions before repair, but had achieved lower NO_x emissions as the result of the repair. These criteria were: Before repair FTP emissions had to exceed 2.0 gpm NO_x, and after repair FTP emissions could not exceed 1.25 gpm. As a result of these criteria, 10 cars out of 169 were selected, and 9 were used in the final cost analysis. Examining the individual vehicle repairs of these 9 vehicles (see Table 5-15) shows that all of them needed EGR repairs to lower the NO_x emissions to levels which could meet the criteria. On 6 of these vehicles, the EGR was replaced, while on the other 3 the EGR passage was cleaned, or the delay valve was replaced.

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

The repair costs of the 9 individual vehicles as well as the overall averages are shown in Table 5-15. For example, the price of the repair parts averaged $44, using Mitchell's Summer Collision Estimating Guide. The labor cost averaged $34, based on 0.68 hours at $50 per hour. These labor hours were determined using Mitchell's 1991 Mechanic's Labor Estimating Guide. In addition, each car was assumed to require 0.5 hours of diagnostic time at the labor rate of $50/hour for an average cost of $25. Summing these costs puts the total average cost of an effective NO_x repair at $103. For input into subsequent cost-effectiveness models this overall cost was rounded to $100.

Table 5-15

NO$_x$ Repair Costs

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

5.4.3 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 LA4 test cycles (the first LA4 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.[10] 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 5-16.

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

Table 5-16

Average Repair Costs and Fuel Economy Benefits

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

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

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

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

In some cases, actual labor times were not available to diagnose or replace a particular part. In these cases estimates were made regarding the duration of a typical repair. For example, gas cap replacement (including diagnosis) duration was not usually itemized and, therefore, was estimated to be 15 minutes. In other cases, repair times from similar repairs on other cars were used. However, for the sake of clarity, both the parts and labor cost basis of each vehicle's repair are noted in Table 2 of reference 8.

5.5 Fuel Economy Benefits

5.5.1 Fuel Economy Benefits of Evaporative System Repairs

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

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

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

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

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

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

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

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

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

4.21 gpm running loss $CH_{2.33}$ * R Factor = 4.21 gpm liquid fuel ($CH_{1.85}$)

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

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

5.5.2 Fuel Economy Benefits of IM240 Repairs

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

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

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

FTP fuel economy before and after repairs for the 52 vehicle sample group.

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

Table 5-17

Zero Improvement Vehicle Sample Size Adjustments

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

5.5.3 Fuel Economy Benefit for the 2500 rpm/Idle Test

The 8.0% fuel economy benefit assessed for identifying and repairing vehicles on the basis of the 2500 rpm/Idle test is based upon two groups of 1983 and newer vehicles recruited at the Hammond test site. The first group consisted of 6 vehicles that failed the 220 ppm HC and/or 1.2% CO cutpoints on their initial 2500 rpm/Idle I/M test, received an IM240 before and after commercial repairs, and received passing scores on the retest. The second group consisted of those vehicles that returned to the Hammond lane after commercial repairs, but again failed the 2500 rpm/Idle test. These latter 6 retest failures are considered to be the result of incomplete repairs, which would be corrected in an enhanced I/M program.

The before and af ter IM240 fuel economy data was "corrected" to reflect FTP fuel economy by employing a correction factor of

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

After successful repairs (i.e., those resulting in a passing retest), some marginal vehicles will fail to realize a noticeable fuel economy improvement. Using a database of 48 cars, it was determined that 4 of the vehicles that failed the 2500 rpm/Idle I/M test were not repaired because their FTP emissions scores were less than twice their certification standards, leading to the conclusion that, had these vehicles been repaired, their fuel economy benefit would be zero. These 4 vehicles represent 8.3% of the 48 database vehicles for which all the necessary data was available. Assuming that 8.3% of the 6 vehicles that were still failing I/M would not get a fuel economy benefit after repairs yields a figure of 0.48 vehicles that will show no noticeable fuel economy benefit. Given that half of a vehicle cannot be added to the database, each of the other 6 vehicles that did pass after repairs were duplicated yielding twelve vehicles, and 1 vehicle was added to represent the "no fuel economy improvement" case. Adding the single “zero improvement vehicle” lowered the fuel economy benefit of the 2500 rpm/Idle test from 8.6% to 8.0%. Table 5-18 further details how these numbers were arrived at.

Table 5-18

Adjusted Zero FE Benefit Vehicle Sample Size

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

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

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

The rates at which vehicles recurrently fail tailpipe tests and emission control inspections in an ongoing I/M program (i.e., the percentage of failing vehicles in a program that has been established for a few years) are used within the Cost Effectiveness Model (CEM) for determining repair costs. Fuel economy credits for repairs resulting from tailpipe tests are based on the hypothetical failure rates that would occur in the first cycle of the I/M program if it were just starting. These hypothetical rates in effect represent vehicles that have been and remain affected by the I/M program that has in fact been operating.

The exhaust test failure rates for calculation of repair costs in CEM are in the form of a zero-mile failure rate and a deterioration rate, such that the fraction of failing vehicles for a given test type is calculated by multiplying the deterioration rate by the average mileage and adding that result to the zero-mile failure rate. Table 5-19 shows the zero-mile and deterioration rates found in the BLOCK DATA section of CEM.

Table 5-19

Exhaust Test Failure Rates
(fraction)

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

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

The recurring zero-mile rate used by the model for the IM240 is half of the first-cycle deterioration rate (0.0373/2 = 0.01995). The recurring deterioration rate used by the model for the IM240 is half of 1/1.87 times the first-cycle failure rate. This method represents a 50-50 compromise between the following two assumptions, either of which would be reasonably plausible: (a) The IM240 test will require vehicle repairs sufficient to return the emission control systems to like-new condition thus yielding a constant failure rate equal to the rate found for the first 10,000 miles of operation (0.0373), and (b) IM240 repairs will deteriorate similarly to idle and 2-speed test repairs, which would yield a deterioration rate of 0.0373/1.87 = 0.01995).

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

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

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

CEM assumes these same initial failure rates in determining fuel economy benefits of purge and pressure tests, since the fuel economy effect of an I/M program in a given year depends on the difference between the number of failures that would exist in a no-program case and the near-zero number present with the I/M program in operation. The fuel economy benefit calculation using these failure rates is described in Section 5.5.

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

Recurring Purge test failure rate: 3.0%

Recurring Pressure test failure rate: 2.5%

Recurring total Purge/Pressure failure rate: 5.0%

The exact use of these rates can be seen in the FAIL function of the CEM program listing (see previous note).

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

5.7 Method for Estimating Cost Effectiveness of I/M Programs

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

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

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

5.7.1 Inspection Costs

Inspection costs are determined by multiplying user-input inspection costs by the number of vehicles adjusted for compliance rate (percentage of vehicles that fail to get inspected). Separate costs are input for tailpipe emission tests, emission control checks, purge test, and pressure test. If a program calls for biennial rather than annual inspections, the inspection costs per year are divided in half. All default costs are found in the SETUP routine of the CEM program listing. Default inspection costs are shown in Table 5-20. Note that the cost of performing the purge test overlaps many of the costs associated with transient testing, including the cost of a dynamometer, video driver's aid (VDA), and the throughput adjustment associated with the longer test time. If purge testing is assumed, the incremental cost of including the transient test is relatively minor, including the cost of a constant volume sampler (CVS) and the analyzers necessary to perform mass emissions testing.

Table 5-20

Default Inspection Costs in CEM4.1

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

5.7.2 Repair Costs

Calculating total repair costs is performed similarly to the inspection costs, except that the costs are only applied to the percentage of vehicles estimated to fail a given I/M test. It is further adjusted for the percentage of vehicles that do not get repaired because they require repairs costing more than the applicable cost waiver limit. Default repair costs are as follows.

Table 5-21

Default Repair Cost in CEM4.1

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

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

5.7.3 Fuel Economy Cost Benefits

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

Table 5-22

Fuel Economy Benefits in CEM4.1

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

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

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

6.1 Emission Reduction Benefits

Gram per mile emission factors were calculated using MOBILE4.1 for the high-tech enhanced program. The design elements and proposed performance standard inputs are detailed below in Table 6-1. These inputs include annual, centralized testing of 1968 and later light-duty vehicles and light-duty trucks, as required by section 182(c)(3)(B) of the Clean Air Act Amendments of 1990. Other inputs reflect national default values assumed in MOBILE4.1. It should be noted that these inputs are substantially similar to those that appeared in the draft version of this document, with the exception of assumed waiver and compliance rates, which have been loosened to reflect more realistically achievable levels. Nevertheless, the emission reductions projected for the enhanced I/M performance standard are within a percentage point of those previously reported.

