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Evaluation of a Four-Mode Steady-State Test With Acceleration Simulation Modes As An Alternative Inspection and Maintenance Test for Enhanced I/M Programs

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1. Executive Summary

1.1 Purpose

On November 5, 1992, the U.S. Environmental Protection Agency (EPA) promulgated a regulation[1] for state-operated enhanced Inspection and Maintenance (I/M) programs. This regulation established the IM240[2] as the benchmark I/M test, against which any alternative test must be found equivalent, or nearly so but with compensating improvements in other program aspects.

EPA performed tests on over 1500 vehicles in Mesa, Arizona to evaluate a four-mode, steady-state procedure utilizing two Acceleration Simulation Modes[3]. (This four-mode test procedure will herein be referred to as the "ASM" test, although only the first two modes are strictly ASM modes.) This evaluation was designed for determining whether the ASM is a suitable alternative to the IM240 for enhanced I/M testing.

The ASM test utilizes equipment costing about half of the anticipated cost of the equipment required for IM240 testing. This equipment is less expensive because the ASM does not involve transient driving and the equipment only approximates mass emissions via pollutant concentration measurements. In contrast, the IM240 is a transient test requiring more expensive equipment measuring true mass emissions during typical driving.

The purpose of this document is to provide:

- EPA's evaluation regarding the effectiveness of the ASM test;
- a description of the analysis techniques EPA used;
- the data used in the evaluation; and

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[1] Inspection/Maintenance Program Requirements; Final Rule 40 CFR Part 51, Federal Register, November 5,1992

[2] William M. Pidgeon, and Natalie Dobie, "The IM240 Transient I/M Dynamometer Driving Schedule and The Composite I/M Test Procedure," EPA-AA-TSS-91-1, January 1991

[3] Thomas C. Austin and Larry Sherwood, "Development of Improved Loaded-Mode Test Procedures for Inspection and Maintenance Programs," Sierra Research, Inc. and California Bureau of Automotive Repair, SAE Technical Paper No. 891120, May 1989.

- a description of the test program.

This is the only ASM study conducted in an official I/M station. The vehicles were randomly selected and tested under the widely varying ambient conditions and preconditioning that normally attend official I/M tests. Many more cars were tested than in any other ASM study. Also, this is the only study to use one sample to develop the ASM mode weighting factors and an independent sample to evaluate their effectiveness. EPA strongly believes that this study should be given far more weight than all previous ASM studies.

1.2 Findings

EPA's findings are based on performance comparisons between the ASM and the IM240 regarding five important considerations:

- their relative ability to fail malfunctioning vehicles (needing exhaust emission control system repairs) and to avoid failing properly functioning vehicles;
- their relative ability to distinguish repaired vehicles (exhaust-repairs) that are sufficiently repaired from those that are insufficiently repaired;
- their relative ability to distinguish between functioning and malfunctioning evaporative canister purge systems;
- their relative costs; and
- the adequacy of the ASM for Enhanced I/M Programs using MOBILE5a.

1.2.1 Ability to Correctly Identify Vehicles Needing Repair

EPA commonly uses the rate of excess emissions identified during an I/M test to objectively and quantitatively compare I/M test procedures. 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 g/mi HC standard whose FTP result was 2.00 g/mi, would have excess emissions equalling 1.59 g/mi HC (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. The more excess emissions an I/M test identifies, the better the test.

EPA uses IDR instead of merely comparing the number of vehicles that correctly fail and correctly pass. The IDR better contrasts the relative merits of competing I/M test procedures because failing vehicles with high emissions is more important than failing those that are only slightly above their certification standards. For example, take two I/M procedures that correctly failed 100 of the 500 vehicles that had FTP emissions greater than their certification standards, but only 50 cars failed both tests. If the fifty cars that failed Test A were high FTP emitters, and the other 50 cars that failed Test B had FTP emissions only slightly above their standards, obviously Test A would be preferred, and its IDR would reflect its better performance. Test A's better performance is not evident in comparing the number of vehicles that correctly fail.

The ASM does not find high emitting vehicles as well as the IM240. Some high emitters which could be caught with the IM240 give low ASM scores. Table 1.2.1 shows the percent decrease in the excess emissions identification rate that would accompany substituting the ASM for the IM240. For example, an IM240-based I/M program's HC and NOx IDRs will suffer nearly a 20% decrease by substituting the ASM test at the same failure rate (18%) that is produced by EPA's recommended cutpoints for biennial I/M programs.

Table 1.2.1 Loss in Identification Effectiveness With ASM Test

Scenario	HC	CO	NOx
Failure Rate Held at 18% (0.8/15/2.0 + 0.50/12.0 IM240 Cutpoints)	19.0%	9.5%	18.5%
Best IDRs with Ecs Held Below 5%	14.0%	14.3%	17.5%

These values are % differences. For example: $\frac{(92.2-74.7)}{92.2} * 100 = 19.0\%$

Source: Table 5.3.1, Section 5.3

An aggressive I/M program, tolerating both higher failure rates and higher false-failure rates would relinquish about 15% of its inspection effectiveness by substituting the ASM test.

Additional related findings are listed below:

- The ASM fails cars that are actually clean more often than the IM240. About 1 in 10 cars failed by the ASM did not appear to need repair, compared to about 1 in 30 for the IM240. EPA knows from other testing that more preconditioning can eliminate IM240 errors; we are not sure whether it can for ASM failures.

- Making ASM cutpoints more stringent in an attempt to get the same effectiveness as the IM240 increases the failure rate and/or the error rate beyond what EPA believes any I/M program would want or is willing to commit to in binding regulation form.

The comparative ability to identify vehicles needing repair is fully discussed in Section 5.3. Why IDRs and associated criteria are important, how the criteria are derived, and the tradeoffs associated with increasing cutpoint stringency to increase IDRs are discussed in Section 5.2.

1.2.2 Ability to Distinguish Sufficiently Repaired Vehicles From Insufficiently Repaired Vehicles

Vehicles that do fail the ASM test and get repaired, can pass ASM cutpoints with repairs that are not as effective as the repairs needed to pass IM240 cutpoints, even when repaired in good faith. Also, the ASM modes are prone to "adjust to pass/readjust after" strategies like the idle and 2500/idle tests.

Several of the 17 cars which failed the Arizona test and the ASM were repaired in local shops, after which they passed the Arizona and ASM test but still had high IM240 emissions. This is the same pattern seen in 2500/idle I/M programs. Repair analyses are discussed in Section 5.6.

1.2.3 Ability to Distinguish Between Functioning and Malfunctioning Evaporative Canister Purge Systems

In purge testing, the ASM and the IM240 should do equally well in identifying malfunctioning purge systems, so their comparative ability to fail vehicles with malfunctioning purge systems has not been an issue. Therefore, the research issue has been whether, and how many properly functioning vehicles would fail. That is, EPA is more concerned with errors-of-commission than with errors-of-omission. About 4-6% of the vehicles failed the ASM evaporative canister purge system test but were actually properly functioning. This is about 38% to 52% of all cars that failed the ASM purge.

About 1% of the vehicles failed the IM240 purge system test, but were actually properly functioning. This is about 12% to 18% of all cars that failed the IM240 purge.

Unlike transient IM240 testing, which requires vehicles to operate through a wide range of speeds and loads, the four steady-state modes of the ASM do not provide a purge opportunity for a significant portion of the fleet. The purge system test results are discussed in Section 5.7.

1.2.4 Test Costs

The 180 seconds required for this four-mode ASM test is the same as would be needed for the IM240 if special algorithms are used to pass obviously clean cars and fail obviously dirty cars early in the cycle. So, the ASM does not save test time or reduce the number of lanes required. A shorter test based on fewer than four modes would have even less benefit.

The only cost advantage for this ASM test is that up to about half the equipment cost can be avoided by not having variable inertia capability in the dynamometer and low-concentration measurement capability in the gas analysis instruments. This savings works out to about 75 cents per test in a centralized program. Test costs are discussed in Section 7.

1.2.5 Adequacy of the ASM for Enhanced I/M Programs

The MOBILE5a analysis results show that even in a maximum annual program, covering all weight classes, with ASM, purge, and pressure testing of all model years and comprehensive anti-tampering inspections, the ASM test yields insufficient benefits to meet the performance standard for HC, CO, or NOx.

2. Background

EPA began development of a transient I/M test procedure, named the IM240, during 1989. EPA published a Notice of Proposed Rulemaking on July 13, 1992 which proposed a performance standard for enhanced I/M programs that assumed the use of the IM240 test procedure.

On May 8, 1992, ARCO Products Company released a report[4] recommending that an alternative to the IM240 be allowed for enhanced I/M programs. The operating modes for ARCO's alternative procedure were not conclusively determined, but the modes were based on "Acceleration Simulation Mode" procedures developed by the California Bureau of Automotive Repair and Sierra Research, Inc.

In contrast to ARCO's report which was somewhat ambiguous on which modes should be included in the alternative test, the earlier BAR/Sierra report[5] had recommended an ASM I/M test that included the traditional 2500/idle test (2 modes) with two loaded dynamometer modes, at 15 mph and at 25 mph. The authors concluded that these two dynamometer modes were needed for NOx correlation with the FTP*, and that the 2500/idle modes were necessary for good HC/CO correlation.

ARCO's report, which reached different conclusions, was based on test results from five newer vehicles that were tested with and without implanted malfunctions, resulting in 30 tests. ARCO's conclusions are directly quoted below:

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[4] Kenneth L. Boekhaus, Brian K. Sullivan, and Charles E. Gang, "Evaluation of Enhanced Inspection Techniques on State-of-the-Art Automobiles," ARCO Products Company, May 8, 1992.

[5] Austin and Sherwood.

* 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 driving cycle includes 31 minutes of actual driving which takes 41 minutes to complete due to a 10 minute engine shut-off between the second and third modes of this 3 mode test.

1. An enhanced IM program utilizing steady-state exhaust emission testing is as effective in identifying cars needing repair as is the EPA's proposed IM240 test. Because the cost of the IM240 equipment is four times that of an enhanced I/M test, the enhanced I/M test is far more cost effective.

2. Canister purging can be tested as effectively in an enhanced I/M test as in an IM240 test.

3. The current BAR90 exhaust emissions test conditions of idle and 2500 rpm/no load are not effective in identifying most malfunctions in state-of-the-art automobiles.

4. The ASM5015 steady-state test condition is effective in identifying malfunctions for HC, CO and NOx and should be included in any enhanced I/M test developed.

5. Further development work is needed to develop one or more other steady-state test conditions to complement the ASM5015 test.

6. The IM240 test correlates better with the FTP test in predicting absolute emissions levels than does the ASM5015 test. With one or more additional steady-state test conditions, steady-state testing would likely correlate as well as the IM240 test.

7. The BAR 90 Test Analyzer System, with NOx analyzer, can be used for enhanced I/M testing incorporating a steady-state dynamometer.[6]

On November 5, 1992, EPA promulgated the final I/M rule establishing the IM240 as the benchmark I/M test, against which any alternative test must be found equivalent. The IM240 is a transient test which measures true mass emissions during typical driving. In contrast, the Acceleration Simulation Mode procedures only approximate mass emissions via pollutant concentration measurements during several steady-state modes. A BAR90 HC and CO analyzer with an NO analyzer is sufficient. Emissions measurements are not made during the accelerations and decelerations between the steady-state driving modes because such measurements require more expensive equipment including a constant volume sampler to dilute the exhaust and measure flow, and analyzers capable of accurately measuring the resulting low concentration samples.

The purpose of EPA's alternative I/M test procedure study is to evaluate whether the IM240's performance as an I/M test can be attained, or nearly so, by a multi-mode, steady-state procedure (including two ASM modes) that utilizes equipment costing about half of the anticipated cost of the equipment required for IM240 testing.

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[6] Boekhaus, et al.

Due to widespread interest and the need for states to move forward with specific testing plans, EPA prepared to initiate a test program to evaluate a steady-state loaded I/M test as a potential alternative to the IM240 for enhanced I/M. EPA's alternative test study focused on the Acceleration Simulation Mode procedures.

EPA needed to select a practicable number of steady-state operating modes, but there was disagreement among the proponents of steady-state testing for enhanced I/M. ARCO concluded that the 2500 rpm & idle modes are not effective for identifying most malfunctions. In contrast, BAR/Sierra recommended an I/M test consisting of the following modes: 5015, 2525, 2500 rpm, and idle.

EPA's desire to evaluate a single steady-state procedure agreeable to all interested parties led to a conference call with the interested parties on July 27, 1992. The participants included: ARCO, Sierra Research, California Bureau of Automotive Repair, Allen Test Products/SAVER, EPA's Testing Contractor (Automotive Testing Labs), and EPA.

The parties reached a consensus that the steady-state test to be evaluated should include four modes (a fifth mode was only to be performed on the first 50 cars with automatic transmissions):

- 15 mph (ASM 5015)*
- 25 mph (ASM 2525)**
- 50 mph at road load horsepower***
- idle (automatic transmissions using Drive rather than Neutral)****
- idle (first 50 vehicles with automatic transmissions using Neutral rather than Drive)****

This test procedure will herein be referred to as the "ASM" procedure, although only the first two modes are strictly ASM modes.

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* This is a steady-state 15 mph mode (5015). The dynamometer load is set to simulate 50% (5015) of the power required to accelerate the particular vehicle being tested at 3.3 mph/second at 15 mph. The ASM does not include a true speed changing acceleration during emissions measurement, instead the speed is held constant while the dynamometer load is set to simulate the power required to accelerate the car. The 3.3 mph/second acceleration rate is the maximum acceleration rate during the Federal Test Procedure (FTP). The FTP is the transient (accelerations and decelerations) procedure used to certify that vehicles comply with Federal emissions standards, which is required before the manufacturer can offer them for sale. The IM240, for the most part, is taken directly from the FTP. The 5015 mode usually requires a higher load setting than the 2525 or the 50 mph road load modes.

** This is a steady-state 25 mph mode (2525). It is analogous to the ASM5015 mode in that the dynamometer load set to simulate 25% (2525) of the power required to accelerate the particular vehicle being tested at 3.3 mph/second at 25 mph.

*** This is a 50 mph mode with the dynamometer set to the power required for a vehicle to maintain 50 mph on level road taking into account air resistance, tire losses, bearing friction in the drivetrain, etc. Air drag is the major resistance at 50 mph.

**** Because the vehicles were to be operated on the dynamometer, it was judged that the vehicles could be safely tested at idle in Drive. Because automatic-transmission-equipped vehicles idle in drive during the FTP, and some ECM algorithms for the emission control system change with transmission selector position, idle in Drive is expected to yield better correlation with the FTP than idle in Neutral. Since all known idle emissions tests had been run in Neutral prior to EPA's ASM evaluation, the first 50 vehicles, or more, were also run in Neutral to allow comparison with other databases.

Having reached a consensus on the procedure to be evaluated, EPA issued a work assignment[7] on July 30, 1992, directing EPA's testing contractor to implement the new procedure. Shakedown testing began in August and the first official ASM test was performed on September 10, 1992. The last as-received ASM test was performed at the I/M lane on March 19, 1993. This analysis includes tests that were performed through February 17, 1993.

Another issue EPA must consider is the impact of approving alternative I/M procedures on the automobile manufacturers. The Motor Vehicle Manufacturers Association, in written comments on the I/M NPRM, said:

> 6.0.0 ALTERNATIVE TEST METHODS
>
> MVMA agrees that EPA should not allow enhanced I/M areas to implement alternative tests until they have submitted substantial data supporting the quality of the test, and showing that the test produces emission reductions equivalent to those of the IM240 Test.
>
> One such report by ARCO describes an acceleration simulation mode (ASM) that was compared to the IM240 test. A substantial cost advantage with this alternative test is that it does not require the use of a constant volume sample (CVS) sampling system. The report references an earlier study by Sierra Research that calculates mass emissions by multiplying a "constant" times "emissions concentration" times "inertia weight". Yet during the comparison of the two test methods, the mass emissions for the ASM were measured utilizing a CVS. For a more accurate comparison, the ASM data should have been calculated in the method prescribed for use in the field, i.e., with BAR-90 readings and without the use of CVS equipment.
>
> Probably of greater concern, however, is the cutpoints selected for each test process. Since cutpoints are an important criteria in comparing and evaluating test processes, realistic cutpoints have to be determined before an accurate comparison can be made. The IM240 Test cutpoints selected for this [ARCO's] comparison are extremely low and thus "create" false failures. In contrast, the [ARCO] selection process for the ASM cutpoints is not well explained and remains ambiguous, making IM240 Test versus ASM Test comparison speculative at best.
>
> ARCO used only five vehicles in the study. Their objective was to "evaluate the viability of an alternative enhanced I/M test." It appears much more work is required before such an alternative could be properly defined and evaluated. In the NPRM preamble, EPA stated that if this ASM test can be shown to be as effective as the IM240 Test, it could be permitted as a

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[7] Statement of Work Change 1, July 30, 1992; Work Assignment 0-2, Contract No. 68-CI-0055, "Test Procedure to Evaluate the Acceleration Simulation Mode and the Emissions Measurement Capabilities of a BAR90 Certified Analyzer With An Integrated Fuel Cell Type NO Analyzer."