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

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

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

Table 6-1

MOBILE4.1 Inputs for the High-Tech Enhanced Model Program

Flag	Input
(Standard Inputs)	
Pre-1981 Stringency	20%
Idle	1968-1980
2500 rpm/Idle	1981-1985
Pressure	1983+
Purge	1986+
Transient	1986+
†Waiver Rate	3%
†Compliance Rate	96%
*Network Type	central
*Test Frequency	annual
*Vehicle Coverage	LDV/ LDT1/LDT2
ATP MY coverage	1984+
Catalyst	Yes
Fuel Inlet	Yes
Air Pump	No
Tailpipe Lead Test	No
Evap Disablement	No
PCV Disablement	No
Gas Cap	No
(Local Inputs)	
Altitude	500 feet
Period 1 RVP	11.5
Period 2 RVP	8.7
Period 2 Start Year	1992
Minimum Temperature	72°F
Maximum Temperature	92°F
Ambient Temperature	87.5°F
Operating Mode	20.6/27.3/20.6
Onboard Controls	no
Stage II Control	no
Vehicle Speeds	19.6 mph
VMT Mix	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.

Table 6-2

Benefits of I/M Programs Options *

	VOC Emission Effects		CO Emission Effects	
Scenario	Emission Factor (gpm)	Percent Reduction	Emission Factor (gpm)	Percent Reduction
Base - No I/M	2.084	-	11.874	-
Basic I/M	1.971	5.4%	10.021	15.6%
Biennial High-Tech Program	1.495	28.3%	8.223	30.7%
Proposed Enhanced Performance Standard	1.503	27.9%	8.230	30.7%

* Total Highway Mobile Source Emissions in 2000

6.2 Cost Effectiveness Estimates

6.2.1 Assumptions and Inputs

EPA's estimates of the cost-effectiveness of I/M 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 assumed cost for an I/M inspection, including a visual check of emission control devices, is $8.50. The incremental cost of adding the evaporative system pressure test is $1.94. The incremental costs of adding the purge and transient tests are $5.19 and $0.87, respectively. As indicated in section 5.6.1, the cost of the purge test includes the cost of a dynamometer and VDA, and also reflects a throughput adjustment to accommodate the longer test; adding transient testing to the purge test requires the addition of a CVS and the necessary emissions analyzers. In addition, gasoline is assumed to cost $1.25 per gallon. The average repair costs shown in Table 5-17 were assumed. It should be further noted that the incremental costs of adding purge and transient testing to a decentralized network ($12.40 and $24.97, respectively) are larger than in a centralized network because of the assumption these additional costs will be spread out over a smaller test volume (i.e., it is assumed that the average number of vehicles tested per station in a decentralized network will not change).

6.2.3 Cost-Effectiveness Calculations

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

Table 6-3

Total Annual Program Cost

Scenario	Cost
Basic I/M	$6,412,000
Annual Enhanced	$11,390,000
Biennial Enhanced	$5,429,000

The next step is to calculate cost-effectiveness ratios, or the annual cost per ton of emission reductions. For areas that are required to do enhanced I/M due to ozone nonattainment (the majority of enhanced I/M areas), the ratios could be calculated by dividing the annual program costs, from Table 6-3, and dividing them by the annual tons of hydrocarbon reductions. The results are shown in Table 6-4. Unlike the total costs in Table 6-3, the cost per ton decreases with program stringency. This is because a major part of the cost is the inspection and the small marginal cost of doing a more effective test is overwhelmed by the large marginal benefit. This is a critical factor to keep in mind when choosing among various different ozone control strategies.

Table 6-4

Cost per Ton Allocating All Costs to VOC

Scenario	Costs per Ton
Basic I/M	$5,410
Annual Enhanced I/M	$1,694
Biennial Enhanced I/M	$879

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

Since CO reductions are not needed in all areas, and only about 44% of the vehicles that will be subject to enhanced I/M are in CO areas, costs are not assigned in all areas. This is done by reducing the tons of emission reduction to 44% of full benefit and using that result to calculate the alternative cost per ton.

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

Table 6-5

VOC Cost per Ton Accounting for NO_x and CO Benefit

Scenario	Cost Per Ton
Basic I/M	$4,518
Annual Enhanced I/M	$1,271
Biennial Enhanced I/M	$461

6.2.4 National Cost of Choosing Less Stringent 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?

Adopting a weak performance standard for I/M means fewer tons of VOC reductions than EPA's proposed high-tech program, as shown in Table 6-6. The low-tech "enhanced" program listed in Table 6-6 is essentially the basic I/M performance standard with light-duty trucks included along with visual inspection of the catalyst and inlet restrictor. This less stringent standard, even when implemented in a centralized network, costs more per ton than the high-tech approach. Thus, if states choose to implement a weak I/M program there is a direct cost to the nation because of the higher expense. In addition to the direct cost, there is also an indirect cost. As more and more controls are imposed on stationary sources, the law of diminishing returns would predict that the cost per ton will rise. It is estimated that the cost of these marginal controls will likely exceed $5,000 per ton.

Table 6-6

Total Cost and Benefits of I/M Options

Per Million Vehicles	Tons	Total Cost
High-Tech Enhanced I/M	6,724	$8,544,000
Centralized Low-Tech I/M	2,245	$8,204,000
Decentralized Low-Tech I/M	2,245	$17,062,000

To estimate the total cost of implementing an only marginally "enhanced" program (i.e., the low-tech program mentioned above) it was assumed that of the 56 million vehicles subject to enhanced I/M 42 million vehicles would be in a decentralized system and 14 million would be centralized. This reflects the current mix of programs in the affected areas. It was also assumed that each ton not obtained from I/M would be gotten from stationary source controls at $5,000 per ton. The results are shown in Table 6-7. The extra direct cost of the low-tech option would be about $353 million while the indirect cost of the more expensive stationary source controls amounts to about $1,254 million, for a total of about $1.6 billion in excess cost.

Table 6-7

Excess Cost of Choosing Low Option I/M

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

6.3 National Costs and Benefits

6.3.1 Emission Reductions

Estimates of the total costs and emission reduction benefits of current and future I/M programs were obtained using CEM4.1. Because average costs and effectiveness vary between centralized and decentralized programs [11] the costs and reductions were modeled differently for each program type. The MOBILE4.1 output showing the scenarios used are in Appendix I. Vehicle population figures are needed in order to calculate total costs and emission reductions. Because figures obtained from the states vary in reliability, estimates were derived based upon Census data for each area.

As shown in Table 6-8 below, current I/M programs obtain estimated total annual emission reductions of 116,000 tons of VOC and 1,566,000 tons of CO. Implementation of a biennial high-tech program would yield estimated annual emission reductions of 384,000 tons of VOC and 2,345,000 tons of CO from enhanced I/M programs, and 36,000 tons of VOC and 500,000 tons of CO from basic programs. Enhanced high-tech I/M programs would also reduce NO_x emissions. The transient test with NO_x cutpoints designed to fail

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

10% to 20% of the vehicles would yield estimated NO_x reductions of 9% relative to emission levels with no program in place.

Table 6-8

National Benefits of I/M

(tons of emissions reduced annually)

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

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

6.3.2 Economic Costs to Motorists

EPA has developed estimates of inspection and repair costs in a high-tech I/M program. The derivation of these estimates is detailed in section 5.0. A conventional steady-state I/M test including ATP currently costs about $8.50 per vehicle on average in a centralized program, and $17.70 per vehicle on average in a decentralized program. A complete high-tech test, including transient, purge, and pressure testing, is expected to cost approximately $17 per vehicle in an efficiently run high-volume centralized program. In a program where 1984 and later vehicles received the high-tech test, and older vehicles received a steady-state test and ATP, and the inspection were performed biennially, the estimated annual per vehicle cost would be about $9. The cost is sensitive to whether test equipment and personnel face a steady stream of vehicles or have idle periods. Therefore the cost would be somewhat higher in a test-only multi-participant system if the inspection network had more excess capacity than a typical centralized program. Test-only stations may also not be as proficient in testing each vehicle quickly, adding somewhat to costs.

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

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

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

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

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

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

Table 6-9

Program Costs and Economic Benefits

(millions of dollars)

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

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

6.4 Motorist Inconvenience Costs

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

EPA calculated the cost-effectiveness of a biennial high-tech program with this additional cost included. Table 6-10 below shows the estimated total program cost per million vehicles, the cost per ton with all costs allocated to VOC reduction, and the adjusted cost per ton of VOC with costs allocated among pollutants as discussed previously.

Table 6-10

Costs of the Biennial High Option including Inconvenience

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

Comparing these figures with those in Tables 6-4 and 6-5 shows that a biennial high-tech program, even with motorist inconvenience costs included, is still more cost-effective than a weak, low-tech program without those costs considered.