> "substitute". MVMA is concerned that "substitute" tests could lead to several alternative tests with varying degrees of effectiveness. MVMA requests that EPA continue to critically assess any alternative tests proposed by enhanced I/M areas. This review process will help assure that any alternative tests are able to properly identify failing vehicles.

EPA is also puzzled by ARCO's conclusions which seem contradictory. ARCO's first conclusion states:

> An enhanced IM program utilizing steady-state exhaust emission testing is as effective in identifying cars needing repair as is the EPA's proposed IM240 test.

Their fourth conclusion states that:

> The ASM5015 steady-state test condition is effective in identifying malfunctions for HC, CO and NOx and should be included in any enhanced I/M test developed.

ARCO's fifth conclusion states that:

> Further development work is needed to develop one or more other steady-state test conditions to complement the ASM5015 test.

These statements suggest that ARCO's testing indicated that the ASM5015 was not as effective as the IM240, that the other modes they evaluated were not helpful, and additional work was required to identify better alternatives. This report will document additional work performed by EPA to evaluate the ASM5015 and three additional steady-state modes.

3. Test Procedures

The best way to compare I/M tests is to utilize actual results from an I/M station in conjunction with FTPs run on a subset of the vehicles also tested at the I/M station. A highly inferior method is to compare the procedures based only on test data collected in a laboratory which is not subject to the range of vehicle operating conditions which normally precede actual I/M tests, nor the range of ambient conditions encountered during actual I/M tests.

It is widely acknowledged that a given vehicle's emissions can vary widely with changes in vehicle operating conditions that precede emissions tests, and a given vehicle's emissions can vary widely with ambient conditions encountered during an emissions test. So, in contrast to laboratory test results, the results from pilot tests run in an official I/M station provide significantly more confidence that the pilot test results will accurately represent future results when the procedure is mandated for official I/M testing.

For these reasons, EPA carried out IM240 and ASM testing (through a contractor) in an I/M station in Mesa, Arizona, with FTP testing in a contractor-owned laboratory also in Mesa. In this respect, EPA's results have much greater applicability to the real world than results from recent "ASM" testing by Environment Canada[8], ARCO, California Air Resources Board, and the Colorado Department of Health.

The test procedures are discussed in detail in Appendix A.

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

4. Data Description

From September 10, 1992 through March 19, 1993, EPA's contractor, Automotive Testing Laboratories (ATL), conducted a vehicle testing program in Mesa, Arizona, a suburb of Phoenix, on mostly 1983 and newer vehicles.

This program included several tasks designed to produce data for an analysis comparing the ASM test to the IM240 test as predictors of actual FTP emissions. These tasks included the operation of an Arizona I/M inspection lane. Vehicles at this lane received IM240s with a functional test of the evaporative canister purge system (referred to as the purge test in the remainder of this report), ASMs with the purge test, Arizona I/M tests, and fuel system pressure tests under real-world I/M testing conditions. In addition, vehicles were recruited from the I/M lane for additional tasks, which included:

- FTP laboratory testing
- IM240 laboratory testing
- Contractor IM240-targeted repairs
- Commercial repairs obtained by vehicle owners to pass the official Arizona I/M test.

Choosing vehicles for laboratory testing was driven by the 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 (see Section 5.2.5.8). But most excess emissions come 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 was employed to deliberately over-recruit dirty cars, based on lane-IM240 results at the Mesa lane. A nominally 50/50 mix of IM240-clean and IM240-dirty vehicles were to be recruited for FTP exhaust testing. In actual practice, more dirty cars than clean have been recruited which is shown in Table 4.2.2.

Specifics concerning the recruitment criteria and the test procedures for these tasks are discussed in Appendix A.

4.1 Data Listings

Appendix B provides a listing of the data used for the cutpoint effectiveness analysis, the contractor repair analysis, and the commercial repair analysis, which are all discussed in Section 5.

Data for the over 1400 vehicles that only received one set of lane tests (no laboratory tests and no after-repair lane tests) are only available on disk. These data include the purge analysis data, and the lane data used to calculate ASM coefficients. The available disk(s) will include all IM240 and ASM lane data including lane data for the laboratory tested vehicles. These can be requested by contacting:

William M. Pidgeon
U.S. EPA
National Vehicle and Fuel Emissions Laboratory
2565 Plymouth Road
Ann Arbor, Michigan 48105-2425
Tel. No. 313-668-4416
Fax. No. 313-668-4497

Fax requests for data disks are preferred and a form is provided at the end of Appendix B; questions can be addressed by phone.

4.2 Database Statistics

The first official ASM/IM240 test series was run on September 9, 1992. Data collected up to March 17, 1993 were considered for these analyses. During that period, 1574 vehicles received 1758 ASM/IM240 test series at the Arizona I/M lane. Priority for testing was given to 1983 and newer model year fuel injected vehicles. The following table illustrates the model year and fuel metering distribution of the tested fleet:

Table 4.2.1
Lane Data By Model Year and Fuel Metering

MYR	PFI	TBI	CARB	Totals
81	-	-	3	3
82	-	2	3	5
83	12	6	26	44
84	31	30	46	107
85	38	42	49	129
86	94	53	45	192
87	105	50	46	201
88	100	61	36	197
89	119	77	17	213
90	133	48	2	183
91	150	35	-	185
92	104	11	-	115
Totals	885	415	273	1574

Of the 1574 vehicles tested 27 were recruited for the commercial repair program and 127 vehicles were recruited to the laboratory for additional tests and for contractor repairs when the repair criteria were met (Section 5.6).

The following list summarizes the criteria used for recruiting laboratory vehicles and for data completeness:

- The IM240 and the ASM were designed to distinguish between malfunctioning and properly functioning newer technology cars, so only 1983 and newer fuel-injected (no carbureted) cars were used.
- One-half of the laboratory vehicles were to exceed 0.80/15.0/2.0 (HC/CO/NOx) on their lane-IM240.
- One-half of the recruited vehicles were to have the lane-IM240 performed prior to the ASM.
- Only vehicles having an as-received FTP, an as-received lane-IM240, and an as-received lane ASM test were used. Vehicles missing any one of these three tests were not included in the analysis.

The resulting database consisted of 106 fuel-injected. Table 4.2.2 lists actual distribution statistics for these laboratory vehicles.

Table 4.2.2
Distribution of Laboratory Recruited Vehicles

Lane-IM240	Fuel Metering	ASM Prior to IM240	IM240 Prior to ASM	Totals
Passed: ≤0.80 / 15.0 / 2.0	PFI	18	14	32
	TBI	5	3	8
Failed: >0.80 / 15.0 / 2.0	PFI	18	23	41
	TBI	14	11	25
Totals		55	51	106

Table 4.2.3 shows the model year and fuel metering distribution for the 106 laboratory recruited vehicles.

Table 4.2.3
Lab Data by Model Year and Fuel Metering

MYR	PFI	TBI	Totals
83	6	2	8
84	12	8	20
85	7	7	14
86	13	6	19
87	9	1	10
88	5	4	9
89	7	2	9
90	6	2	8
91	7	1	8
92	1	-	1
Totals	73	33	106

Table 4.2.4 provides FTP HC/CO emitter group statistics for these recruited vehicles. FTP emitter groups are defined based on FTP emissions as follows:

Normals:	HC<0.82	and	CO<10.2

Highs:	0.82≤HC<1.64	and	CO<13.6
		or	
	HC<1.64	and	10.2≤CO<13.6

Very Highs:	1.64≤HC<10.2	and	CO<150
		or	
	HC<10.2	and	13.6≤CO<150

Supers:	HC≥10.2	or	CO≥150

Table 4.2.4
Lab Vehicle FTP HC/CO Emitter Category Distribution

Normals	Highs	Very High	Supers
67	13	25	1

For more detailed information on the data used for these analyses refer to Section 5. For details on the data excluded from these analyses refer to Section 4.3 and Appendix C.

4.3 Quality Control (QC) Protocol

This Section provides a general description of the QC process. For more detailed descriptions of the QC criteria and data excluded from these analyses see Appendix C, which lists the QC criteria in detail and the vehicles removed due to the QC protocol.

Data were received from ATL in two forms. Calculated cycle-composite values for all tests (lab and lane), except the ASM tests, and second-by-second data for lane-IM240s and ASMs were provided. The calculated data and the raw second-by-second data followed separate but similar QC processes. The calculated data were processed using a program which performed checks on FTP data and IM240 (lab and lane) data. These checks included bag result comparisons, fuel economy checks, test distance checks, dynamometer setting checks, and test-to-test comparisons. For details on these checks see Appendix C.

The second-by-second data were processed by a separate program which performed similar checks for the raw data. The QC checks for the second-by-second data included checks for acceptable speed, correct test/mode duration, sampling continuity, reasonable ambient background concentrations, acceptable purge flow, and reasonable fuel economy. Again details concerning these QC criteria are included in Appendix C. The second-by-second QC program also calculated composite values for the IM240 and ASM tests.

In addition to the QC program comparisons, the calculated results reported by ATL were compared to those results calculated from the second-by-second data. Significant differences were investigated. All lab vehicles violating the QC criteria were hand checked by EPA staff and the data were corrected or removed, as warranted. Due to the volume of lane data, lane vehicles that violated QC tolerances were removed from all pertinent analyses, without further attempts to "save" the data unless solutions were obvious. These unutilized data will be checked, as time permits, for future use. In contrast, because the vehicles that received FTPs were relatively precious, significant effort was expended to correct data that were identified by the QC process.

Vehicles removed from the sample are discussed in Appendix C on page C-4 through C-8.

5. Analyses/Discussion

5.1 Introduction

The purpose of Section 5 is to present the analysis EPA used to assess whether the ASM test is sufficiently effective in identifying high emitting cars needing repair when compared to the IM240 test, and the findings of that analysis. Additionally, it provides a comparison of the repair issues for those vehicles that were identified as needing repairs.

Section 5.3 compares the ability of the ASM and the IM240 to identify vehicles needing repair, and presents EPA's major findings regarding the effectiveness of the ASM as an alternative to the IM240 for enhanced I/M programs. It discusses comparisons of IM240 versus ASM using information from cutpoint tables. Section 5.2 provides information needed to understand how the cutpoint tables were derived.

Section 5.4 compares the correlation of the IM240 and ASM with the FTP using traditional regression analysis. Section 5.5 discusses the somewhat specialized issue of how four ASM scores are combined in one score and the uncertainties and sensitivities in this process.

Section 5.6 discusses the repairs performed by the contractor and repairs performed by commercial repair shops.

Section 5.7 discusses canister purge system test results and Section 5.8 discusses methods that will be explored to improve the power of the IM240.

5.2 Analyses Techniques

This section discusses the methodology and criteria EPA used to compare the ability of the ASM and the IM240 to identify vehicles needing repair. This section explains why the criteria are important, how the criteria are derived, and indicates the tradeoffs associated with these interrelated criteria. Then, Section 5.3 contrasts the ASM and the IM240 using the criteria explained in Section 5.2.

5.2.1 Reducing Four Steady-State Modes to a Single Score per Pollutant For Comparison to One Cutpoint per Pollutant

This section explains how the final ASM score is computed. Two questions will be answered in this section:

1. Should the four mode scores for each pollutant be combined to calculate a single result or score for each pollutant, or should a separate score be reported for each of the four modes, and apply those separate scores to separate cutpoints for each of the four modes?

2. How is the score computed for each ASM mode?

5.2.1.1 Reporting Overall ASM Results Versus Reporting Individual Mode Results

There are three alternatives for reporting overall ASM test results. The first alternative does not combine the scores from the separate modes, so this alternative is analogous to the way 2500/idle test results are reported. The HC and CO scores are reported for the 2500 mode and separate HC and CO scores are reported for the idle mode for a total of four scores and up to four cutpoints. For the four mode ASM test, this is too complicated. With NOx added, three cutpoints are needed for the 3 dynamometer modes and two cutpoints (HC and CO only) for the idle mode, necessitating 11 separate cutpoints. (Because NOx emissions are insignificant during an idle test, NOx is only considered for the 3 dynamometer modes.) This first alternative is too unwieldy for a four mode test.

The second and third alternatives are two different ways to report a single score for each pollutant by combining one pollutant's scores from all the modes.

For the second alternative, the single score would be the sum of the scores from each mode, using a weighting of 25% for each mode. For example, to calculate the single ASM score for HC, the equation would be as follows:

$$\text{ASM HC} = (0.25 * \text{5015 HC}) + (0.25 * \text{2525 HC}) + (0.25 * \text{50RL HC}) + (0.25 * \text{idle HC})$$

In the third alternative, which EPA used, a single score is determined from the sum of the individual mode scores, but the weighting or coefficient for each was determined by regression techniques. A multiple regression was performed wherein all four of the mode scores are independent variables that were regressed against FTP scores. The regression produced coefficients for each mode, plus a constant. These coefficients weight each mode more appropriately than the second alternative's method of just assigning each mode a weighting of 25%. BAR/Sierra used this regression method, and likewise EPA's analyses for this report also used this regression method, with one difference that is discussed in Section 5.5. This yields an equation to calculate a single ASM score for each pollutant. For example, the equation for calculating a single ASM HC score is as follows:

$$ASM\ HC = (x * 5015\ HC) + (y * 2525\ HC) + (z * 50RL\ HC) + (t * idle\ HC) + Constant$$

the x, y, z, t, and constant terms are listed in Table 5.2.2.

While ASM advocates have used this concept, none have proposed specific coefficients for EPA to evaluate. Thus, EPA had to develop coefficients.

The remaining question is: "How were each of the individual mode scores determined?"

5.2.1.2 Determination of Individual Mode Scores

Emission concentrations were measured on each of the four ASM modes (see Section 5.2.3 for more details). These concentration measurements were then converted to simulated grams/mile emissions, because concentration measurements do not provide a reliable indication of the magnitude of pollutants emitted per mile traveled. At the same exhaust concentration level, a heavy vehicle will emit more per mile than a light vehicle.

To calculate simulated g/mi results, EPA followed BAR/Sierra's method, which was also followed by ARCO, wherein the measured concentration values are multiplied by the Inertia Weight (engine displacement for the idle mode) of the vehicle. *The Idle Mode was not considered for NOx since it is a no load test.* EPA also divided these simulated g/mi results by the scaling factors listed in Table 5.2.1. Using these factors yield overall ASM scores that have magnitudes similar to FTP and IM240 magnitudes.

Table 5.2.1: Scaling Factors Used to Keep Regression Coefficients of Equal Magnitude

Pollutant	Modes 1-3 [CONC] * IW / x	Mode 4 [CONC] * Disp(L) / x
HC	10^5	10^3
CO	10^2	10^0
NOx	10^6	NA

5.2.2 Multiple Linear Regressions to Find ASM Coefficients

As previously discussed, multiple linear regressions were performed using the four modes (three for NOx) of the ASM test as the independent variables

(X1,...,X4) The one difference mentioned in Section 5.2.1.1 above is that the IM240 (rather than the FTP) was used as the dependent (Y) variable*. This was done for tests on which the ASM was run first only, because the corresponding IM240s are pre-conditioned, and thus more closely resemble an FTP.

Vehicles that were recruited to the lab or received commercial repairs were not included in the database used to develop coefficients, because these are the cars to which the coefficients were applied. EPA determined that including these would cause the developed coefficients to mask the test variability of the ASM. (This is also discussed in Section 5.5.)

The multiple linear regressions were run on a database of 608 lane ASM tests versus pre-conditioned lane-IM240s, giving the following coefficients for each mode.

Table 5.2.2
Coefficients Developed from Multiple Regression ASM Versus IM240
(see Table 5.2.1 for scaling factors)

Mode	HC	CO	NOx
Constant	0.083	2.936	0.258
5015	0.025	0.040	0.061
2525	0.059	0.043	0.219
50 MPH	0.136	0.356	0.352
Idle	0.124	1.350	NA
Adjusted R^2	29.0%	50.1%	59.1%

5.2.3 Applying ASM Coefficients

The coefficients were then used to calculate composite ASM scores for all lab vehicles and commercially repaired vehicles. These are the ASM scores that are reported in the ensuing cutpoint tables, scatterplots, and regressions.

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* Why the IM240 was used as the dependent variable, rather than the FTP, is explained in Section 5.5. This is not discussed here because the purpose of this section is to explain how, rather than why. Also, this issue requires a lengthy discussion and relies on information presented in Section 5.5, so repetition is also avoided.

5.2.4 ASM Concentration Measurements

The ASM concentrations were measured over a 40 second period. Because the exhaust sample delay to the most downstream analyzer cell is almost 10 seconds, the first 10 seconds of data were ignored. The concentrations that are used in the composite ASM score calculations are actually reported averages over the last 30 second period. For various reasons, the time allotted for measured concentrations was occasionally less than 30 seconds. In these few cases, EPA calculated the average concentrations over this shortened period and reported these values. No ASM tests were accepted with concentrations averaged over a period of less than 20 seconds.

5.2.5 Explanation of the Criteria Used To Compare I/M Tests

In assessing the overall effectiveness of the ASM relative to the IM240, it is important to determine their effectiveness in measuring and determining a variety of factors, including the excess emissions identified, the failure rate, the error-of-commission rate, the two-ways-to-pass criteria, the discrepant failures, and the unproductive failure rate. Each of these is discussed below. These criteria are used in Section 5.3 to compare the effectiveness of the two procedures.

5.2.5.1 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. 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 g/mi HC standard whose FTP result was 2.00 g/mi, would have excess emissions equalling 1.59 g/mi HC (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 g/mi 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:

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

EPA uses IDR instead of merely comparing the number of vehicles that correctly fail and correctly pass. The IDR better contrasts the relative merits of competing I/M test procedures because failing vehicles with high emissions is more important than failing those that are only slightly above their certification standards. For example, take two I/M procedures that correctly failed 100 of the 500 vehicles that had FTP emissions greater than their certification standards, but only 50 cars failed both tests. If the fifty cars that failed Test A were high FTP emitters, and the other 50 cars that failed Test B had FTP emissions only slightly above their standards, obviously Test A would be preferred, and its IDR would reflect its better performance. Test A's better performance is not evident in comparing the number of vehicles that correctly fail.

5.2.5.2 Failure Rate

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

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

The ideal I/M test is one that fails all of the dirtiest vehicles while passing those below the FTP standard or close to it but still above it. The potential emission reduction benefit decreases as emission levels from a vehicle approach the standard, because the prospect for effective repair diminishes. Thus, achieving a high IDR in conjunction with a low failure rate (as a result of identifying fewer vehicles passing or close to the standard) efficiently utilizes resources.

5.2.5.3 Error-of-Commission (Ec) Rate

Properly functioning vehicles which pass FTP standards sometimes fail the I/M 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." Automobile 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 the FTP standards. The error-of-commission rate equals the number of vehicles that fail the I/M test while passing the FTP divided by the total number of vehicles which were I/M tested:

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

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.

5.2.5.4 Two-Ways-To-Pass Criteria

The theory behind the two-ways-to-pass criteria for the IM240 is as follows. Assuming that the IM240 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 HC molecules and that they 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 emissions during Mode-2 (the last 136 seconds of the 239 second cycle) should be lower than the composite results. On the other hand, if the vehicle is actually malfunctioning, Mode-2 emissions should remain high.

Catalyst temperature can also affect 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 fail, when, in fact, it should be passed. Under the two-ways-to-pass criteria, Mode-1 acts as a preconditioning mode, thus providing insurance against this particular variety of false failure.

NOx cutpoint criteria are not included in EPA's two-ways-to-pass algorithm. So a vehicle which meets the IM240 NOx cutpoint (i.e., composite NOx ≤ 2.0) only fails if both its composite emissions exceed the HC or CO composite cutpoints, and its Mode-2 emissions exceed the HC or CO Mode-2 cutpoints. In other words, a vehicle can pass by having low HC/CO emissions in Mode-2 even if its Mode-1 HC/CO emissions were high. EPA is mandating this approach to IM240 cutpoints.

The IM240 cutpoint tables, in Appendix E and Table 5.3.1 in the next section, were calculated using the two-ways-to-pass-criteria.

The two-ways-to-pass criteria were optimized **only** at the cutpoints EPA recommends for biennial enhanced I/M programs, which are referred to as "standard" or "recommended" IM240 cutpoints. For composite emissions, the standard cutpoints are 0.80 g/mi HC, 15.0 g/mi CO and 2.0 g/mi NOx. The Mode-2 criteria for the standard cutpoints are 0.50 g/mi HC and 12.0 g/mi CO. The Mode-2 cutpoints were carefully selected from EPA's IM240 data collected in Indiana, to pass properly functioning vehicles while continuing to fail malfunctioning vehicles. (The Mode-2 criteria were not redetermined for this new Arizona sample.) The Mode-2 criteria, listed in the cutpoint tables in Appendix F and Table 5.3.1, simply increase proportionally with increasing composite cutpoints (i.e., become less stringent) and decrease proportionally with decreasing composite cutpoints (i.e., become more stringent). The point is that these Mode-2 criteria have not been optimized at every stringency level to provide the best tradeoff among IDR, failure rate, and Ecs, so it is probable that the effectiveness of the IM240 Mode-2 cutpoints can be improved.

5.2.5.5 Discrepant Failures (DFs)

Discrepant failures are vehicles that fail an I/M test for HC and/or CO and pass the FTP for HC and CO, but fail the FTP for NOx, or vice versa. The table below illustrates one possible discrepant failure scenario:

Test	HC or CO	NOx
Short Test	Pass	Fail
FTP	Fail	Pass

In this example, a false failure for NOx happens to occur on a vehicle which is a false pass for HC/CO.

Repair diagnostic routines are frequently selected on the basis of which pollutant caused the I/M test failure. Given that HC/CO and NOx move in opposite directions with changes to the A/F ratio, there is not much reason to expect that fixing a NOx problem will reduce HC/CO emissions. Therefore, these scenarios represent an error of sorts for the short test. If a vehicle was to fail the short test for NOx, whereas the only high FTP pollutant was CO, chances are the mechanic will be looking for a problem that causes high NOx. In this case, the problem that is causing high CO emissions is not likely to be found.

5.2.5.6 Unproductive Failure (UF) Rate

The unproductive failure rate represents the percentage of vehicles that will be identified as needing repair, but either repair is not needed (Ecs), or it is not likely the reason for repair will be found (DFs). The unproductive failure rate is calculated by adding errors-of-commission to discrepant failures, and dividing the quantity by the total number of vehicles which were I/M tested. Keeping with the same example as above, take an I/M area which tests 1000 vehicles. 100 fail the I/M test, 50 of those 100 failing vehicles are Errors-of-Commission, and 5 are Discrepant Failures:

$$\frac{\text{50 Ecs + 5 DFs}}{\text{1000 vehicles tested}} * 100 = 5.5\%\ \text{UF}^{*}\ \text{rate}$$

*Unproductive Failure

5.2.5.7 Vehicles with Malfunctions That Were Not Counted as Ecs and DFs

Errors-of-commission in I/M programs have been most often caused by test-to-test variability or incompatibility between the I/M test procedure and vehicle emission control systems (e.g., air pump switching), so attempting to repair Ec vehicles were fruitless. With the IM240, however, EPA has found that some vehicles that had failed the IM240 and passed the FTP actually did have malfunctions, so they were correctly identified and air quality would suffer by ignoring them. By the strict definition of Ecs, the IM240 is penalized despite its successfully identifying malfunctioning vehicles.

A likely reason for vehicles passing the FTP despite a malfunction is that malfunctions are sometimes intermittent. Vehicle 3172 provides a good example. This vehicle had a number of IM240s performed, some with high NOx and others with low NOx. The mechanic indicated that the vehicle had a sticky EGR valve. The mechanic's diagnosis was not influenced by the FTP result because the contractor had been instructed to report only IM240 scores to the mechanics, not the FTP score. This has become standard practice to allow the contractor-repairs to simulate commercial repairs, where mechanics will not have access to FTP results.

For this analysis, EPA did not count vehicles as Ecs when they had a malfunction that would logically explain the IM240 test failure. To facilitate a fair comparison between the ASM and the IM240, the ASM failing vehicles that passed the FTP, but had malfunctions, also were not counted as Ecs when their malfunction would logically explain the ASM failure.

EPA was very conservative in that a vehicle was counted as an Ec unless the malfunction clearly explained the ASM or IM240 test failure. For example, vehicle 3239 failed the IM240 with 2.4 g/mi NOx yet passed the FTP. The vehicle was diagnosed as having a slow responding O2 sensor and it was replaced. Because (1) a report of a slow-responding O2 sensor does not indicate that objective criteria were used, (2) NOx failures are not strongly associated with defective O2 sensors, and (3) all of its other IM240 tests had passing NOx, the car was counted as an Ec despite the mechanic's judgement the the O2 sensor should be replaced, which he did.

Using the similar logic, some vehicles with discrepant failures were also not counted as DFs when their malfunctions could logically explain the I/M test failure and a proper repair could be expected to reduce FTP emissions of the affected pollutant even though FTP emissions of that pollutant were initially below FTP standards. For example, the vacuum leaks on vehicle 3154 could cause a lean air/fuel ratio which can lower the catalyst's NOx conversion efficiency and cause higher combustion temperatures, both of which can cause high NOx on the IM240 and ASM. FTP NOx emissions should also be affected but perhaps not enough to cause an FTP failure. Because it is logical for a mechanic to check for vacuum leaks on a car that fails NOx, and this vehicle did have vacuum leaks, the I/M tests shouldn't be penalized for correctly identifying the malfunction. On the other hand, if this vehicle had failed CO on an I/M test and NOx on the FTP, the mechanic would look for problems causing a rich air/fuel ratio, which would probably preclude looking for vacuum leaks.

Table 5.2 lists the five vehicles the met the strict definitions for Ecs or DFs, but were not counted for the reasons discussed. *Note that while these vehicles were not counted as Ecs or DFs in the cutpoint tables, they still do count toward the Failure Rate.*

Table 5.2.3.1: Cars not Counted as Ecs or DFs

Vehicle	Original Status	Malfunctions Explaining I/M Test Failure
3154	*Discrepant Failure;* failed IM240 and ASM NOx, but failed FTP CO only.	Injector seals leak at intake manifold; distributor advance vacuum hose broken.
3172	*Error-of-Commission;* IM240 NOx.	EGR valve sticks, EGR valve vacuum line plugged.
3200	*Discrepant Failure;* failed IM240 and ASM NOx, but failed FTP HC only.	EGR position sensor out of range.
3216	*Error-of-Commission;* ASM HC	ECM malfunction
3244	*Error-of-Commission;* IM240 and ASM NOx.	Injector malfunctions intermittently.

5.2.5.8 Weighting Factors to Correct Biased Recruiting

The criteria used to recruit vehicles for laboratory testing heavily biased this laboratory sample toward IM240 failing vehicles. Sixty-two percent of the 106 laboratory vehicles had failed the lane-IM240 criteria (>0.80/15.0/2.0), whereas only 19% of 2,070 cars tested at the lane failed the IM240. This resulted in a laboratory sample that was highly biased toward failing vehicles. (Two-ways-to-pass criteria was not considered for laboratory recruiting.)

Using this biased database results in unrealistically high excess emission identification rates, and unrealistically low error-of-commission rates. So the laboratory database must be corrected to represent the pass/fail vehicle ratio in the in-use fleet to correctly determine IDRs, failure rates, and Ecs. The database was corrected using the weighting factors presented in Table 5.2.5.2.

Weighting factors are used as follows: If the 66 failing vehicles that received FTP tests had excess HC emissions which totaled 100 g/mi, the database would be corrected in this case by multiplying 100 by the 5.97 weighting factor, resulting in corrected total excess emissions of 597 g/mi for the dirty vehicles. In comparison, the total excess emissions of the

IM240-clean vehicles have to be multiplied by 41.9 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 sample of 40 clean vehicles provides confidence in conclusions about a test's relative tendency to avoid failing clean cars.

Table 5.2.5.2
Weighting Factors Used To Adjust the Laboratory Database

	IM240 at Lane	# at Lane	# at Lab	Weighting Factor
Pass:	≤0.80/15.0/2.0	1676	40	41.90
Fail:	>0.80/15.0/2.0	394	66	5.97

The resulting weighted database was used to produce the realistic estimates of IDRs, failure rates, and Ecs that are listed as cutpoint tables in Appendices D & E. These cutpoint tables are sorted by failure rates. For the cutpoints that produce the same failure rate, the results are sorted first by HC IDRs (in descending order) and then by NOx IDRs.

5.3 Comparison of IM240 Versus ASM Using Cutpoint Tables

In assessing the overall effectiveness of I/M test procedures, as discussed in Section 5.2, it is important to determine the test's effectiveness in terms of IDR, the failure rate, discrepant failures and unproductive failure rate.

Appendices D and E list the same criteria for many different cutpoints. Table 5.3.1 provides a summary of these criteria to compare the ASM with the IM240 for the following three important scenarios:

- ASM cutpoints selected to achieve the same 18% failure rate (using the cutpoint tables that are reweighted to correct the lab sample bias) that result from EPA's recommended IM240 two-ways-to-pass cutpoints of .80/15.0/2.0 + 0.50/12.0. Among the ASM cutpoint combinations with this failure rate (see Appendix E), a combination was selected that produced the maximum IDRs for all the pollutants simultaneously, so there was no need to set priorities among pollutants.

- ASM cutpoints selected to achieve IDRs similar to the IDRs that result from EPA's recommended IM240 two-ways-to-pass cutpoints of .80 / 15.0 / 2.0 + 0.50 / 12.0. Because ASM CO and NOx IDRs could more favorably be presented by excluding HC, two ASM cutpoint sets are presented, one to provide matching ASM and IM240 HC IDRs (resulting in better IDRs for CO and NOx), and the second to provide matching ASM and IM240 CO & NOx IDRs.

- ASM and IM240 cutpoints selected to achieve the highest IDRs possible while keeping the unproductive failure rate below 5%. This case was addressed on the possibility that an aggressive I/M program might be willing to operate with such a high Ec rate.

Table 5.3.1
Comparison of the Ability of IM240 and ASM to Identify Vehicles Whose Emissions Exceed Certification Standards Based on 106 Lab Vehicles Weighted to Represent 1676 Lane Vehicles

Test	Scenario	Failure Rate	Excess Emissions Identified			Ec*	Discrepant Failures	Unproductive Failure Rate**	Cutpoints
		%	HC %	CO %	NOx %	#	#	%	
IM240	Standard Ctpts.	18	92.2	67.5	83.4	0	12	0.6	.80 / 15.0 / 2.0 + 0.50 / 12.0
ASM	Same Fail Rate	18	74.7	61.1	68.0	42	6	2.3	1.00 / 8.0 / 2.0
ASM	Similar HC IDR	42	92.4	78.1	95.0	174	180	17.1	1.00/8.0/1.0
ASM	Similar CO & NOx IDRs	24	80.4	66.2	89.4	84	48	6.4	1.00/11.0/1.4
ASM	Best IDRs w/UF @ <5%	28	82.5	67.0	80.1	48	48	4.6	.40 / 8.0 / 1.5
IM240	Best IDRs w/UF @ <5%	33	95.9	78.2	97.1	60	12	3.5	.30 / 9.0 / 1.7 + .19 / 7.0
	Weighted # of Vehicles =	1676							

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* Excludes Ec vehicles that had malfunctions that caused an I/M test failure, but because they were intermittent malfunctions, did not fail the FTP. FTPs were always performed on a different day. Since they were correctly identified by the I/M test, they are not vehicles that will "ping-pong".

** The Unproductive Failure Rate includes the traditional Ec vehicles and the discrepant failures, without including the traditional Ec vehicles that were found to have intermittent malfunctions that were not identified by the FTP test.