7.0 REGULATORY FLEXIBILITY ANALYSIS

7.1 Regulatory Flexibility Act Requirements

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

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

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

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

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

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

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

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

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

7.1.1 The Universe of Affected Entities

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

Table 7-1

Affected Businesses

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

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

7.2 Types of Economic Impacts of Concern

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

7.3 Changes in Repair Activity

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

7.3.1 Repair Activity in Current I/M Programs

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

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

7.3.2 Repair Activity in Future I/M Programs

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

Table 7-2

Repair Expenses in Enhanced I/M Programs

(millions of dollars)

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

The $311 million in extra repair expenditures is estimated to comprise about 40% parts cost and the remainder for labor, profit, and overhead. The automotive parts industry estimates that 20,000 jobs are created for every $1 billion spent on parts. Hence, the additional parts demand ($125 million) will create 750 jobs in parts manufacturing as well as additional business for retailers and distributors, and is likely to create more jobs for clerks and delivery employees. The remaining 60% is estimated to comprise about 50% profit and overhead at the repair shop and 50% labor. Hence, mechanics will earn an additional $93 million over all program areas. At an average pay rate of $25 per hour, this translates into 1,800 full time equivalents (FTE) over all program areas.

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

7.4 Changes in Emission Testing Activity in I/M Areas

7.4.1 The Existing Market in Centralized and Decentralized Programs

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

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

Table 7-3

Number of Inspection Stations by State

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

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

Table 7-4

Inspection Stations by Category

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

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

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

Table 7-5

Inspection Station Volumes and Incomes

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

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

The costs incurred by inspection stations are driven by a number of factors. Labor (i.e., the amount of time required to perform the inspection and the inspector's hourly wage) appears to be the largest component of cost. The cost of the analyzer is the second largest component. PC-based (BAR90) analyzers are the latest generation of analyzers used in decentralized programs. Their cost can vary from $13,000 to $20,000. The most common price appears to be approximately $15,000 each. A number of service station based programs in areas required to implement enhanced I/M are currently using BAR84 analyzers. These cost approximately $5,000 each. Many stations in the older BAR84 programs have paid off the cost of their analyzers, which in turn decreases their annual inspection expenses. Analyzer service

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

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

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

contracts and calibration gas add lesser increments to the total cost.

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

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

Table 7-6

Average Inspection Station Revenues, Costs, and Profits

State	Vehicles /Station	Fee	Net Revenue	Annual Cost	Net Profit
California[11]	734	$48.39	$31,127	$11,899	$19,228
Colorado	1,104	$9.00	$8,279	$5,202	$3,078
Georgia	1,729	$10.00	$16,422	$9,320	$7,102
Houston[13]	1,348	$11.25	$10,444	$7,075	$3,369
Louisiana[13]	1,037	$10.00	$4,926	$5,444	($518)
Massachusetts[15]	1,321	$15.00	$16,518	$13,498	$3,020
Nevada	1,260	$16.00	$16,386	$7,681	$8,705
New Hampshire	564	$14.00	$7,195	$4,257	$2,938
New York[11]	1,071	$17.00	$16,868	$20,268	($3,400)
Pennsylvania[14]	834	$8.50	$6,675	$2,811	$3,864
Rhode Island[14]	684	$12.00	$8,211	$2,653	$5,557
Virginia	1,301	$13.50	$14,829	$5,546	$9,283
Average	963	$15.39	$18,914	$10,818	$8,096
Average w/o CA	1,086	$12.39	$12,357	$10,238	$2,120
Average w/o CA & NY	1,091	$11.93	$10,741	$6,645	$4,097

This analysis revealed anomalies in the California and New York programs relative to the others. California has a much

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

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

These figures, based on the average inspection volumes for each state, show that inspection services, by themselves, do not yield significant profit to the average inspection station. While the average profit is low, the amount of revenue and profit can vary a great deal among inspection stations since inspection volumes vary considerably as well. The best available data on station volumes was obtained from the California program. The data covers a three month time period and is shown in Table 7-7.

Table 7-7

Inspection Volumes in California

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

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

Table 7-8

Station Revenues and Profits by Volume

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

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

7.4.2 Future Market in Enhanced I/M Programs

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

7.4.3 Centralized Programs

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

7.4.4 Decentralized Programs

Enhanced areas that currently have decentralized programs will have two options in meeting the requirements of the proposed action: they can institute either a multi-participant test-only network, or a single operator centralized system.

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

Data correlating average inspection volume with station type are not available. However, survey data of motorists in I/M programs point to the fact that stations that currently focus on repair work and that do a steady volume of repairs are often unable to make facilities available to provide inspections promptly on request [16]. 27% of motorists in decentralized programs reported being asked to bring their vehicles back for testing another time. 20% reported having to take their vehicles to more than one station to obtain a test. Nearly one out of three had to leave their vehicles for inspection. On the average, the vehicles had to be left for five hours. These data suggest that a focus on repair leads to reduced opportunities to perform inspections and probably to lower inspection volumes as a result.

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

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

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

Table 7-9

Assumed Station Distributions

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

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

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

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

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

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

The remaining 2 5% that do not have a clear orientation toward engine repair, and that do not perform a high volume of inspections, are a mix of service stations, whose business is a mix of gasoline sales and, in some cases, engine repairs including I/M repairs on some portion of the vehicles they test; non-engine repair shops, such as tire shops, muffler shops, transmission shops, etc.; and retailers. Members of this group are assumed to make up the other half of the 22% of stations that do no inspections. These stations would not be adversely affected by this rulemaking since they are currently deriving no income from the inspection business.

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

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

Table 7-10

Revenues and Profits for Low and Medium Volume Stations

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

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

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

If a single contractor centralized program were instituted in an area where a decentralized program is currently operating, the option to pursue the test-only business would not be available to the 23% of the station population that would be likely to pursue it. Based on the foregoing analysis, these stations have current inspection volumes of 200% or more of the program average, and may have average profits of roughly 220% or more of the program average. Members of this group without profitable alternatives would also face the risk of closure.

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

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

7.4.5 Impact on Jobs in Decentralized Programs

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

Table 7-11

Numbers of Inspectors per Station by State

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

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

Table 7-12

Estimated Inspection FTE

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

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

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

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

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

EPA estimates that in a high volume enhanced I/M lane, testing an average of 7.5 vehicles per hour, 3-4 inspectors would be needed per lane instead of the 1-2 typically employed in current high volume systems. Using an industry estimate of 267 FTE per million vehicles, and assuming a 20% retest rate, 5,340 FTEs are required to test the 33 million vehicles in currently decentralized programs on a biennial basis (this estimate is based on the assumptions and methodology developed in Section 5.2 of this report, "Estimated Cost of High-Tech I/M Testing").

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

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

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

Table 7-13

Summary of FTE Gains and Losses

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

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

7.4.6 National Impact on Jobs

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

Table 7-14

Impact on Jobs of I/M Proposal

Current Test and Repair Jobs		FTE
Inspector Jobs		
	Decentralized Programs	6,600
	Centralized Programs	2,500
Repair Jobs		
	Decentralized Programs	800
	Centralized Programs	1,500
Total Current Jobs		11,400
Future Test and Repair Jobs		
Enhanced I/M Programs		
Inspector Jobs		
	Multiple Independent Supplier	10,500
	Single Contractor	2,700
Inspector Job Subtotal		2,700 - 10,500
Repair Jobs		5,500
Basic I/M Programs		
Inspector Jobs		2,700
Repair Jobs		700
Total Future Inspection and Repair Jobs		11,600 - 19,400
Other Job Gains		
Parts Manufacturing		1,034
Construction		1,800
Small Business Services		800
Total Net Gain in Jobs		3,800 - 11,600

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

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

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

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

In some states that are currently decentralized and will have to implement enhanced I/M, analyzers have been in use for 10 years or more and are fully amortized. In states that upgraded to BAR90 equipment (California and New York), the equipment was purchased since 1990, and has years of useful life left. A number of other states upgraded their equipment to BAR84 in the period from 1987 to 1990. Stations in these areas are likely to still be paying for their equipment (see the footnote to Table 7-6). One means by which the state could provide direct assistance to current test stations would be to set up some type of state-supported analyzer buy-back program for stations that were no longer going to participate in either the test or repair business, possibly using funds obtained from inspection fees. BAR90 analyzers would be needed in the repair business both for diagnostic and repair work as well as to check whether repairs on old technology vehicles were effective. BAR90 analyzers could also be used to test older technology vehicles in test-only stations. This concept would allow stations that were planning to leave the I/M business to recover all or part of their capital investment for equipment that could not be used for diagnostics and repair. Such a buy-back program might allow a fairer transition to test-only status.

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

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

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

A third strategy would be to provide targeted assistance to stations to assure they were able to provide high-tech repair services. This would require pre-program start-up training to bring repair technicians in these stations up to speed on the high-tech tests, vehicle diagnosis, and engine repair. It might mean tuition grants or other financial assistance. This dovetails with stronger repair technician training programs which EPA envisions as being part of future I/M requirements, but differs in terms of funding, timing, and intensity. This approach might also include financial assistance to stations for the purchase of equipment to perform sophisticated diagnosis and repair on new technology vehicles or to upgrade tools and equipment for more sophisticated diagnosis and repair.

7.6 Public Comment

Two independent analyses of job impacts were conducted by the Coalition for Safer, Cleaner Vehicles (CSCV) and EPA's Office of

Policy Planning and Evaluation (OPPE). Both projected an increase in employment opportunities as a result of the implementation of enhanced I/M. The magnitude of the estimated increase varies between the two studies and the estimates discussed above. The OPPE study projects an increase of 1,300-1,400 FTE in the areas that currently have decentralized test-and-repair programs as a result of the implementation of enhanced I/M, while CSCV's study projects an increase of 4,670 FTE in those areas, and a total increase of 8,420 FTE in all enhanced areas. Hence, there is general agreement among the parties that have tried to quantify the overall employment impacts of the proposal that employment opportunities will increase, although the magnitude of the projected increases varies.

The National Automobile Dealers Association (NADA) submitted comment questioning the conclusion that there will be a net increase in emission control employment as a result of the implementation of enhanced I/M. However, NADA offered no analysis of its own on employment affects, nor did it critique EPA's analysis in any detail.

Some test-and-repair station owners commented that the inspection business generates $7,000 per month in revenues. This figure appears to include repair revenues as well as inspection revenues. The previous analyses indicate that inspection revenues average about $10,000 annually per station, or less than $1,000 a month. These stations would still be able to pursue emission repair business in a test-only program and there would be a considerable increase in this business. Many of these commenters appeared to be under the impression that, in the event of a switch to a test-only system, they would be barred from doing repairs as well as inspections. This is not the case.

The comment was made that the profit margin on gasoline sales is low and that service station dealers depend on ancillary sales, such as inspections and repairs. The foregoing analysis shows, and independent analyses confirm that repair business will increase significantly with the implementation of enhanced I/M, and that service stations with a strong orientation toward engine repair will have an opportunity to increase profits. EPA's analyses indicate that inspections do not generate large profits for the average station, hence, the loss of this business will not necessarily result in significant losses for other service stations that do not have a strong orientation toward engine repair.

The New Hampshire Department of Environmental Services and the Texas Automobile Dealers Association were both supportive of the concept of buying back old test equipment, but were concerned about how such a program might be funded. New Hampshire suggested that EPA recommend a means to fund such a program without increasing the cost of emission testing. States are encouraged to consider these measures, but they are not mandated. A wide variety of funding mechanisms besides a surcharge on the inspection fee could be found to fund such a program. What means might be available and appropriate are likely to vary from state to state.

Virtually all commenters supported allowing transitional mechanisms such as phase-in of test-only and high-tech testing, and the final rule allows for these transitional mechanisms. No specific comments were received on the targeted re-training assistance concept, although the comments reflected overwhelming support for technician training in general.

8.0 ONBOARD DIAGNOSTICS AND ON-ROAD TESTING

8.1 Onboard Diagnostics, Interim Provisions

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

8.2 On-road Testing, Interim Provisions

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

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

EPA has specified that on-road testing be defined as "the measurement of HC, CO, NO_x, and/or CO_2 emissions on any road or roadside in the nonattainment area or the I/M program," and that it be required in enhanced programs and an option for basic I/M areas. Minimally, the on-road testing effort must evaluate the emission performance of at least 0.5% of the subject fleet each year. EPA believes that the on-road testing requirement can be fulfilled by a range of approaches, including, but not limited to: remote sensing devices (RSD), random road-side pull-overs using tailpipe tests and emission control device checks, or road-side pull-overs of vehicles with high RSD readings, as well as through the use of portable analyzers that can be placed on the vehicle prior to on-road driving.

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

Given its non-intrusive nature and potentially high throughput capabilities, RSD warranted further investigation. EPA has conducted a preliminary analysis of RSD (see Appendix J, "Identifying Excess Emitters with a Remote Sensing Device: A Preliminary Analysis") that investigated the comparability of the results obtained to those in the 2500 rpm/Idle test. EPA found that, under controlled conditions and using stringent cutpoints, RSD's performance in measuring CO emissions was comparable to the 2500 rpm/Idle test. Since then, other researchers, such as the California Air Resources Board (CARB), have found that the accuracy of the device for measuring HC emissions, while less accurate than for CO, is within a practical range for roadside monitoring. For example, CARB researchers recently reported to the CARB I/M Review Committee [17] that the device, under highly controlled operating conditions, yielded results that compared to calibrated on-board measurements as follows: The remote sensors accurately measured CO within ± 5% and HC within ± 15% of the instrumented vehicle measurements, respectively. EPA, however, knows of no current RSD methodology for detecting and measuring NO_x emissions, although developmental work is being done in this area. EPA encourages the states to be innovative in fulfilling the on-road testing requirement.

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

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

Denver, where the first RSD testing strategies were developed. The bibliography [18] of research in this area continues to grow.

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

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

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

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

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

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

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

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

9.0 ALTERNATIVE TESTS

9.1 Status of Alternative Exhaust Tests

In 1988, the State of California, Southwest Research Institute, and Sierra Research, Inc. did developmental work on a series of loaded steady-state test modes known as Acceleration Simulation Modes or ASMs. EPA was involved in reviewing the results of the testing that California had undertaken at that time. The testing, based on 18 vehicles, found that two ASM modes - ASM5015 and ASM2525 (the first two digits refer to the load factor while the second two refer to the speed of steady-state operation) - had some potential for identifying vehicles with NO_x problems related to exhaust gas recirculation (EGR) valve malfunctions (which had been induced in the vehicles tested). A Society of Automotive Engineers (SAE) paper (#891120) was issued and the authors found that the tests did poorly on the identification of HC and CO failures. The SAE paper concluded that retention of the idle and two-speed tests would be necessary and that the primary benefit of the ASMs was for NO_x testing.

In early 1992, five low mileage 1992 model year vehicles with induced failures were tested by ARCO using the ASM5015 and the ASM2535. ARCO reported that the ASM5015 test may identify excess NO_x emissions as well as effectively test for evaporative system purge. ARCO suggested an equipment package consisting of a single power absorption curve dynamometer with no inertia simulation capability, a raw exhaust, concentration-type emission analyzer, and a mass flow measuring device. ARCO did not specify a specific flow measuring device and suggested that its testing indicates that mass flow measurement may not be essential since an approximation can be made on the basis of engine size and dynamometer power absorption setting. This equipment may be substantially less expensive than the transient test equipment, which could in turn lead to a more cost-effective program, if the emission reduction benefits of the test were found to be comparable. However, ARCO suggested a more complete test program would be necessary to assess the effectiveness of the procedure and the equipment arrangement ARCO suggests.

CARB has also been testing the ASM5015 and the ASM2525 in a laboratory setting. At the time of the proposal of this rule, EPA expected that data from the CARB effort, along with data from the FTP and other steady-state tests California was conducting in its program, would provide better insight into the effectiveness of the ASM tests. Unfortunately, the data developed by California turned out to be defective in that it was produced using incorrect dynamometer settings and the State has withdrawn the data from the docket as a result.

Environment Canada conducted lab ASM and FTP testing on 40 Canadian vehicles and forwarded the test results to EPA. Only 20 of the 40 vehicles are representative of the U.S. fleet (since 1981) because Canada has had lower standards in effect and recruited vehicles from the older part of the fleet. The results of this testing are discussed below.

Vancouver, British Columbia began pilot testing of the ASM5015 and the ASM2525 along with idle and 2500 rpm modes in its regular I/M lanes early this summer - the first time this has been attempted in an I/M setting. Unfortunately, Vancouver's FTP lab was not in operation in time to do tests on any of the vehicles that were run through the trial program. Nevertheless, the program has forwarded important information that contributes to the discussion of the ASM procedures. British Columbia officials found serious problems with the ASM5015 and the Province decided to drop the mode from its official test procedure. These findings leave serious questions about the viability and practicality of the ASM5015 for actual I/M lane use and are discussed in the next section.

Regardless of less-than-impressive preliminary findings, EPA is pursuing the development of emission reduction credits for the ASM tests and began performing ASM tests in Mesa, Arizona on September 14, 1992 (although data from these tests were unavailable for the analyses in this report). The test procedure being used in Arizona was discussed and agreed to by representatives of ARCO, the Society of Automotive Vehicle Emission Reductions, Inc. (SAVER - represented by Allen Testproducts, Inc.), Sierra Research, and the California BAR. The procedure includes the ASM5015, the ASM2525, a 50-mph steady-state mode, and an idle test. In light of the experience in Vancouver, EPA believes it is likely that a preconditioning mode or immediate opportunity for a second-chance test will be necessary to avoid false failures on this test. EPA's testing program is designed to address this possibility. This testing will also help assess whether the ASM5015 is a practical test mode for an I/M program lane. The test program in Arizona is similar to that used for evaluating the IM240, where vehicles coming to the station for a regular I/M test are also given the test sequence under evaluation and an IM240. Vehicles will be recruited for FTP testing at a contractor lab. EPA also plans to evaluate the performance of the test in ensuring adequate repairs. At this point, sufficient data are not available to determine the emission reduction benefits for this four-mode test.

9.2 Current Analysis of Available Data on ASM Tests

EPA has completed an analysis of the available ASM data, using a database of 31 vehicles. The data were gathered from programs performed by three different organizations: Environment

Canada[19], Sierra Research [20], and ARCO Products [21]. As stated above, EPA started performing ASM tests in Mesa, Arizona on September 14, 1992, but these data were unavailable in time for this analysis. Detailed discussions of this database and EPA's analysis follow in the subsequent subsections of this report.