For the first scenario with an 18% failure rate for both tests, the ASM statistics in Table 5.3.1 show that the IM240 identifies 18 percentage points more of the excess HC emissions and 15 percentage points more of the excess NOx emissions than the ASM identifies, with a significantly lower unproductive failure rate. Expressed differently, an IM240-based program would relinquish about 19% of its HC effectiveness and 18.5% of its NOx effectiveness by substituting the ASM test at the same failure rate. Some relatively dirty vehicles are missed by the ASM and replaced by relatively clean vehicles. This scenario is illustrated in Figure 5.3.1.

The second scenario shows that in order to achieve HC IDRs similar to the IM240's at an 18% failure rate, the ASM's failure rate must be increased to 42%, resulting in an unacceptable Ec rate of 17%. To achieve similar CO and NOx IDRs with the ASM, an ASM failure rate of 24% is necessary, and that also results in an unacceptable unproductive failure rate of 6.4%. This scenario is illustrated in Figures 5.3.2 and 5.3.3.

The last scenario compares the tests at the maximum IDRs achievable while limiting the unproductive failure rate to less than five percent. Again, the IM240 IDRs are significantly higher than the ASM's, with a lower unproductive failure rate. The IM240 HC IDR is 14% higher, the CO IDR is 14.3% higher, and the NOx IDR is 17.5% higher, with an Ec rate that is 1% lower. Expressed differently, an aggressive IM240-based program with a 3.5% unproductive failure rate would relinquish about 14% of its HC and 17.5% of its NOx effectiveness by substituting the ASM test at at an even higher unproductive failure rate. This scenario is illustrated in Figure 5.3.4.

These statistics indicate that the ASM test is significantly less effective than the IM240 as an I/M test.

The second scenario, wherein the ASM's HC IDR is raised to match the IM240's HC IDR of 92%, is anticipated to raise the following question:

> Why didn't EPA make the ASM's HC cutpoint more stringent to increase the ASM's IDR without increasing the stringency of the ASM's NOx cutpoint, thereby allowing a lower ASM failure rate?

The answer is that eight vehicles (see Table 5.3.2) have a major impact on the ASM HC IDR, but their ASM HC scores are less than 0.3 g/mi. Although their ASM HC scores are very low, they account for roughly 10.5% of the total excess FTP HC emissions. These eight vehicles also have ASM CO scores below 8.0 g/mi. While developing the ASM cutpoint tables, EPA found that ASM cutpoints below 0.3/8.0 caused failure rates and Ecs to increase excessively, so the final cutpoint tables did not include tighter cutpoints. So to achieve the IM240's HC IDR, the only "practical" way to identify these cars is through the NOx cutpoint.

Five of the eight cars with high FTP HC that pass the ASM HC cutpoints are failed by a NOx cutpoint of 1.5 or less. These five cars account for 7.6% of the total excess HC emissions. So the 1.0 g/mi ASM NOx cutpoint achieves an HC IDR comparable to the 92.2% achieved by the IM240 at EPA's standard cutpoints.

Table 5.3.3 summarizes the ASM cutpoint table in Appendix E to show that the only way for the ASM to achieve the IM240's HC IDR of 92.2% at the recommended cutpoints for biennial programs is to lower the ASM NOx cutpoint to 1.0.

Table 5.3.2: Vehicles that Pass a 0.30 g/mi ASM HC Cutpoint While Failing FTP HC

Vehicle	HC FTP	CO FTP	NOx FTP	HC ASM	CO ASM	NOx ASM
3180	0.96	9.75	1.22	0.15	3.64	0.68
3192	0.49	6.31	0.53	0.20	6.42	0.92
3195	0.51	5.80	0.66	0.18	3.26	1.27
3199	0.53	10.90	1.53	0.29	3.89	1.53
3201	0.94	19.73	1.72	0.17	4.73	1.22
3254	1.87	35.87	1.16	0.29	7.37	1.13
3257	1.26	8.57	0.90	0.25	4.65	1.03
3259	1.94	14.95	0.53	0.23	4.61	1.22

Table 5.3.3: Alternative ASM Cutpoints For High HC IDRs

ASM Cutpoints	Identification Rates HC	CO	NOx	Failure Rate	Ec Rate*	Discrepant Failures	UF Rate
0.30 / 8.0 / 2.0	88.0%	69.2%	74.9%	29%	4.3%	0	4.3%
0.30 / 8.0 / 1.8	88.2%	69.3%	78.2%	30%	4.3%	0	4.3%
0.30 / 8.0 / 1.5	89.0%	71.0%	82.7%	33%	4.3%	42	6.4%
0.30 / 8.0 / 1.4	90.3%	75.1%	89.5%	38%	6.4%	42	8.4%
0.30 / 8.0 / 1.3	90.3%	75.2%	89.5%	40%	6.4%	84	10.4%
0.30 / 8.0 / 1.2	91.4%	76.4%	89.9%	42%	6.4%	126	12.4%
0.30 / 8.0 / 1.0	96.6%	82.1%	95.0%	48%	8.7%	132	15.0%
0.40 / 8.0 / 1.0	92.4%	78.8%	95.0%	45%	8.7%	138	15.3%
1.00 / 8.0 / 1.2	84.1%	71.9%	89.8%	32%	4.0%	132	10.4%
1.00 / 9.0 / 1.0	91.3%	74.9%	95.0%	40%	8.4%	221	19.1%
1.00 / 8.0 / 1.0	92.4%	78.1%	95.0%	42%	8.4%	180	17.1%

To achieve an HC IDR rate greater than 89% a NOx cutpoint of less than 1.5 is necessary. To achieve an HC IDR rate greater than 91.4% a NOx cutpoint of less than 1.2 is necessary, and to achieve an HC IDR rate greater than 92% a NOx cutpoint of 1.0 is necessary. Once a tight NOx cutpoint is used to fail these cars with excess HC, the HC cutpoint no longer determines the result, at least in this sample. So, ASM cutpoints of 1.00/8.0/1.0 are the least stringent ASM cutpoints that can achieve a 92% HC IDR.

Another consideration is that the ASM cutpoints have been optimized for this database. In contrast, the IM240 recommended cutpoints were optimized for the Indiana IM240 database. Because of sample to sample differences, the optimum cutpoints are expected to vary slightly from one database to another. So the optimum ASM cutpoints are being compared to standard IM240 cutpoints, which while optimum for the Indiana data, are not the optimum cutpoints for this database. Applying ASM cutpoints optimized for this data base, to a different database, is expected to further lower the ASM's performance.

Figure 5.3.1
Comparison of ASM to IM240
Using IM240 Standard Cutpoints
With Maximum ASM IDRs at Equivalent Failure Rates

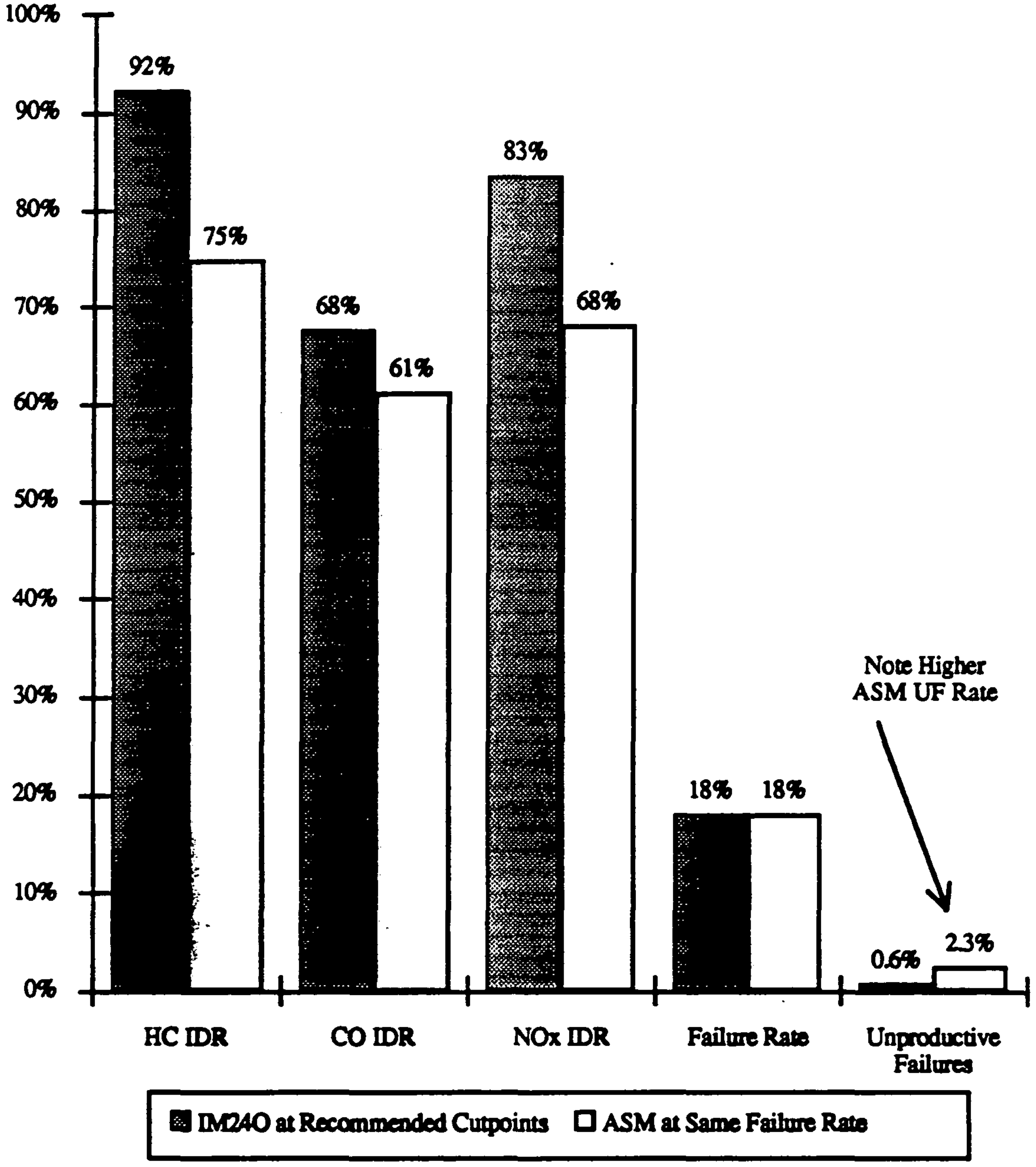


Figure 5.3.3
Comparison of ASM to IM240
With ASM CO & NOx IDRs Matching IM240 IDRs

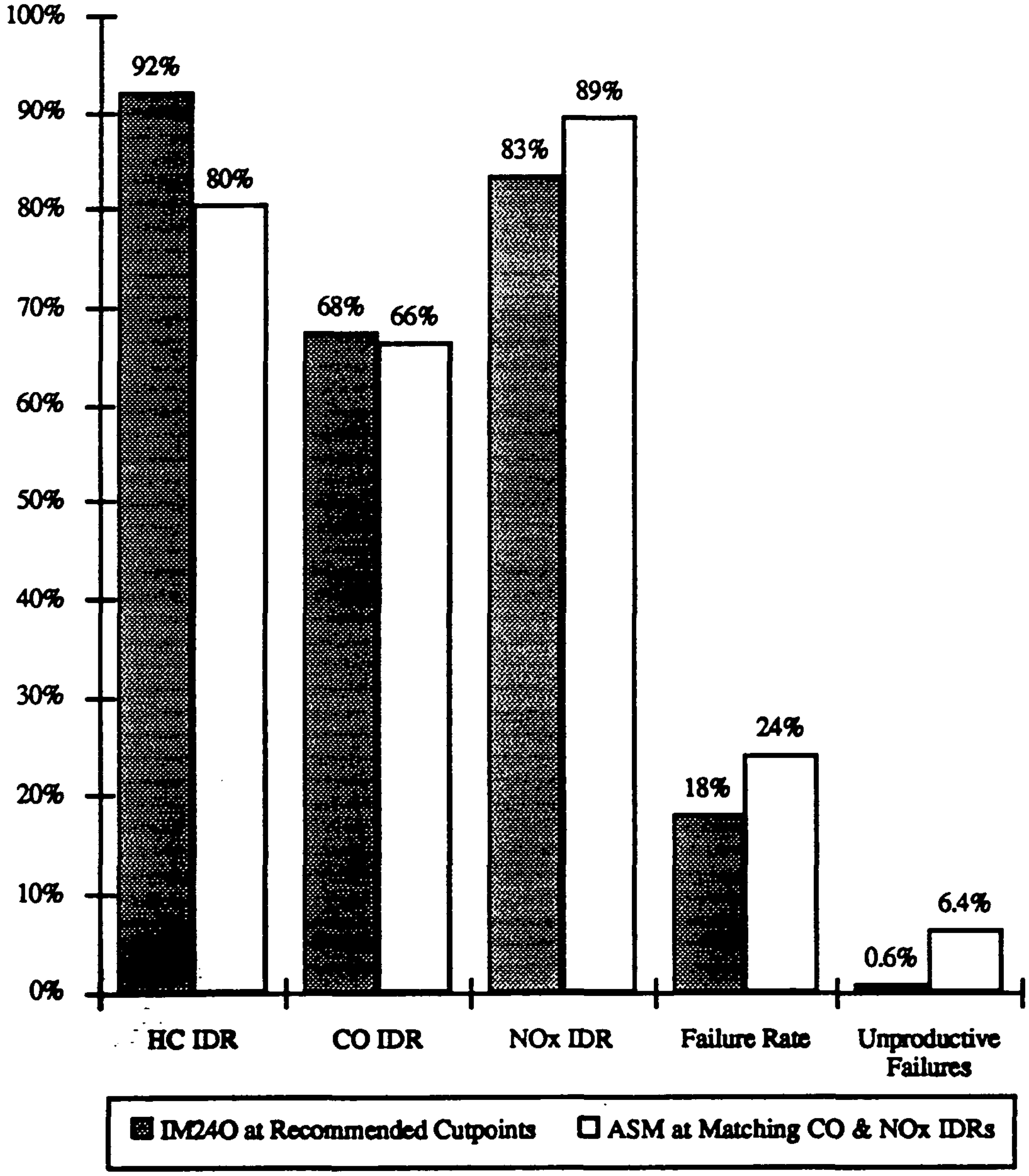
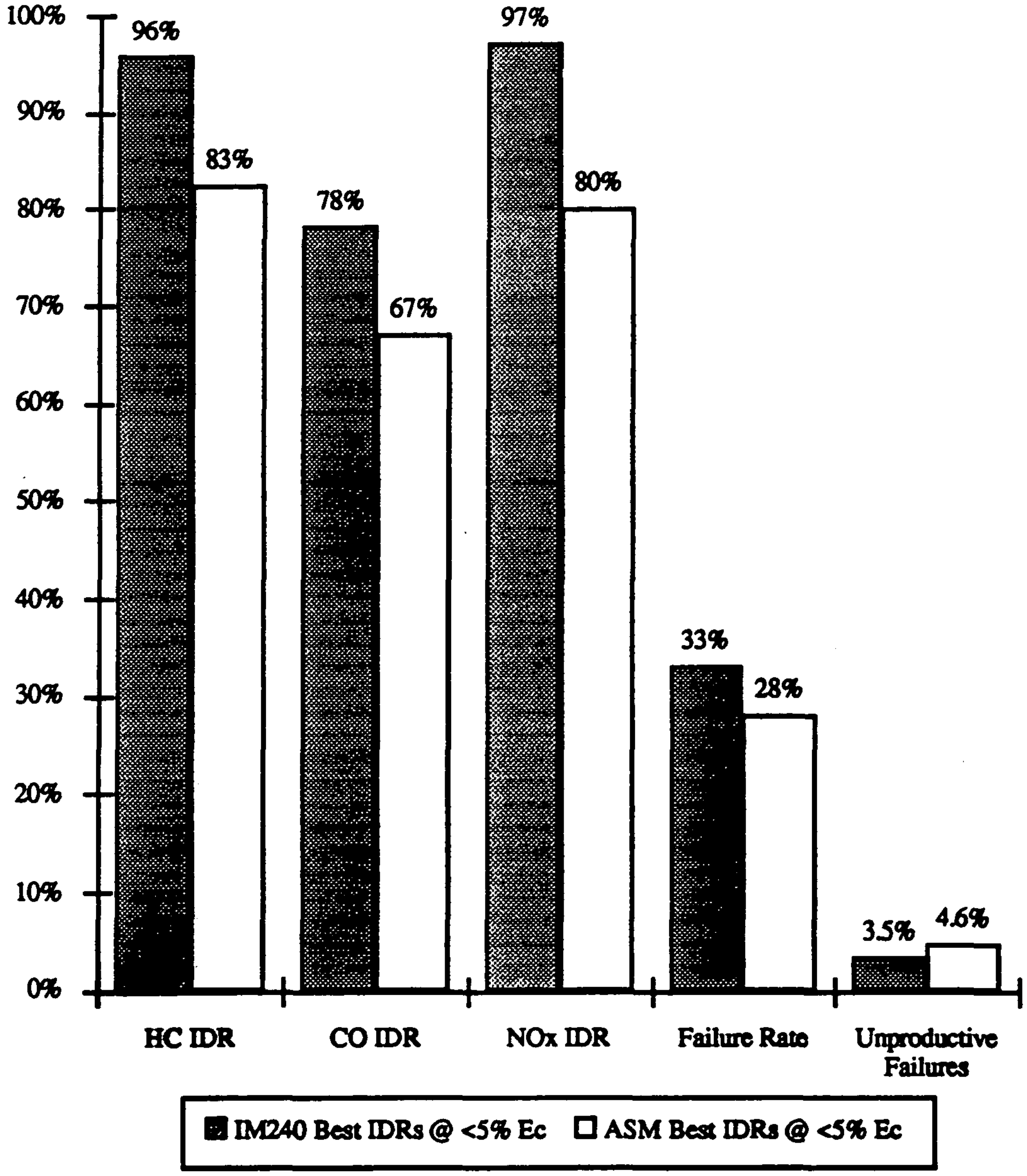


Figure 5.3.4
Comparison of ASM & IM240
Maximum IDRs @ Ec <5%



5.4 Comparison Using Scatter Plots and Regression Tables

The objective of this analysis was to check the correlation of both the IM240 and the ASM test with the FTP. The correlations are illustrated in Figures F-1 through F-9, in Appendix F. Appendix F includes regression tables along with these scatterplots. The regressions show similar R^2 over the entire data range, but the IM240 correlates much better to the FTP for vehicles emitting closer to the FTP standards.