The small sample, the lack of representativeness, and the fact that these are laboratory data would normally lead EPA to hesitate making any comments until additional information is available. There is intense interest, however, in the ASM tests; so, limited, preliminary findings are included for the sake of this report. As mentioned previously, EPA plans to have a more complete analysis prepared by the end of the calendar year and will be in a position at that time to say something more definitive about the ASM tests. Not only will more EPA data be available, but also data from Vancouver and California.

In brief, the two-mode ASM tests have been found to be considerably less well correlated with the FTP than is the IM240 under controlled laboratory conditions, as evidenced by subjective analyses of the scatter plots (see Appendix M) and objective measurements using the standard error statistic. Testing at real-world I/M lanes will add considerably more variability to both ASM and IM240 tests because of conditions known to affect emissions such as temperature, humidity, and vehicle operating conditions prior to the test. Variability on the ASM or IM240 test will cause a reduction in the quality of the correlation with the FTP test. For the IM240, lane-to-FTP data is available and demonstrates good correlation. The uncontrolled lane variables may add proportionally more variability to a steady-state test like the ASM, but not enough data has been accumulated to confirm this hypothesis. It is possible, however, that the loss in correlation due to increased variability associated with actual I/M testing may be somewhat offset for the ASM by adding two additional modes; a 50 mph steady-state mode at road-load horsepower, and an idle mode. Of course, it is also possible that

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[19] Ballantyne, Vera F. Draft, Steady State Testing Report and Data, Environment Canada, August 28, 1992.

[20] Austin, Thomas C., Sherwood, Larry, Development of Improved Loaded-Mode Test Procedures for Inspection and Maintenance Programs, Sierra Research, Inc. and California Bureau of Automotive Repair, SAE Paper No. 891120, Government/Industry Meeting and Exposition, May 2-4, 1989.

[21] Boekhaus Kenneth L., et al. Evaluation of Enhanced Inspection Techniques on State-of-the-Art Automobiles. ARCO Products Company Report, May 8,1992.

these additional modes may contribute error-of-commission problems of their own. This four-mode ASM procedure is currently being performed by EPA as part of the Mesa, Arizona I/M test program, and EPA looks forward to having a better database in the near future. Once an adequate database is available, emission reduction credits can be assigned and official test procedures established.

Although not part of this analysis (due to a lack of FTP testing capability at the time of the pilot program) the experience of the Vancouver pilot program provides some very telling information regarding the ASM tests. Vancouver, British Columbia began official, mandatory testing in its I/M program on September 1, 1992 after several months of pilot testing its four-mode test in the actual I/M lanes. The Vancouver program was designed to include the ASM5015 and the ASM2525 along with idle and 2500 rpm modes. This pilot program represents the first time ASM tests have been used in an actual I/M program setting. Unfortunately, as previously mentioned, Vancouver's lab was not in operation in time to do FTP tests on any of the vehicles that were run through the trial program.

Problems with the ASM5015 reportedly became apparent during the pilot phase of the Vancouver program and, ultimately, the test was dropped as an official test procedure. Information from Vancouver indicates that the inspection contractor's drivers were having great difficulty maintaining the 15 mph cruise within the ±1.5 mph required for the ASM5015 (intuitively, driving a steady 15 mph against substantial load on a dynamometer with low inertia would be difficult). It was reported that vehicles with small engines produced excessive engine lugging and spark knock. Drivers had difficulty selecting the smoothest-running gear on vehicles with manual transmissions. Vancouver also experienced problems with suspiciously high failure rates on the test. For example, 1992 model year vehicles were failing at rates of 8% according to data supplied by the Province using extremely loose NO_x emission standards. While no FTPs could be done to verify that nothing was wrong with these vehicles, EPA's experience in Hammond, Indiana showed no NO_x failures among 1991 and/or 1992 model year vehicles. It is therefore likely that these were false failures. Vancouver decided to drop the ASM5015 from the test sequence and to add preconditioning for all vehicles.

British Columbia officials also reported that false failures were a problem across the board with the test procedure, probably because all vehicles were not being preconditioned. Vancouver added preconditioning to control the false failure problem. At this point Vancouver is running the ASM2525, along with the 2500 rpm and idle tests, and the FTP lab is now in operation. EPA looks forward to additional information becoming available on this three-mode test procedure. The ASM2525 is very much like the steady-state loaded test that EPA approved for I/M use in 1980.

Like the idle and 2500 rpm tests, EPA believes this test has not been very effective in identifying high-emitters and insuring effective repair. The ASM2525 was also reported in SAE paper #891120 to be less effective at identifying high NO_x cars. So, it may be that the ASM2525 alone (or in combination with the 2500 rpm and idle) will not be sufficient.

9.3 Alternative Purge Tests

Of the potential alternatives to EPA's recommended tests, the one which has garnered the most attention is the suggestion by some that steady-state loaded testing using a simple non-inertial dynamometer (or a dynamometer with some small fixed inertia) can be used to perform the purge check. EPA pursued transient testing instead of steady-state because our best engineering and technical judgement suggested that steady-state testing as a mechanism for conducting the purge check would lead to higher errors-of-commission, and, ironically, higher overall costs per ton of emission reductions produced because each error of commission would lead to extra costs for attempted repairs, retests, and special administrative handling. If false failures are too frequent, emission reductions themselves would be imperiled by adverse public reaction and a skeptical and negligent attitude by inspectors, administrators, and technicians. As expressed in the draft of this report, the rationale behind the assumption that higher errors-of-commission rates would result is the fact that purge strategies vary from vehicle to vehicle, and the possibility of developing a few-mode steady-state test that successfully addresses this variety by catching each car in one of its purging conditions is small to none. New analysis of test data supports this rationale.

Figure L-1 in Appendix L depicts instantaneous purge data during the IM240 from the vehicles described in Table 9-1. All vehicles passed the purge test. By comparing the top trace in the figure, which represent vehicle speed during the IM240, to the instantaneous purge rates, it is clear that different vehicle purge systems respond differently to the same operating mode. Test vehicles 238 and 393 behave somewhat similarly in that the purge is generally initiated during accelerations, and is generally maintained during the reasonably steady-state portions of the IM240 (i.e., between 60 seconds and witness line #3, and between 140 seconds and witness line #5). Vehicles represented by these tests would would be expected to pass a steady-state purge test rather easily. However, it is clear that the calibration of the design in test vehicle 238 uses almost double the purge flow rate of the design in test vehicle 393.

In contrast to test vehicles 238 and 393, test vehicle 354 shows a greater degree of purge sensitivity to speed changes, and turns off or reduces purge flow under some conditions to a greater extent than test vehicles 238 or 393. Test vehicle 118 appears to be extremely sensitive to acceleration, and seems to act almost in an on-or-off mode. It is particularly important to note that during steady-state operation from about 70 seconds to witness line #3, the purge flow in test vehicle 118 drops to very low levels. Similar performance is also noted between 140 and 165 seconds for this test. Whereas a vehicle with a purge design similar to test vehicle 354 would likely pass a steady-state test, it would be more difficult to make such a judgement on vehicles with a purge design similar to test vehicle 118 - particularly if the calibration of the design operating like test vehicle 118 used a lower flow rate during steady-state operation.

Table 9-1

Purge Vehicle Descriptions

Test Veh. #	Mod Yr	Make	Model	Purge Vol (l)
118	'87	Nissan	Sentra	56.2
236	'88	Ford	Taurus	7.1
238	'86	Chev	Sprint	178.0
354	'91	Plym	Acclaim	43.7
393	'87	Mits	Tredia	25.4
427	'88	Linc	Cont'l	18.4

The most marked difference in purge design is apparent in test vehicles 236 and 427. Neither test vehicle exhibits any significant flow until well after 150 seconds. Prior to 150 seconds, test vehicle 236 exhibits a series of spikes with extremely low flow typically at the end of an acceleration, and the purge system appears to respond to the slight variations in speed during the steady-state portions, but again with extremely low flow. In the case of test vehicle 427, a purge delay or warm-up timer might be assumed to be the cause for the delay of significant purge flow. However, this car shows practically zero purge flow in the steady-state section between 140 to 165 seconds after some purge flow is evident earlier. Even more telling is the fact that the engine size, engine family, and evaporative family is the same between test vehicles 236 and 427. The only difference is that the evaporative systems have different calibrations.