5.4.1 Using the Coefficient of Determination (R^2) and Standard Error of the Estimate for Objective Comparisons

R^2 represents the percentage of variability in the dependent variable (FTP result) that is explained by the independent variable (I/M test result) and is often used to compare one I/M test's effectiveness with another's, but R^2 can often be misleading. Since R^2 is often used in correlation studies, it does provide an indication of comparative test accuracy that would be of interest to readers accustomed to seeing such comparisons. More important, however, is how well these tests discriminate between malfunctioning and properly functioning vehicles at an I/M station, which is best measured using the techniques discussed in Section 5.2.

For a vehicle to fail an IM240, it must fail the two-ways-to-pass-criteria developed by EPA (see Section 5.2.2). The R^2 values presented in this section are for composite IM240 scores only and do not account for this. Two-ways-to-pass affects the quantitative correlation between IM240 and FTP significantly because the Mode-2 HC and CO values are often more representative of vehicles' actual FTP emissions. However, EPA believes it is not appropriate to mix and match composite and Mode-2 scores into one quantitative correlation analysis.

Additionally, the R^2 comparisons presented here do not account for the sample's bias toward high emitters (discussed in Section 5.2.5.8). The 106 vehicles that were recruited to the lab for FTP testing were purposely biased to include a high number of dirty vehicles. When regressing the I/M test scores versus the FTP to determine R^2 values, these high emission values disproportionately influence some regression statistics, given the typical distribution of in-use emissions data. Thus the emission values close to the FTP standards (where comparing I/M tests is most important), have less influence on the R^2 statistic than desirable for determining the actual merits of these tests. Cutpoint tables account for this sample bias by weighting each vehicles' emissions according to the population of vehicles tested at the I/M lane.

To account for these limitations the sample was divided into the following three groups:

- **All Vehicles.** This database is not very useful for comparing correlation because the cleanest and dirtiest vehicles dominate the R^2 statistic. Both tests correctly differentiate these. More pertinent are the vehicles with emissions closer to the FTP standard, where the capability of I/M tests is not masked by the very clean and very dirty vehicles. Also, vehicle 3211 is a CO outlier for both tests. It has a major effect on the regression equation and the R^2 , thus masking the typical capability for both procedures.

- **Vehicle 3211 Removed** for HC, CO, NOx. This database better characterizes the correlation of both short tests with the FTP, but for the reasons discussed, it is not the most relevant for comparing the effectiveness of the tests.

- **Marginal Emitters:** Only vehicles that are not very clean or not very dirty on FTP using following criteria:

  HC ≥0.30 g/mi and <1.5 g/mi on the FTP
  CO ≥2.5 g/mi and <25.0 g/mi on the FTP
  NOx ≥0.5 g/mi and <2.25 g/mi on the FTP
  Also, Vehicle 3211 was excluded as an outlier.

  All vehicles with FTP emissions less than 0.30 HC, 2.5 CO, and 0.5 NOx passed the ASM and IM240 tests, for all the cutpoint sets evaluated in Section 5.3.

The standard error is an objective measurement of test variability expressed in the units (g/mi. in this case) of the variables used in the regression. Because R^2 are expressed as percents, standard errors have an advantage of being less abstract.

Table 5.4.1 provides a summary of R^2 and standard errors for Figures F-1 through F-9 in Appendix F, divided into the 3 groups just discussed. The "Marginal Emitters" group indicates that the R^2 for the IM240 are considerably higher for HC and NOx, and somewhat higher for CO. Likewise, all the standard errors are lower for the IM240, most notably for HC.

Table 5.4.1 Summary of R^2 and Standard Errors

	Data Set:	All Vehicles		Vehicle 3211 Removed		Vehicles Near Standards	
	n:	106		105		43	
	Procedure:	IM240	ASM	IM240	ASM	IM240	ASM
HC	R^2 =	82%	73%	83%	74%	63%	17%
	Std. Error =	0.62	0.76	0.61	0.75	0.19	0.28
CO	R^2 =	54%	68%	75%	80%	25%	13%
	Std. Error =	13.4	11.2	10.0	8.9	4.3	4.6
NOx	R^2 =	70%	71%	70%	71%	46%	26%
	Std. Error =	0.65	0.64	0.66	0.64	0.34	0.39

The standard errors listed in Table 5.4.1 can be used to estimate the lowest FTP value that would confidently predict a dirty vehicle. For example, the HC standard error is 0.28 g/mi for the "Marginal Emitters" group. Since 95% of the time, a vehicle's result will be within ±2 standard errors, this suggests that the lowest ASM HC score that confidently predicts an HC-dirty vehicle (i.e., FTP HC > 0.41) is the ASM HC score that yields (using the regression equation) an FTP HC of 0.97 g/mi [0.41 + (2 * 0.28)]. In contrast, using the IM240 error of 0.19 g/mi means the lowest IM240 score that confidently predicts a HC-dirty vehicle is 0.79 g/mi, over 18% less than the score needed to confidently predict an ASM HC dirty vehicle.

5.4.2 Advantage of Using Weighted Modes

The ASM test is given a big advantage in the way the regressions are performed because each mode is weighted separately according to the IM240. On the other hand, the IM240 score is a non-weighted score. EPA developed the IM240 to contain similar driving conditions as the FTP. However, the frequency of each condition is not proportional to the FTP. By weighting different modes of the IM240 to the FTP similar to the way EPA has weighted the 4 modes of the ASM test, EPA has found the R^2 for the IM240 to improve immensely. The current score reported for the IM240 is something like weighting each mode of the ASM test 25%. This would hurt the correlation of the ASM with the FTP, because, as is shown in Section 5.5, the 50 mph mode accounts for roughly half of the composite ASM scores for each pollutant.

5.4.3 Observations of Scatterplots

The scatterplots for the first two sets of data (Figures F-1 through F-6) do not appear much different for either test, mainly because the high emitters cause the emissions close to the standards to appear as a tight pack of data. The plots for vehicles near the standard only (Figures F-7 through F-9), however, suggest the following:

HC - The IM240 identifies the dirtier cars much better. Notice on the ASM HC plot how many high emitters (FTP HC>0.82 g/mi) still score relatively low on the composite ASM score. Six vehicles pass the very tight ASM HC cutpoint of 0.3 predicted g/mi, yet have FTP emissions greater than twice the FTP standard (0.82 g/mi).

CO - Neither test appears to correlate very well over this emission range for CO. Two issues come into play that explain why this is. First, cars with loaded canisters will have high IM240 Mode-1 CO emissions at the lane, causing the short test to have a high score while the FTP at the lab is relatively low. The second scenario is cold start problems. Two vehicles in the database (Vehicles 3175 and 3227) appear to have cold start problems, with high Mode-1 FTP CO emissions, and low Bag-3 FTP CO emissions. Since the lane test is a hot start test, these vehicles will show up clean at the lane, and the cold start FTPs will be significantly dirtier.

NOx - The IM240 has a slightly tighter fit to the regression line, and more of the FTP dirty cars fall to the upper right of the scatterplot (i.e., fail the test properly).

5.4.4 Poor ASM HC Correlation

As discussed in Section 5.3, ASM HC scores do not correlate very well with FTP HC scores. This section briefly discusses theoretically why some of these vehicles had very low ASM HC emissions, yet failed the IM240 and FTP for HC emissions. Because the contractor's mechanics were not aware of the ASM scores, vehicles were not diagnosed with the objective of determining the cause of the performance differences on these I/M tests.

The first four vehicles in Table 5.4.2 were found to have ignition problems. This is logical considering that misfire, which causes high HC, is sometimes related to load. As load increases the voltage required to jump the spark plug gap also increases. Some portions of the IM240 load the vehicle more heavily than any of the ASM modes, so a marginal ignition system that only causes misfire during the higher IM240 loads will not be identified by ASM HC.

Vehicles 3180 and 3264 were found to have bad O_2 sensors and other malfunctions. Slow responding O2 sensors are more likely to be identified during a transient test, because changing throttle position tends to cause air/fuel ratio excursions that will cause high emissions unless the fuel induction system rapidly compensates to maintain the optimum air/fuel ratio. So slow responding O2 sensor might explain the high HC on the IM240 and low HC on the ASM.

The disconnected vacuum lines on vehicle 3201 could have caused lean-misfire during accelerations on the IM240 that would not be apparent on the steady-state modes of the ASM.

These explanations can not be proven with the existing data, but they should indicate that a steady-state test suffers from known disadvantages in identifying vehicles with these types of malfunctions.

Table 5.4.2 Vehicles with Poor ASM HC Correlation

VEH	ASM HC	FTP HC	IM240 HC	Problem Found
3259	0.23	1.94	1.50	Ignition Module
3257	0.25	1.26	1.92	Plug Wires, Plugs Transducer, Ignition Coil Transistor
3155	0.34	3.25	2.77	Incorrect Plugs, Torn wire boot
3210	0.35	1.40	1.04	O2 Sensor, Spark Plugs, Fuel Hose, Catalyst
3180	0.15	0.96	1.33	O2 Sensor and Injectors
3264	0.49	1.36	2.16	O2 Sensor, Vacuum Switching Valve
3254	0.29	1.87	2.26	ECU Intermittent, Catalyst
3201	0.17	0.94	1.15	Vacuum Lines Disconnected
3165	0.39	1.96	1.59	Dirty Injectors

5.5 Derivation of ASM Coefficients and Mode Contribution Variations From Sample to Sample

This section discusses why the ASM coefficients that EPA based its analyses on were developed using the IM240 as the dependent variable rather than the FTP. BAR/Sierra and ARCO used the FTP to develop ASM Coefficients.

Also discussed are the rather large variations in the ASM coefficients with different samples, and the variation in the contribution of each ASM mode to the final ASM score (expressed as percent contribution).

5.5.1 ASM Versus IM240 As The Dependent Variable For Determining ASM Coefficients

EPA faced a dilemma in determining the best method for developing the ASM equation coefficients. No ASM advocate has recommended specific coefficients, on which, EPA should accept or reject the ASM approach. So two options were to: 1) perform the multiple regressions on all the lab recruited vehicles for ASM versus FTP. Or, 2) perform the multiple regressions for ASM versus IM240 on a subset of the lane sample, excluding all lab recruited cars.

Obviously, the ideal method is to regress the ASMs versus FTPs (i.e., option 1), but this raises a problem. To evaluate how well the ASM identifies FTP failing vehicles, the coefficients must be applied to the lab recruited vehicles to calculate simulated grams/mile scores. However, good statistical practice mandates applying the coefficients to a different sample than those from which they were developed.

This interlinking method, wherein the coefficients are applied to the same vehicles from which they were developed, would minimize the effects of the test's variability. This improper interlinking is illustrated using results from Vehicle 3211. This vehicle's lane-IM240 CO score was 93 g/mi and its ASM CO score was 65 g/mi using the coefficients from the 608 vehicle sample listed in Table 5.5.1 (The relevance of the other samples in this table will be discussed later). Its FTP CO score was only 10.8 g/mi.

Table 5.5.1
CO Coefficients Developed from Different Samples

Mode	CO Sample 1	CO Sample 2	CO All 608	CO vs FTP
Constant	2.814	2.836	2.936	5.533
5015	0.035	0.116	0.040	**-0.047**
2525	0.072	**-0.058**	0.043	0.565
50 MPH	0.425	0.391	0.356	0.050
Idle	0.891	2.014	1.350	1.968
Adjusted R^2	34.2%	58.4%	50.1%	80.6%

The scatter plots below show that using the IM240-developed coefficients cause this vehicle to be easily identified as an outlier. In marked contrast, using the FTP-developed coefficients make it look like this vehicle's ASM score highly correlates to its FTP score. The ASM mode scores are weighted differently, so the high scoring mode(s) are de-emphasized. But these same-sample FTP-based ASM coefficients are obviously peculiar to this sample, and highly dependent on it containing this one particular car. (See Tables 5.5.1 and 5.5.6.)

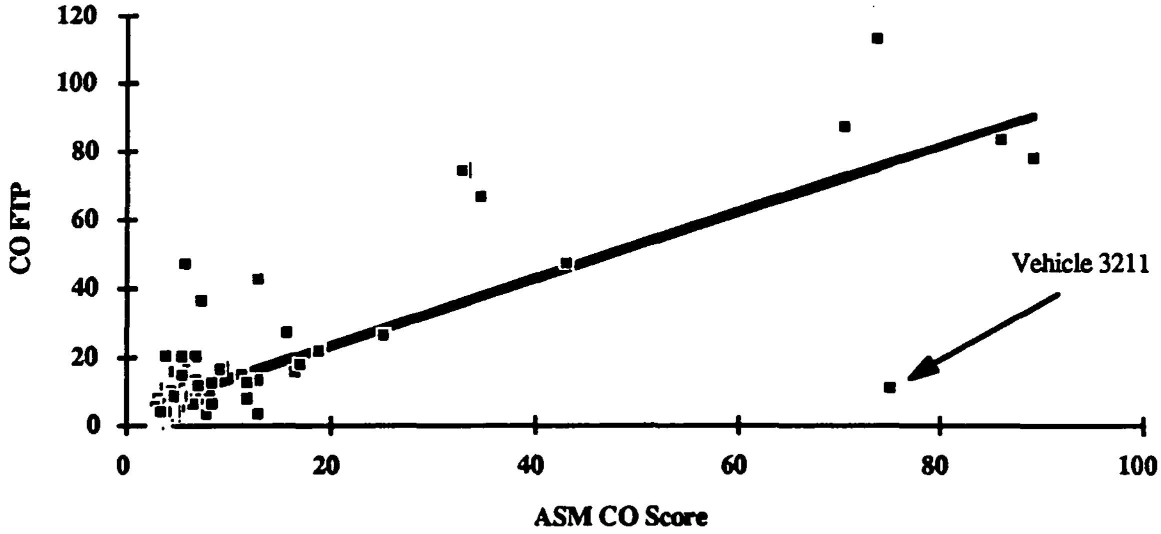
Still not answered is which ASM coefficients better indicate whether the vehicle is malfunctioning or not. Some could argue that this vehicle should not be an outlier. Instead, the IM240-developed coefficients inappropriately make it appear as an outlier. Attempting to resolve this, the raw ASM concentration measurements were checked. This vehicle's 50 mph mode CO concentration was 4.96%, which is higher than 97% of vehicles recruited to the lab (103 of the 106 vehicles).

Using the same-sample, FTP-based ASM coefficients prevents this vehicle from being an outlier because they adjust themselves to minimize the effect of the 50 mph mode score from all cars. Additionally, the very high concentration measurement (4.96%) proves that the vehicle had a malfunction causing very high emissions that had been inappropriately minimized. (This was also verified during the mechanic's inspection which found a defective O2 sensor and that an ECM PROM update was required.) This evidence strongly supports EPA's properly using the preconditioned IM240s as the dependent variable for developing ASM coefficients to compare the ASM and IM240 correlations with the FTP.

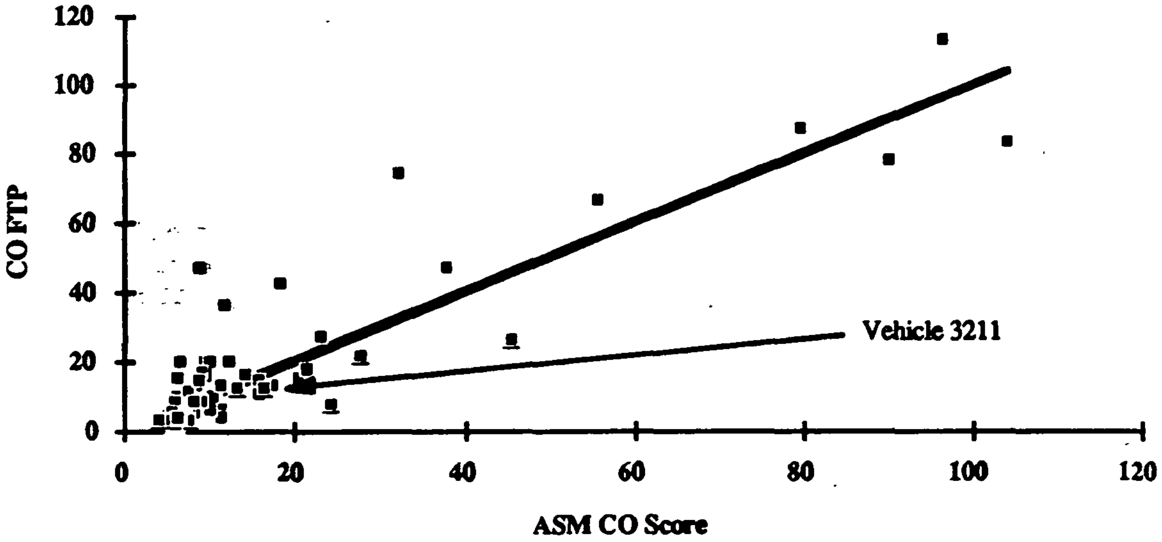
This evidence also casts doubt on conclusions developed from test programs that used interlinked coefficients. Interlinking makes the correlation between the ASM, or any other test, and the FTP significantly better than could be expected in an official I/M program. Since I/M programs will apply ASM coefficients to vehicles that were never FTP tested, the opportunity for interlinking will not exist, so ASM performance should not be evaluated using interlinked coefficients.

Another reason for EPA's not using FTP-based coefficients is because some are negative, which means that as ASM5015 emissions increase, FTP emissions decrease. This is counter-intuitive.

ASM Coefficients Developed
from
608 Lane ASM vs Pre-Conditioned IM240s



ASM Coefficients Developed
from
106 Lane ASM vs Lab FTP

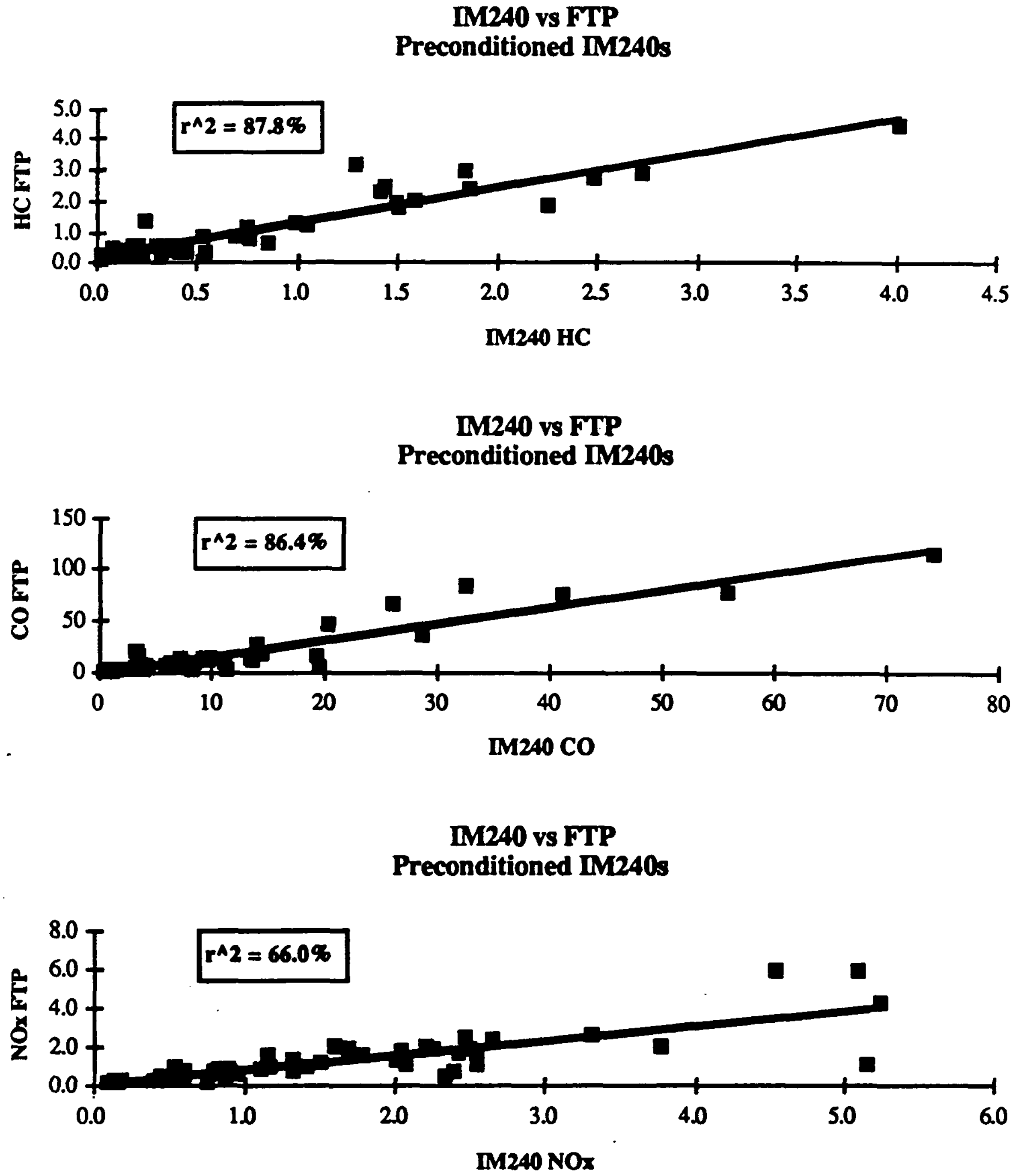


EPA decided that the best method, using the Arizona data, was to regress the four steady-state modes (three for NOx) against lane-only, preconditioned IM240s. There were three major factors leading to this decision. First, this allowed applying the coefficients to a different subset of data (the lab recruited vehicles). Second, the sample size was considerably larger (608 vs. 106 tests). EPA's FTP sample was too small to divide and use half to determine coefficients and the other half to evaluate ASM effectiveness, which is supported by the negative coefficient yielded for the ASM5015 listed in Table 5.5.1. Third, only preconditioned IM240s were used because they correlate better with the FTP than non-preconditioned IM240s. The only significant compromises in using IM240s instead of FTPs is that the composite ASM score does not include a cold start excess (which would be independent of warmed-up ASM mode concentrations anyway) and that the mix of speeds and loads in IM240 is not exactly like that in the full FTP driving cycle (a hardship borne by the IM240 in its own correlation to the FTP).

Figure 5.5.1 illustrates that preconditioned IM240s strongly correlate with the FTP. These data are from the 106 lab recruited vehicles, but are restricted to IM240s that were performed following the ASM at the lane, making them preconditioned IM240s.

NOx has the worst correlation because of a few outliers at the high end, but this is not a concern for the ASM since the NOx coefficients are relatively stable, which is discussed in the next section.

Figure 5.5.1 High Correlation of Preconditioned Lane-IM240s with FTPs



5.5.2 Variability of ASM Coefficients

The objective of the following analysis was to investigate the stability of the coefficients used to calculate composite ASM simulated grams/mile scores. The database was divided into four samples for comparison.

Sample 1 was developed by using a random number generator to select 304 vehicles from the lane-only fleet of 608. The remaining 304 vehicles became Sample 2. Sample 3 was all 608 vehicles, and the fourth sample was the 106 laboratory vehicles. The ASM coefficients for the first three samples were developed using the IM240 as the dependent variable and the FTP sample used the FTP for the dependent variable. The resulting coefficients are listed in the following tables. (Table 5.5.3 is a duplicate of Table 5.5.1.).

Table 5.5.2

HC Coefficients Developed from Different Samples

Mode	HC Sample 1	HC Sample 2	HC All 608	HC vs FTP
Constant	0.080	0.073	0.083	0.291
5015	0.045	0.008	0.025	-0.261
2525	0.047	0.059	0.059	0.507
50 MPH	0.147	0.123	0.136	0.238
Idle	0.084	0.585	0.124	0.154
Adjusted R^2	21.7%	38.9%	29.0%	79.4%

Table 5.5.3

CO Coefficients Developed from Different Samples

Mode	CO Sample 1	CO Sample 2	CO All 608	CO vs FTP
Constant	2.814	2.836	2.936	5.533
5015	0.035	0.116	0.040	-0.047
2525	0.072	-0.058	0.043	0.565
50 MPH	0.425	0.391	0.356	0.050
Idle	0.891	2.014	1.350	1.968
Adjusted R^2	34.2%	58.4%	50.1%	80.6%

Table 5.5.4
NOx Coefficients Developed from Different Samples

Mode	NOX Sample 1	NOX Sample 2	NOX All 608	NOX vs FTP
Constant	0.230	0.279	0.258	0.190
5015	0.088	0.045	0.061	0.148
2525	0.206	0.212	0.219	0.093
50 MPH	0.386	0.333	0.352	0.291
Adjusted R^2	60.2%	57.9%	59.1%	71.1%

The negative coefficients are highlighted in bold. One could infer from the negative coefficients that increasing the emissions during that mode of the ASM would lower the composite score.

These coefficients were used with the ASM data, from each of the 106 lab-recruited vehicles, to calculate the emissions for each mode and the percent of the total emissions that each mode contributed. These mode contributions give a better indication of each modes importance in the final ASM score, than the coefficients, which are more difficult to interpret. The results are listed in the following tables:

Table 5.5.5
Average Contribution of Total HC Emissions by Mode

Mode	HC Sample 1	HC Sample 2	HC All 608	HC vs FTP
Constant	17%	17%	19%	11%
5015	20%	4%	12%	-75%
2525	17%	22%	22%	116%
50 MPH	43%	39%	43%	45%
Idle	2%	18%	4%	3%

Table 5.5.6
Average Contribution of Total CO Emissions by Mode

Mode	CO Sample 1	CO Sample 2	CO All 608	CO vs FTP
Constant	26%	27%	29%	28%
5015	4%	12%	4%	-5%
2525	7%	-6%	4%	55%
50 MPH	57%	53%	51%	7%
Idle	6%	15%	11%	15%

Table 5.5.7
Average Contribution of Total NOx Emissions by Mode

Mode	NOX Sample 1	NOX Sample 2	NOX All 608	NOX vs FTP
Constant	15%	20%	17%	20%
5015	11%	6%	8%	22%
2525	24%	27%	27%	13%
50 MPH	50%	47%	48%	45%

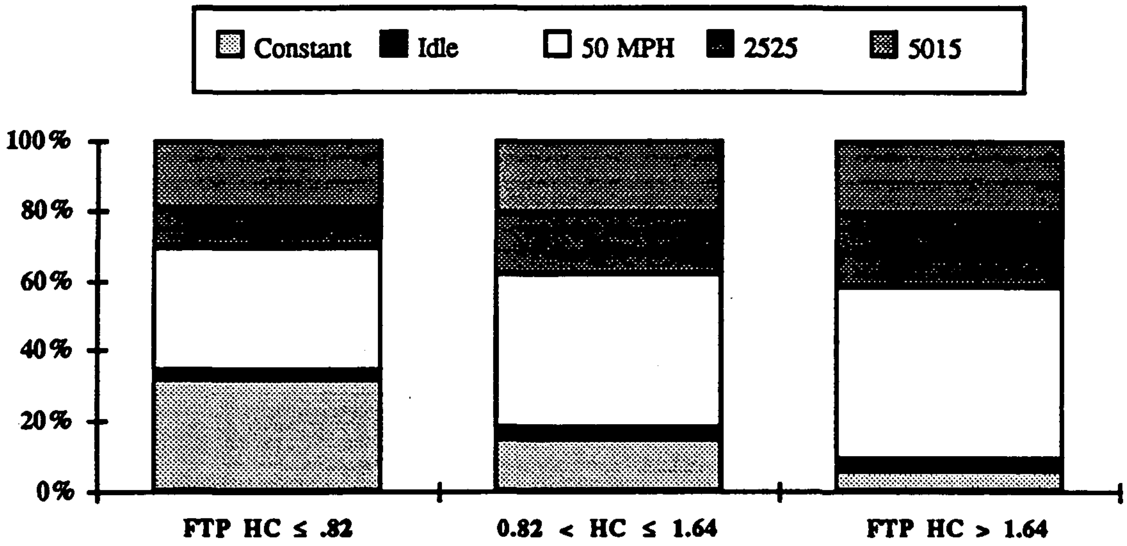
The HC coefficients in particular are very volatile, and that the negative FTP-developed coefficients are counter-intuitive. When applying the coefficients from Sample 1, the idle mode, on average, only contributes 2% to the total score. This contribution jumps to 18% when the coefficients from Sample 2 are applied. Similarly the ASM5015 contribution drops from 20% to 4%. These examples indicate that the largest sample (608 vehicles) with preconditioned IM240s was the best sample available for developing ASM coefficients.

5.5.3 Significance of Mode Contributions

The ASM mode contributions also vary as the composite ASM score moves from low values (for which the constant term will be the primary contributor to the composite score) to relatively high values (for which the constant term will be a relatively small contributor to the composite emission). This is illustrated in Figures 5.5.2 to 5.5.4. For CO, the ASM5015 and ASM2525 are combined, because of the negative contributions of 2525 and the small contribution of the ASM5015 in relation to the 50 mph mode.