The difference in these calibrations is highlighted in Figure L-2 in Appendix L. Whereas Figure L-1 represented instantaneous purge flow, Figure L-2 shows the accumulation of the instantaneous rates over time. For test vehicle 236 all of the little spikes add up so that the vehicle exceeds the one liter cutpoint by about 70 seconds, and the total flow accumulated is around 7 liters. On the other hand, test vehicle 427 does not exceed the cutpoint until around 140 seconds, and accumulates over 18 liters. Recognizing that these cars were certified to a cycle similar to the IM240, it is clear that the calibration engineer made conscious trade-offs between timing of the flow and accumulated volume over the cycle to meet the new certification standard. Further, as an indication of different design philosophies, a vehicle with only a marginal increase in accumulated flow (test vehicle 393 in Figure L-2) over test vehicle 427 exceeds the purge cutpoint in about 15 seconds on the IM240. Although vehicles that require extended time to begin purging may represent a measurable portion of the fleet (i.e., both samples were Ford Motor Company vehicles), most of the vehicles purge fairly quickly (i.e., in the first 30 seconds) on the first acceleration of the IM240, and therefore, extended purge vehicles should not significantly affect average IM240 test time when employing fast purge algorithms.

Clearly, purge strategies vary substantially among existing vehicles. The degree of difference among existing designs is such that no one steady-state test could avoid falsely failing some vehicles. It might be possible to add an acceleration mode to a steady-state test, but to insure proper test consistency, the base inertia of all dynamometers used throughout the country would need to be exactly the same, and a prescribed acceleration profile would need to be maintained (probably with a video monitor). Adding these two quality control features would increase the cost of the steady-state purge dynamometer, making it comparable to the IM240 dynamometer. In addition, the acceleration test on the steady-state dynamometer would lengthen the average test time. In any event, no data is available on any specific steady-state acceleration test that would allow an informed judgement to be made.

Since EPA does not dictate design strategy, and because new vehicles will be required to meet additional evaporative requirements for certification, EPA cannot predict the purge strategies that might be used by vehicle manufacturers in the future. The result of failing to address the full range of current and future purge strategies in an I/M program is easy to predict: Cars that should pass will fail, leading to unnecessary expense and hardship for motorists, with no environmental benefit. Clearly, using the IM240 - which is similar to the new car certification test - is a prudent and conservative way to avoid incorrectly failing cars that should pass. Given the lack of hard test data on other possible approaches, EPA has no choice but to proceed with the IM240 purge test as proposed for the purposes of establishing the enhanced I/M performance standard.

Another purge test alternative has been proposed which calls for a variation not on the test cycle, but on the test procedure itself. In EPA's proposed purge test, a flow meter is inserted into the evaporative purge line between the canister and the engine. Some have proposed use of an alternative, tracer gas technique. This alternative purge test strategy uses the concentration of the tracer gas measured at some point down-stream, and the known quantity supplied upstream to determine the dilution of the injected gas. From the dilution of the known quantity, the flow can be determined.

In this proposed alternative procedure, the known quantity of tracer gas (helium) would be introduced into the gas tank through the gasoline filler neck. The down-stream measurement would take place in the exhaust stream after it enters the CVS. Although this technique is intriguing and elegant, there are several issues that need to be considered. First, what is the detectable limit of the tracer gas detector? Depending on the particular purge system, after the tracer gas leaves the gas tank it has the opportunity to be diluted to an unknown extent by the atmospheric vent in the canister. During canister purging, the tracer gas is again diluted by the engine intake air. If the car has a secondary air system, the tracer gas gets diluted in the exhaust system. And finally, the entire exhaust is diluted upon entering the CVS. In each of these dilution steps the degree of dilution will depend on the calibration of the entire emission control system. As shown in Figure L-1, purge strategies can vary significantly.

Given the multiple dilutions that occur, making a measurement of purge volume comparable to the standard procedure (e.g., 1 liter ±100%) would seem to be difficult. Among other things, the accuracy of the amount of tracer gas injected would need to be very precise. Some have suggested that any detection of the tracer gas in the exhaust should be sufficient to indicate purge flow. At this point, EPA has no data to support this contention. In either case, however, the detectable limit would need to be set sufficiently low to avoid falsely failing vehicles with low purge flow designs, such as test vehicle 236 in Figure L-2. It should also be pointed out that under a tracer gas scenario, multiple dilutions could increase the amount of time necessary to determine fast pass for purge.

On the vehicle side, consideration needs to be given to the amount of inert tracer gas introduced into the gas tank. Normally, there is a mixture of fuel and air in the gas tank, and a fuel mixture or just air in the canister. The engine management system is designed to handle both. However, if the inert tracer gas displaces a significant quantity of mixture or air, the inert tracer gas behaves as additional EGR, thus altering the engine operation. As a result, tracer gas purge testing may have to be performed separately from exhaust emission analysis for HC, CO, and NO_x, further lengthening the overall test time.

The final consideration is background levels of tracer gas in the test facility. Normally, background levels of helium are very low. But, with the multiple dilutions in the system, measurement levels may approach background levels, particularly if the test itself contributes to the background. This could occur after the tracer gas is introduced into the system and the gas cap is re-sealed, if during the driving cycle, the pressure in the fuel tank increases (because of temperature increases), and the purge valve shuts off (see Figure L-1). In this case, the fuel-air mixture in the fuel tank would flow to the canister, where the fuel would be retained, and the air, including the tracer gas, would exit the atmospheric vent in the canister. Air flow from the cooling fan would likely carry the tracer gas under the vehicle, and into the mixing funnel for the CVS. In fact, there could be less dilution from the canister vent to the CVS, than in the path through the engine. In this scenario, the potential for passing a car with a completely inoperative purge valve seems high.

Two similar alternatives have been suggested for the pressure test. The pressure test as proposed involves locating the fuel tank vent line at the canister, disconnecting it, and pressurizing the fuel tank though the vent line. After pressurization, the amount of leakage is determined by monitoring the pressure drop over two minutes. If the pressure drop is less than allowed, the system passes. Given the intrusive nature of the test procedure, commenters have expressed concerns about the ability of an inspector to find the canister, whether there is physical access to the canister, and potential damage that could occur during removal and re-attachment of the vent line.

Both alternatives to EPA's proposed pressure test involve pressurizing the gas tank through the filler neck with a special adapter. In one case, the helium used for an alternative purge check would also be used for the pressure check, and a probe would sniff for helium around and under the car. A concern with this alternative is that the degree of leakage is not quantifiable. Additionally, the helium molecule is much smaller than diatomic nitrogen (N_2). Therefore, the size of the leak detected by the helium would be significantly smaller than than that detected by N_2. The fact that this alternative would not provide a quantifiable measure of the leak could lead to the improper identification of inconsequential leaks (i.e., false failures). Furthermore, this procedure appears to require an operator to manually probe around the cars to detect leaks, thus reintroducing the potential for human error in the test results and violating the Clean Air Act's requirement that testing procedures be computerized.

Another proposed alternative to EPA's pressure test procedure also uses the filler neck as the avenue for pressurizing the evaporative system. However, this alternative uses diatomic nitrogen, and monitors the pressure drop over the specified time interval. This system has some apparent advantages, but upon closer inspection, they are illusory. The first apparent advantage is that by pressurizing the system through the filler neck, the inspector does not need to locate the canister. This is not true. To be able to pressurize the system with this alternative the canister must be located, and the vent line plugged or pinched-off. If the line is plugged, the vent line had to be removed, and so the system could just as easily be pressurized from the vent line. If the line is to be pinched-off, there are several considerations. Typically, vise-grip ® type pliers would be used. If the canister is difficult to get to in the first place, there may also be a problem in having sufficient clearance-room to actuate the handles of the pliers. Secondly, if the pliers do not completely close-off the vent line, this could result in a false failure. In addition, some systems use plastic lines with rubber nipples at the ends (i.e., at the tank and at the canister). Attempting to pinch a plastic line could easily crack it, and because plastic lines are generally not easily deformable, the seal would be questionable. Furthermore, the outcome of the test is more subject to operator influence (i.e., how good is the seal) than is EPA's proposed test procedure.

Another issue to consider is that each lane will need to maintain a series of filler neck adaptors to accommodate various cars. Some have suggested that only 6 adaptors may be needed. However, the inspector will still need to make a judgement in selecting the proper adaptor for each car.

Finally, there is the question of the interface between the gas cap seal and the vehicle's filler neck. On older cars, particularly in northern climates, the filler neck can become corroded leaving a rough sealing surface. If the seal in the mating gas cap is also weathered and non-compliant, a leak in the system can occur (leaks around the gas cap are a common cause for pressure test failures). Such a leak would not likely be detected when testing the components separately with special adaptors. On the filler neck side, the adaptor would generally have a new compliant seal that could conform to the corrosion pits in the filler neck. And on the gas cap side, the non-compliant seal would more likely seal on a smooth adaptor surface.

Of all of the alternatives to the evaporative tests proposed by EPA (i.e., the steady-state loaded-mode purge test, and the tracer gas purge and pressure tests), the only one which appears to warrant more study is the pressure test which uses diatomic nitrogen introduced through the filler neck. Nevertheless, EPA is open to demonstrations by states or their representatives that proposed alternative testing strategies are equal or superior to EPA's proposed tests in terms of identifying excess emissions and keeping false failures to a minimum.