Figure 5.5.2
Mode Contributions for HC

Using Sample 1 Coefficients



Using Sample 2 Coefficients

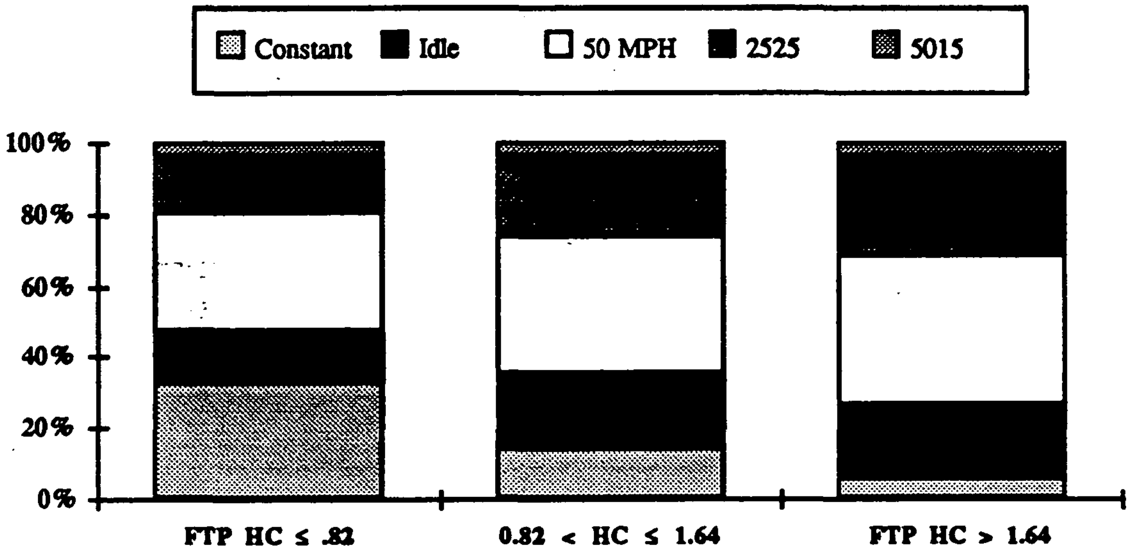
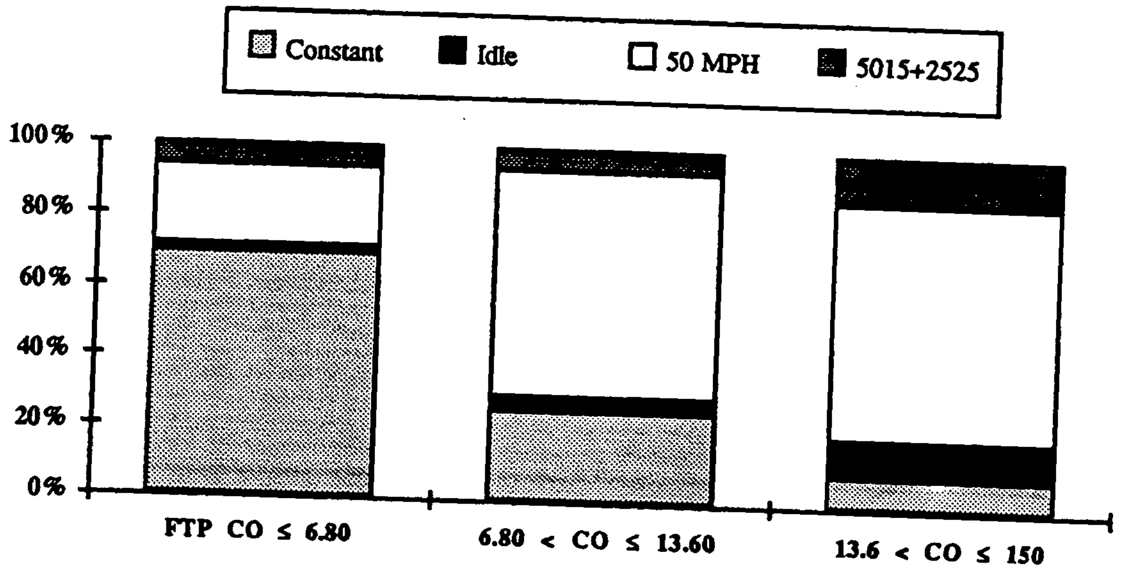


Figure 5.5.3
Mode Contributions for CO


Using Sample 1 Coefficients

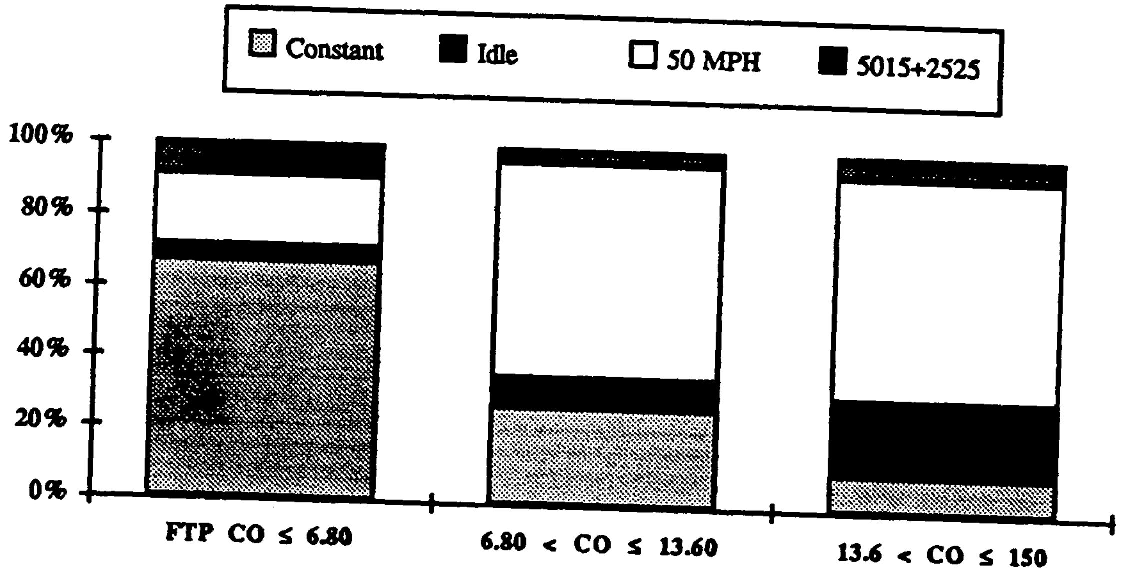
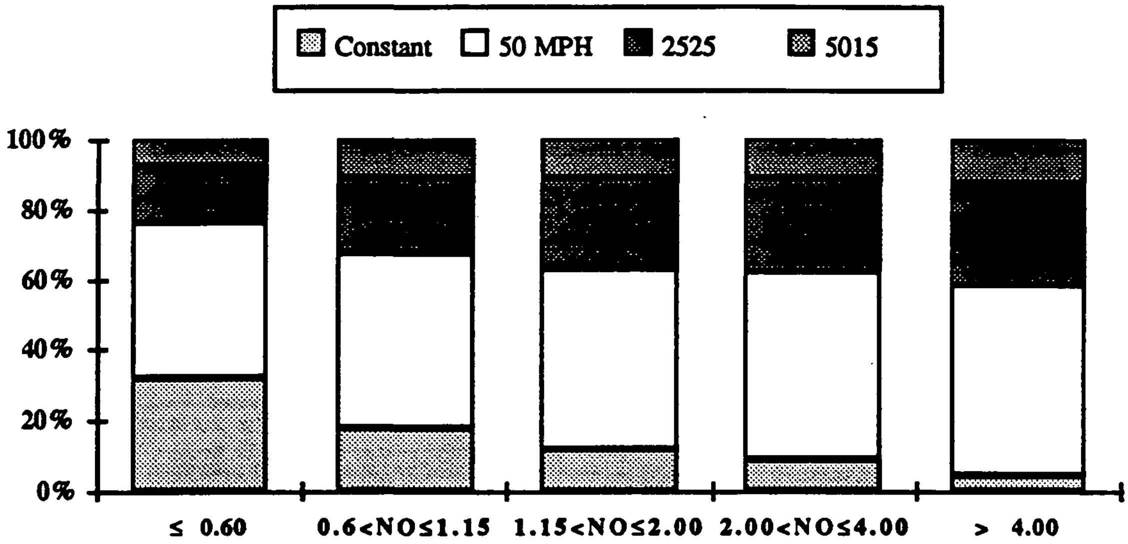
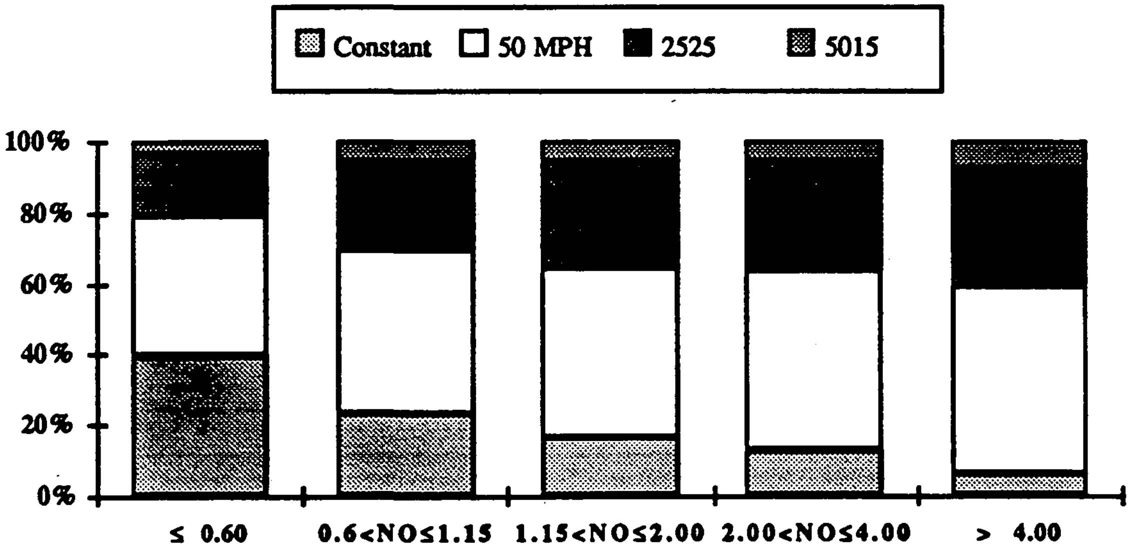

Using Sample 2 Coefficients

Figure 5.5.4
Mode Contributions for NOx

Using Sample 1 Coefficients



Using Sample 2 Coefficients



The fact that the 50 mph mode contributes so much to the composite score for each pollutant is also reason for concern. This opens the opportunity for mechanics to adjust vehicles to lower emissions for just one mode (namely the 50 mph), which will be further discussed in Sections 5.6.3 and 5.6.4.

5.5.4 Conclusions on ASM Mode Contributions

While not a mode that was recommended by the ASM developers, the 50 mph mode at road load horsepower appears to be more important for identifying dirty vehicles than the lower speed, acceleration simulation modes (ASM5015 and ASM2525). Surprising was the small contribution of the ASM5015 (mode 1) for identifying dirty vehicles considering that BAR/Sierra and ARCO both found this mode to be the most effective. This suggests that the first mode in a four mode sequence serves mainly to precondition vehicles for the following modes. Randomizing the order of the modes may be useful in determining the best sequence.

For the cutpoint analysis in Section 5.3 and the regression analysis in Section 5.4, the ASM scores used were those calculated from the coefficients developed from the 608 ASM versus preconditioned lane-IM240s. However, the variability of the HC coefficients between the two random subsets of 304 tests suggest that a different sample of 608 tests might produce substantially different equation coefficients. The resulting change in HC (and in some cases CO and NOx) ASM scores would produce different failure rates, IDRs, and Ec rates in the cutpoint tables, and different R^2 values in the regressions of ASM versus FTP. So the volatile coefficients may vary from sample to sample, or worse yet region to region, resulting in disparate I/M programs which would be hard to evaluate on a consistent basis.

5.6 Repair Analyses

5.6.1 Contractor Repairs

The objective of this analysis was to investigate the performance of both the IM240 and the ASM tests as predictors of changes (i.e., decreases or increases) in FTP emissions following contractor-performed, IM240-targeted repairs.

Of the 106 vehicles used in the cutpoint analysis (Table 4.2.2), 56 exceeded the lane-IM240 0.80/15.0/2.0 + 0.50/12.0 cutpoint and were repaired by the contractor. Of these, 52 received each of the three following tests both prior to repairs (i.e., as-received) and following repairs:

- a Lane-IM240,
- a Lane-ASM, and
- an FTP.

These 52 were used in this analysis and are included with the data listed in Appendix B. The resulting database of those 52 fuel-injected vehicles has the following distribution:

	Order of Lane Testing	
Fuel Metering	**ASM Prior to IM240**	**IM240 Prior to ASM**
PFI	14	16
TBI	11	11

The contractor was instructed to perform the minimum repairs necessary in order that each vehicle's IM240 emissions after repair (as tested at the contractor's laboratory) meet the following criteria:

- composite IM240 HC $\leq$ 0.80 g/mi,
- composite IM240 CO $\leq$ 15.00 g/mi, and
- composite IM240 $NO_X \leq$ 2.0 g/mi.

The contractor was allowed multiple repair attempts if the first set of repairs did not reduce the IM240 emission levels enough. The repairs were limited to $1,000 per car. And, the contractor was instructed that "the mechanic should only be aware of the IM240 scores for the IM240-targeted repairs." Because ASM cutpoints, that could distinguish malfunctioning vehicles from properly functioning vehicles, were not yet developed, only IM240-targeted repairs were performed.

These IM240 emission repair criteria were met at the contractor's laboratory for all cars prior to the second and final FTP, with the highest after-repair laboratory IM240 composite HC emission score of 0.56, CO of 10.82, and NOx of 1.93 (g/mi). The effects of those IM240-targeted repairs on FTP emissions are illustrated in the following table:

Table 5.6.1.1

FTP Emissions Prior to and Following IM240-Targeted Repairs

FTP	Emissions	Mean	Range of Emissions Minimum	Range of Emissions Maximum
HC	As-Received	1.458	0.16	13.07
	After Repair	0.326	0.10	0.75
CO	As-Received	19.707	0.28	113.40
	After Repair	3.331	0.63	8.82
NOx	As-Received	1.649	0.20	7.56
	After Repair	0.739	0.05	1.81

The resulting FTP emissions after the IM240-targeted repairs were essentially independent of the as-received FTP emissions. (That is, the R-squares associated with before and after HC, CO, and NO_X were only 0.1%, 1.2%, and 1.0%, respectively.)

The data from these repaired vehicles can give insight into the question of whether the IM240 test and cutpoints cause repairs to be made which also reduce FTP emissions. In other words, does the IM240 and the FTP correlate well on a single vehicle? This correlation is to be expected based on the realistic nature of the IM240 driving cycle, and the good correlation found in samples of vehicles not repaired.

For each of those 52 vehicles (all 1983 and newer fuel-injected cars), the change in each pollutant (HC, CO, and NO_X), following contractor repairs, was calculated for each of those three test cycles. Regressing the reductions in the lane emissions against the reductions in FTP emissions produced Tables 5.6.1.2 and 5.6.1.3. The six graphs (Figures 5.6.1.1 through 5.6.1.3) that follow those regression tables illustrate the results of this analysis.

Table 5.6.1.2

Regression of Changes in Lane-IM240 Emissions Following Contractor Repairs Versus Corresponding Changes in FTP Emissions

Dependent variable is: Δ(FTP HC)

R^2 = 81.9%

s = 0.8320 with 52 - 2 = 50 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	156.693	1	157	226
Residual	34.611	50	0.69222	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**
Constant	-0.365173	0.1524	-2.4
Δ(IM240 HC)	1.4106	0.0938	15

Dependent variable is: Δ(FTP CO)

R^2 = 47.5%

s = 18.50 with 52 - 2 = 50 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	15469.4	1	15469	45.2
Residual	17110.1	50	342.203	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**
Constant	4.64057	3.103	1.5
Δ(IM240 CO)	0.846373	0.1259	6.72

Dependent variable is: Δ(FTP NOx)

R^2 = 64.5%

s = 0.8846 with 52 - 2 = 50 degrees of freedom

Source	**Sum of Squares**	**df**	**Mean Square**	**F-ratio**
Regression	71.1008	1	71.1	90.9
Residual	39.1265	50	0.78253	

Variable	**Coefficient**	**s.e. of Coeff**	**t-ratio**
Constant	-0.275563	0.1747	-1.58
Δ(IM240 NOx)	0.738523	0.0775	9.53

Table 5.6.1.3

Regression of Changes in Lane-ASM Emissions Following Contractor Repairs Versus Corresponding Changes in FTP Emissions

Dependent variable is: Δ(FTP HC)
$R^2 = 71.7\%$
s = 1.040 with 52 - 2 = 50 degrees of freedom

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	137.187	1	137	127
Residual	54.1169	50	1.08234	

Variable	Coefficient	s.e. of Coeff	t-ratio
Constant	0.270944	0.1633	1.66
Δ(ASM HC)	2.18967	0.1945	11.3

Dependent variable is: Δ(FTP CO)
$R^2 = 79.5\%$
s = 11.55 with 52 - 2 = 50 degrees of freedom

Source	Sum of Squares	df	Mean Square	F-ratio
Regression	25906.3	1	25906	194
Residual	6673.29	50	133.466	

Variable	Coefficient	s.e. of Coeff	t-ratio
Constant	5.71775	1.775	3.22
Δ(ASM CO)	1.08685	0.078	13.9

Dependent variable is: Δ(FTP NOx)
$R^2 = 70.8\%$
s = 0.8016 with 52 - 2 = 50 degrees of freedom