9.4 Alternative NO_x Testing

Section 182(c)(3) of the Act requires that programs in enhanced I/M areas achieve NO_x reductions. EPA has found that NO_x emission testing (as opposed to visual inspection of emission control devices) is essential for NO_x emission reductions.

Some have suggested that a heavier loaded, steady-state test (i.e., one using a heavier load than the EPA-approved steady-state loaded test currently being used in Arizona) is an adequate alternative to transient emission testing for NO_x. In particular, ARCO and others have proposed that an ASM test be allowed in lieu of the IM240 exhaust test. As noted previously, the ASM concept was first publicized in SAE paper #891120, by Austin and Sherwood, and was intended primarily as a method to improve the effectiveness of no-load I/M procedures by providing a method for measuring NO_x. Also as previously noted, in 1992, the Province of British Columbia began a pilot program utilizing the ASM test prior to official implementation of an I/M program in Vancouver for HC, CO, and NO_x.

As it has currently evolved, the ASM concept involves operating a car at lower vehicle speeds (15 or 25 mph) while loading the vehicle at a fraction of the inertia load needed to accelerate the vehicle at 3.3 mph/sec^2 plus the windage load at the test speed. The 3.3 mph/sec^2 acceleration is the maximum acceleration that occurs on the transient test used to certify new cars. The ASM modes are designated by the fraction of the load and by the test speed (i.e., ASM5015 represents 50% of the inertia load for a 3.3 mph/sec^2 acceleration at 15 mph). The SAE paper by Austin and Sherwood concluded that the current 2500 rpm/Idle test was better than the ASM test in identifying HC and CO emitters, and that the only benefit of the ASM test was for NO_x. Subsequent data and comments provided to the EPA support this earlier conclusion.

An issue with the ASM proposal arises from the requirement under Section 182(c)(3) of the Act that programs in enhanced I/M areas must achieve NO_x benefits. A question EPA must evaluate is whether the ASM adequately identifies high NO_x emitters to the extent that NO_x benefits can be quantified, and whether the ASM falsely fails low NO_x emitters.

It is claimed that the ASM more heavily loads the vehicle than other steady-state tests, and that this heavier loading results in the ability to test for NO_x. The load for the ASM test is determined by dividing the inertia weight of the vehicle by a constant. A separate constant is used for each of the two ASM modes proposed (i.e., the ASM5015 and the ASM2525). Figure L-3 and Figure L-4 show the relationship of load versus speed for the ASM, the EPA steady-state loaded test, and the IM240 for a 2,200 pound vehicle and a 3,000 pound vehicle. For a 2,200 pound vehicle, which would likely have a 3 or 4 cylinder engine, the ASM5015 clearly would load the vehicle more than the EPA steady-state loaded test, and would require the vehicle to meet the load at a lower speed. The ASM2525 would also load the vehicle somewhat higher, but at the same speed. It is also clearly evident that the IM240 loads the vehicle much greater than either the ASM or EPA's steady-state loaded test.

For a 3,000 pound vehicle (Figure L-4) which will likely have a 6 to 8 cylinder engine, the ASM5015 load is only marginally higher than the upper limit for the EPA steady-state loaded test, and the ASM2525 is effectively the same as the Arizona load. As with the 2,200 pound car, the IM240 loads the vehicle significantly greater than either the ASM or the EPA steady-state loaded test.

The load imposed on a vehicle is not the only factor in its NO_x production; also important are the rates at which the load and speed change, and the NO_x control strategy used for the vehicle. The instantaneous second-by-second NO_x emission (gpm) data in Figure L-5 helps identify which operations in the IM240 cycle produce NO_x. Clearly, all of the vehicles described in Table 9-2 produce NO_x during acceleration. However, it is equally clear that under steady-state conditions similar to those encountered in the ASM (i.e., segments 1 and 2), NO_x is particularly low. In nearly all cases the average NO_x over these steady-state portions is below a cutpoint of 2 gpm.

It should be noted that the time interval for segments is around 10 to 15 seconds (which might be a typical measurement window for an ASM test) after the emissions from vehicle have stabilized at the specified test speed.

Table 9-2

NOx Vehicle Description*

Test #	Model Yr.	Make	Model	HC (gpm)	CO (gpm)	NOx (gpm)
238	'86	Chev	Sprint	1.07	32.90	0.87
343	'86	Ford	Escort	0.13	0.50	4.55
393	'87	Mits	Tredia	0.37	1.90	2.93
435	'86	Honda	Accord	0.76	9.00	2.93
461	'88	Pont	Grd Am	0.16	4.10	1.64

*All gpm numbers are IM240 measurements

In reviewing the NO_x performance of the vehicle represented by test 393 in segment 1 and 2, it is difficult to distinguish test 393 from tests 238 or 461. In fact, the accumulated NO_x over segment 1 for tests 238 and 461 clearly exceeds that in test 393. It is less clear when making this comparison in segment 2. However, the important point is that while test 393 produced nearly 3 gpm of NO_x over the IM240 cycle, both tests 238 and 461 were well below the 2 gpm cutpoint for the IM240 (the NO_x measured for test 238 was 0.87 gpm; for test 461, 1.64 gpm). In reconciling the differences between test 393 and the two passing tests in IM240 NO_x emissions, it is obvious that heavy accelerations were the major cause for the differences.

Another interesting comparison is that while the complete IM240 produced over 4.5 gpm NO_x in test 343, the NO_x performance in segments 1 and 2 would suggest that a steady-state test would result in only around 2 gpm, or less than half the NO_x produced during a full transient test. Here again, the heavy accelerations contributed the most NO_x in this test.

The fact that accelerations contribute the most to NO_x production should not come as a surprise. Granted, accelerations require that the engine put out more power than a steady cruise. However, the response of the feedback control system and its sensors can also have a significant effect. For instance, a slow oxygen sensor that has recognized a deceleration with a resulting deceleration lean-out, might not immediately recognize a following acceleration, resulting in a lean condition at the start of the acceleration and higher-than-normal NO_x emissions. Such a condition would not be identified by a steady-state test like the ASM, because the vehicle would be operated at one speed long enough for the sensor to catch-up, which would not be the case in real-world driving. In other cases, the duration of the ASM steady-state test would generally be sufficiently long for the feedback feature in the emission control module (ECM) to "learn" how to be clean. On the mechanical side, a partially plugged EGR passage could allow sufficient flow at the lower speeds of the ASM to pass the ASM cutpoint, but restrict the EGR flow necessary for the heavy acceleration at about second 160 in the IM240.

Based on the evidence, it appears that it would be unlikely that a steady-state test can fully characterize the NO_x performance of in-use vehicles. Therefore, it would be difficult for EPA to quantify the NO_x reductions from such tests without additional data.

Another issue that needs investigation is the possibility of errors of commission resulting from use of the ASM test. The standards for the ASM5015 proposed in the SAE paper by Austin and Sherwood were concentration-based standards, and were based on a 2% error-of-commission rate relative to the FTP. The concentration value (in ppm) of the standard was determined by dividing the inertia weight of the vehicle into the constant, $753x(10)^3$. In developing this equation, data from fifteen 1982 and later closed loop cars, along with 3 mid- to late-1970s open loop vehicles were used. Using this equation would result in a concentration standard of 228 ppm for a 3,000 pound vehicle (3,000 pounds curb weight plus 300 pounds).

When the Vancouver ASM study program began, constants of $3100x(10)^3$ and $2650x(10)^3$ were used for the ASM5015 and ASM2525, respectively. These new equations resulted in concentration standards of 939 ppm and 803 ppm. These concentrations represent more than a four-fold increase over the original proposal. However, after testing more than 7,000 vehicles, the program office determined that even these standards, when combined with other failure modes (e.g., HC and CO) would result in an unacceptable overall failure rate - particularly since the program office did not have its FTP lab operational, and could not confirm the NO_x failures. Therefore, prior to implementing the official I/M program on September 1, 1992, the program office revised the

NO_x standards, effectively setting a NO_x cutpoint of 1000 ppm as the minimum standard for three-way catalyst equipped feed-back cars. Using the 1000 ppm NO_x standard, and the equation presented in the SAE paper for estimating ASM concentration in gpm would result in a NO_x level of 9.55 gpm for a 3,000 pound vehicle. Even considering that the SAE conversion equation possibly overestimates NO_x mass emissions, the Vancouver NO_x benefits are likely to be small with a 1000 ppm cutpoint.

In addition to revising the standards, the program office in Vancouver dropped the ASM5015, and only retained the ASM2525. There were a variety of reasons for dropping the ASM5015. Analyses of the Vancouver vehicles indicated little difference in NO_x failure rates between the ASM5015 and the ASM2525. This observation is contrary to the observation by Austin and Sherwood that the ASM5015 was clearly superior to other ASM modes in finding high NO_x emitters. A 1992 report by Boekhaus, Sullivan, and Gang of ARCO also reached a similar conclusion. Quite possibly the high concentration standards used in the Vancouver program account for the difference. Austin and Sherwood used NO_x concentration standards in the 200 ppm range, while ACRO used a NO_x standard of 0.7 gpm.

However, even at the high standards used during the study period (800 to 900 ppm), the Vancouver program office reported that 9 of 112 (or 8%) of 1992 model year cars tested during the study failed for NO_x. Anecdotal information on calls from the public and new car dealers to the program office commenting that nothing was apparently wrong with a relatively new vehicle which failed NO_x, suggests that some of the late model NO_x failures could be false failures. Even one of the cars tested by ARCO, a 1992 Chevrolet (on an ASM2535 mode), would have been a false failure, and would have failed the 1000 ppm Vancouver standard, even though that car registered only 1.75 gpm on the IM240 (1.5 gpm on the FTP). The program office suggested that a possible cause for the late model failures could have been due to extended idling or engine shut-down in the test lanes. However, while a similar situation existed in the IM240 lane (and at a 2 gpm IM240 standard) no recorded NO_x failures for 1991 or 1992 model year cars have been observed at this point in time.

In addition to the recorded late model NO_x failures in the Vancouver study, the program office indicated that it was sometimes difficult to stay within the ±1.5 mph window at 15 mph with the ASM5015 load, although this is the same tolerance that is used in the Arizona I/M program at higher vehicle speeds. Also, in some cases, vehicles with small engines produced excessive engine lugging and spark knock which could disturb the public - particularly if the inspector selected an incorrect gear for testing with manual transmissions. Because of the suspected vehicle cool down in the lane, the potential lugging and pinging problem, and anecdotal evidence that simply replicating the first ASM mode (which happened to be the ASM5015) improved the chances of passing, the Vancouver program office elected to substitute a preconditioning mode for the ASM5015 test mode.

The second-by-second NO_x traces in Figure L-5 clearly show that the majority of the NO_x is produced during acceleration, and that NO_x levels can be fairly low under steady-state conditions for even dirty cars. Under such conditions it appears that it would be difficult to discriminate between dirty NO_x cars and clean ones. This perceived difficulty in discrimination is likely at the heart of the problems encountered in the Vancouver program. The evidence of false ASM NO_x failures in the ARCO data (when realistic cutpoints are applied) simply serves to confirm this hypothesis.

Based on this evidence, it appears unlikely that a steady-state test can fully characterize the NO_x performance of in-use vehicles, and it would be inappropriate for EPA to consider substituting the ASM for the IM240 at this time. Nevertheless, as indicated earlier, EPA is open to demonstrations by states or their representatives that proposed alternative testing strategies are equal or superior to EPA's proposed tests in terms of identifying excess emissions and keeping false failures to a minimum.

9.5 Repair Grade IM240 Testing

The argument has been made that high-tech testing will have limited success due to the fact that I/M programs will still need to ensure successful repairs to net the emission reduction benefits of the program. One complaint is that by separating testing and repair, and introducing a costly test procedure, EPA is making it impossible for repair facilities to confirm the effectiveness of their repairs, and, in effect, is requiring the repair industry to perform repairs in the dark. One rationale for trying to develop cheaper alternative tests is, in fact, to fill this diagnostic and confirmatory testing niche.

In response to this clear need, EPA is developing an inexpensive repair-grade IM240 emission measurement system. This repair-grade system is primarily designed to aid the service and repair industry in verifying repair of vehicles which have failed an official IM240 emission test. This equipment is designed to provide an approximate measurement of IM240 mass emissions levels. By measuring the vehicle's emissions before and after vehicle repairs, the mechanic can determine the direction and approximate magnitude of any changes in mass emission levels.

The current direction of the repair-grade system is based on a chassis dynamometer with inertia weights, an exhaust dilution system, a BAR90 analyzer, and an appropriate computer and software. The dynamometer will have a fixed inertia weight of 2,500 pounds with additional dynamic inertia provided by the power absorber (if available, a function of speed and absorber type). Because of installation concerns, only electric power absorbers will be evaluated. Two exhaust dilution systems are being evaluated as part of this diagnostic system. The first emission dilution system uses a 100 standard cubic feet per minute (SCFM) critical flow venturi for a flow controller and the configuration of the system is similar to a laboratory type unit. The second emission dilution system uses a squirrel cage type blower and low velocity air flow in order to reduce power requirements. The trade-off of the second system is that while the air flow would not be strictly constant, it would be assumed to be constant for calculation purposes, with some error resulting. The estimated costs for the individual components of this equipment system are listed in Table 9-3.

Table 9-3

Estimated Costs for Repair-Grade IM240 Emission System

ITEM	New Equipment	Retrofit
Dynamometer	$14,000.00	$14,000.00
386-based BAR90 w/ extras	$15,000.00	$3,000.00
CVS Venturi	$1,800.00	$1,800.00
CVS Blower and Motor	$2,000.00	$2,000.00
Squirrel Cage Type Blower	$500.00	$500.00
Tubing for dilution system	$600.00	$600.00
Total with CVS:	$33,400.00	$21,400.00
Total w/ Squirrel Cage Type Blower:	$30,100.00	$18,100.00

Emission analysis of the diluted sample is performed by either a BAR84 or BAR90 emission analyzer. The emission analyzer, which operates with either of the above dilution systems, samples and analyzes the diluted flow and transmits the information to the computer. For the CVS system, the computer calculates the instantaneous and average emission values, using the flow conditions, which are then stored in a file for later use. At a minimum, an 80386-based IBM-compatible computer is required to perform the computational and control functions for the equipment system. The squirrel cage system would not require instantaneous flow measurements to be calculated, but would still require emission measurement computations during the test cycle.

The dollar figures in Table 9-3 are based on start-up numbers; mass production of these items is expected to significantly lower costs. For example, the individual cost of a dynamometer in a very large order, or for a market known to be very large, might be below $10,000. The BAR90 estimates are slightly higher than current street prices, but the high estimate is expected to cover the additional cost of special programs and driver cards for integrating the sample, computing the CVS flow, interfacing with the dynamometer, and providing a drivers' aid. The cost to retrofit a BAR90 unit, if a service facility already has one in use, should be only about $3,000.00 (a savings of approximately $12,000.00 on the estimated new equipment price) Other costs (for example, the cost quoted for a squirrel cage blower) are based on our purchase costs or prices obtained from supply catalogs such as W.W. Granger. Because BAR grade analyzers currently measure only HC and CO, a NO_x channel will need to be added. Currently, a fuel-cell type NO_x analyzer would add between $2K and $6K to the system ($2200 for ESP, and $5900 for Allen), although this cost range is not reflected in the above estimates.

Because of the interest in the ASM test, a comparison of repair-grade equipment costs based on the two tests has been developed. In determining the price difference between equipment for IM240 repairs and ASM repairs, it is assumed that the ASM equipment will include the same analyzer as in the IM240 set-up (i.e., a BAR90 with NOx capabilities) and a dynamometer, but would not include a CVS unit. The lack of a CVS unit would save between $1,100 and $4,400. The dynamometer would be somewhat simpler than the IM240 which would have a base inertia of 2,000 pounds. Compensating for the lower base inertia in the ASM dynamometer might save $1,000. Additionally, the ASM equipment would not require as extensive a software upgrade in the BAR90 as the IM240 equipment, but would still require significant upgrades. The software savings may only be around $1,000.

Compiling the numbers (using the values in Table 9-3), the estimated price to upgrade an existing BAR90 for repair-grade analysis with NOx is between $20.3K and $27.3K. Subtracting the savings in the previous paragraph for ASM would result in a range of estimates for the ASM repair equipment between $17.2K and $20.9K. Thus, the reduction in price to upgrade BAR90 repair equipment for ASM as opposed to IM240 could be as low as $3,100 or a high as $6,400.

If a BAR 90 analyzer were not available for upgrading, adding a BAR90 unit would increase the price about $12K, but the increased price would apply equally to IM240 and ASM repair-grade equipment. Adding a BAR90 analyzer to the ASM upgrade price estimate would result in a price range of $29,200 to $32,900. This range compares favorably with the price of around $30,000 for a BAR90 (w/o NOx) with a dynamometer (somewhat comparable to that which would be expected in ASM repair-grade equipment) that is currently marketed in limited quantity in Florida.

Appendix A	Evaporative Emissions and Running Loss Emission Factor Derivation
Appendix B	Purge and Pressure Test Effectiveness Figures and Spreadsheet
Appendix C	Exhaust Short Test Accuracy: IM240 vs. Second-chance 2500 rpm/Idle Test
Appendix D	MOBILE4.1 Technology Distribution and Emission Group Rates and Emission Levels
Appendix E	Regression Analyses and Scatter Plots for Fuel Injected 1983 and Later Vehicles
Appendix F	IM240 Cutpoint Tabel Analysis
Appendix G	Evaporative System Purge and Pressure Diagrams
Appendix H	Evaporative System Failures and Repairs
Appendix I	MOBILE4.1 Performance Standard Analyses, By Option
Appendix J	Identifying Excess Emitters with a Remote Sensing Device: A Preliminary Analysis
Appendix K	Model Year Failure Rates by Test Type
Appendix L	Comparative Purge Flow Data