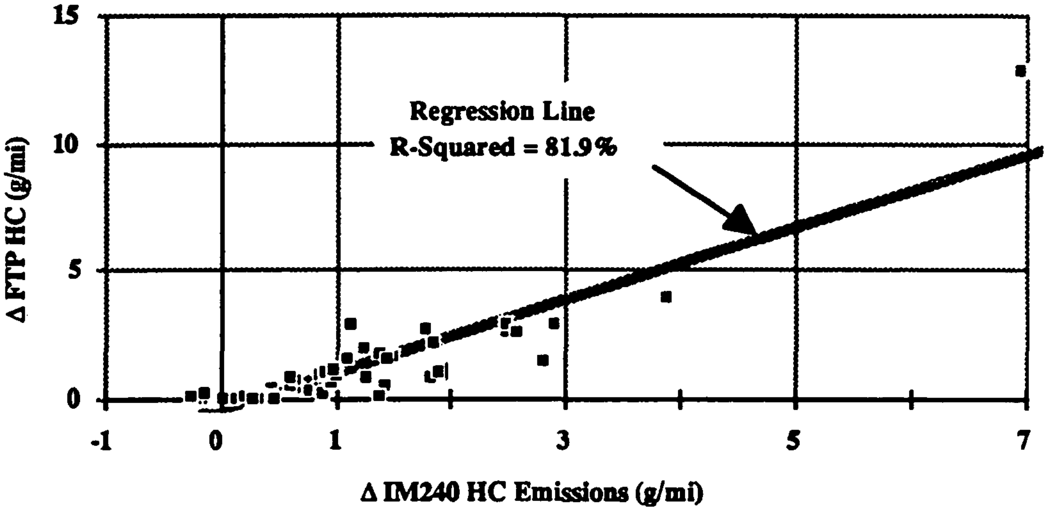
Source	Sum of Squares	df	Mean Square	F-ratio
Regression	78.0956	1	78.1	122
Residual	32.1317	50	0.642635	

Variable	Coefficient	s.e. of Coeff	t-ratio
Constant	-0.013624	0.1392	-0.098
Δ(ASM NOx)	0.829714	0.0753	11

Figure 5.6.1.1

Decreases in HC Emissions Following Repairs

ΔFTP vs ΔIM240 HC



ΔFTP vs ΔASM HC

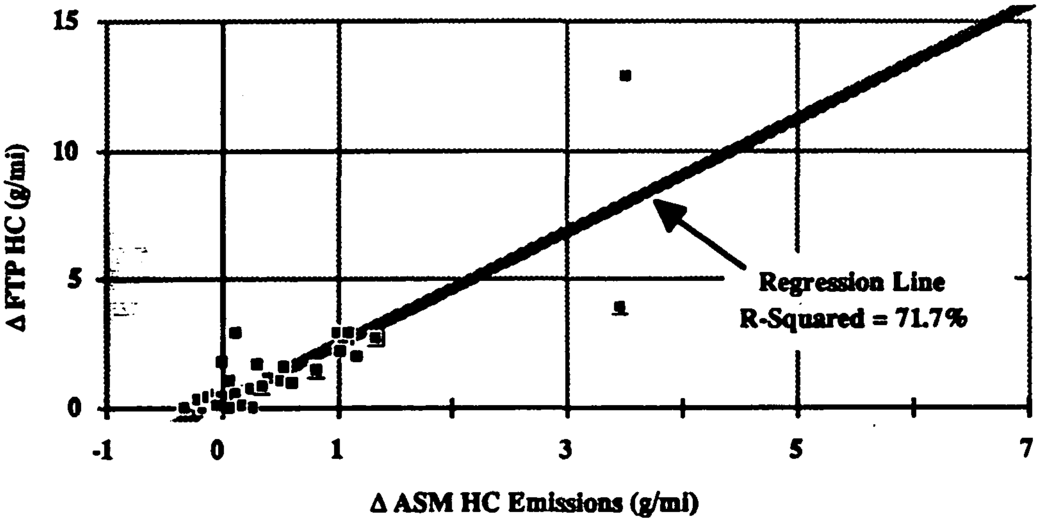
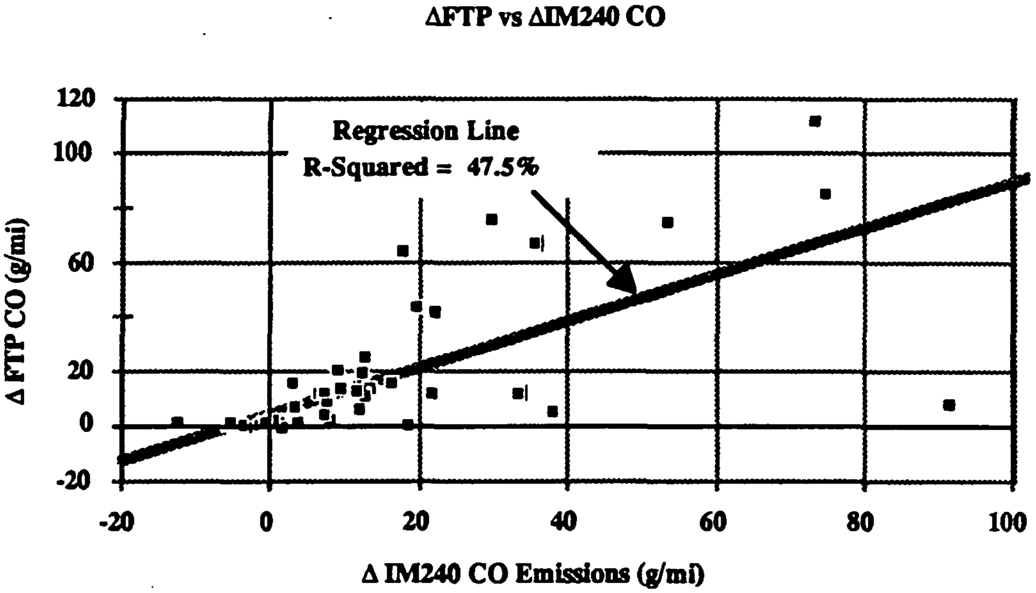


Figure 5.6.1.2

Decreases in CO Emissions Following Repairs


ΔFTP vs ΔIM240 CO

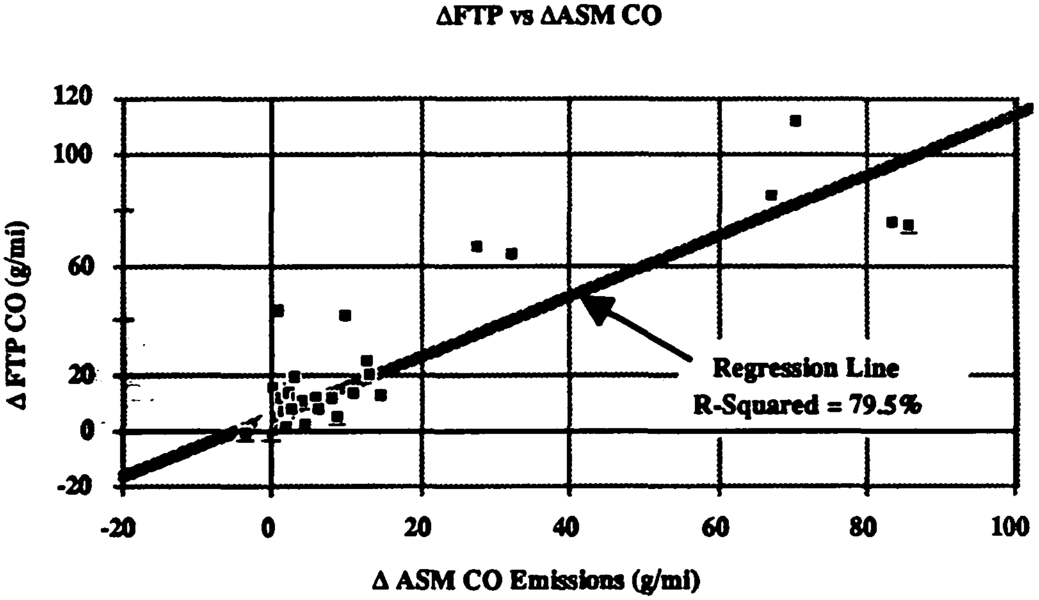
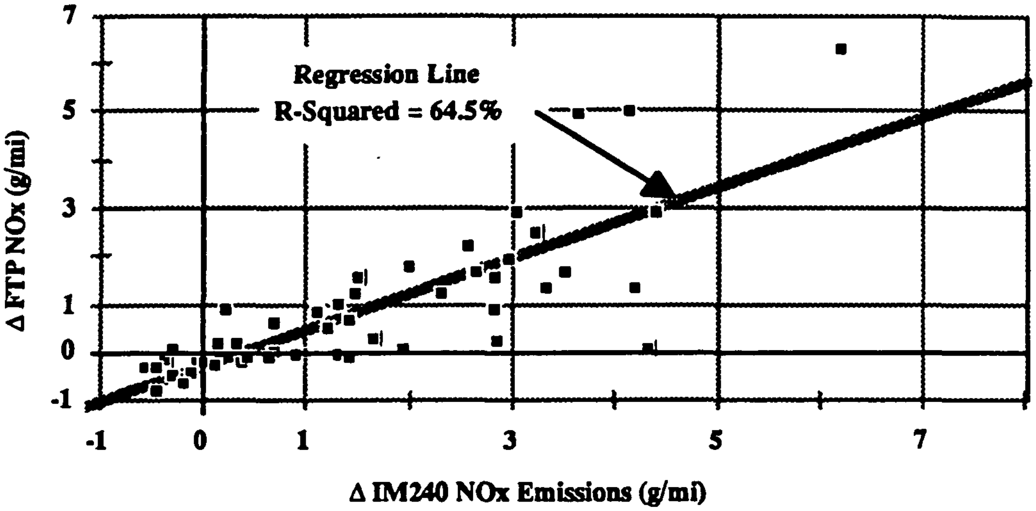

ΔFTP vs ΔASM CO

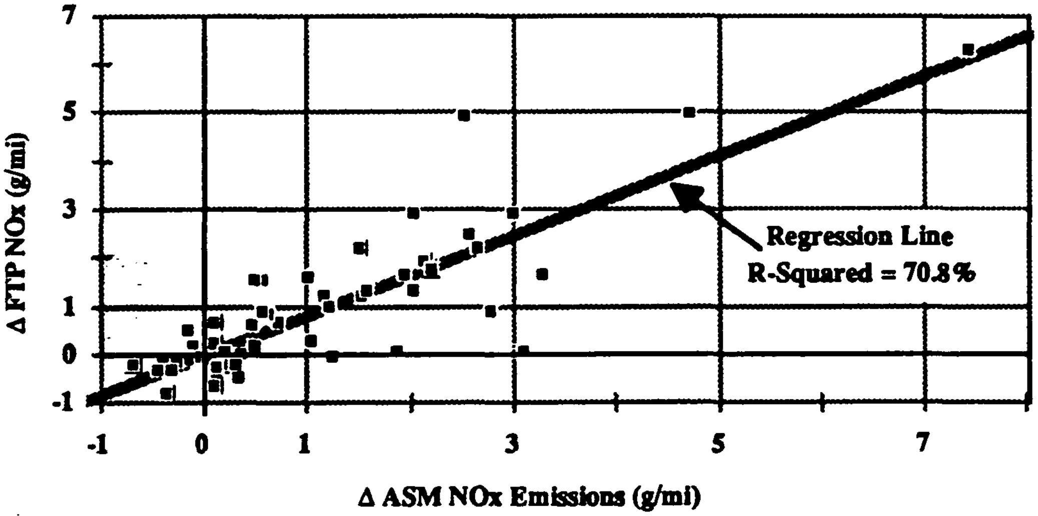
Figure 5.6.1.3

Decreases in NOx Emissions Following Repairs

ΔFTP vs ΔIM240 NOx



ΔFTP vs ΔASM NOx



Comparing the two graphs that examine the changes in HC emissions (Figure 5.6.1.1), it is apparent that one vehicle (vehicle number 3190) exhibited a reduction in FTP HC emissions substantially greater than any of the other 51 vehicles (12.88 g/mi HC reduction compared to only 3.86 for the next larger FTP HC reduction). Since it is possible that one such vehicle could substantially affect the regression analysis, a second set of regressions were performed on the remaining 51 cars (i.e., with vehicle number 3190 deleted) to determine the effect. The effects on the slopes of the regression lines are given in Tables 5.6.1.4 and 5.6.1.5.

Table 5.6.1.4
Effect on IM240 Regression Line
For HC Emissions
Of Deleting Vehicle 3190

	Based on All 52 Vehicles	Based on 51 Vehicles
Constant	-0.365173	0.018227
Coefficient	1.4106	0.93431
R^2	81.9%	74.7%

Table 5.6.1.5
Effect on ASM Regression Line
For HC Emissions
Of Deleting Vehicle 3190

	Based on All 52 Vehicles	Based on 51 Vehicles
Constant	0.270944	0.452113
Coefficient	2.18967	1.35391
R^2	71.7%	67.8%

From Tables 5.6.1.4 and 5.6.1.5, we see that deleting that potential HC outlier (vehicle number 3190) has a similar effect on each regression line. The slope of the IM240 regression line decreases 11.6 degrees, and the slope of the ASM regression line decreases 11.9 degrees. Since deleting the change in HC emissions of vehicle 3190 from the sample has the same effect on both regression lines, it would be advisable to use the equations based on 51 cars to estimate changes in FTP HC emissions based on IM240 and/or ASM HC changes, for IM240 and/or ASM HC changes between -1.0 and +4.0 g/mi.

Comparing the two graphs that examine the changes in CO emissions (Figure 5.6.1.2), it appears, at first glance, that the composite IM240 tends to over predict the repair benefit to CO emissions for some vehicles with relatively small FTP CO repair benefits. However, the actual situation is that several relatively cleaner vehicles (though still exceeding FTP standards) had unusually high IM240 results on their first test. IM240 CO was a lot lower after repair, but the FTP emissions had comparatively little room to improve. The five vehicles in Figure 5.6.1.2 that exhibit this problem (vehicles numbered: 3157, 3175, 3211, 3213, and 3214) all have as-received composite FTP CO less than 15 g/mi. For two of those five, most of the high composite IM240 emissions resulted from the first mode (i.e., the first 93 seconds) of the IM240. For this reason, EPA has recommended that vehicles which fail the composite HC or CO cutpoint be given a second chance to pass by examining the Mode-2 emissions (see "Two-ways-to-pass" in Section 5.3). A similar situation cannot happen for the ASMs as analyzed in this report because the weighting factors, in effect, cause the CO scores on the first mode (5015) to be ignored. One vehicle that deserves special note is vehicle number 3211. That vehicle exhibited the largest IM240 CO reduction (91.70 g/mi), but an FTP CO reduction of only 8.00 g/mi. This high lane-IM240 CO reduction resulted from a high initial (i.e., as-received) lane test score of 93.07 g/mi, but an initial FTP CO score of 10.79. (However, the lane score was confirmed by an indolene-fueled lab-IM240 following the FTP which had a CO result of 52.48 g/mi.) The ASM tests on this vehicle did not exhibit a large CO reduction following repairs because <u>both</u> the initial ASM and the ASM following repairs exhibited very high CO emissions (more than 5%) during the 50 mph cruise mode. (Thus, the ASM did not over estimate the CO repair benefit on vehicle 3211 because the ASM over estimated both the initial FTP CO emissions, as well as, the FTP CO emissions following repair.) In spite of the few over predictions of emission benefits from repairs, it should be noted (as illustrated in Table 5.6.1.1) that following the IM240-targeted repairs, no vehicle was left with high unrepaired FTP emissions.

Most of the vehicles, which exhibited very little if any HC or CO improvement following the IM240-targeted repairs, had been recruited for repairs because they exhibited, on the lane-IM240 test, low HC and CO, but high NO_X. Therefore, no significant improvement in either FTP HC or CO was to be expected.

Comparing the two graphs that examine the changes in NO_X emissions (Figure 5.6.1.3), it is apparent that one vehicle (vehicle number 3202) exhibited a reduction in FTP NO_X emissions greater than any of the other 51 vehicles (6.31 g/mi NO_X reduction compared to 4.98 for the next larger FTP NO_X reduction). Since it is possible that one such vehicle could substantially affect the regression analysis, a second set of regressions were performed on the remaining 51 cars (i.e., with vehicle number 3202 deleted) to determine the effect. The effects on the slopes of the regression lines are given in Tables 5.6.1.6 and 5.6.1.7. From Tables 5.6.1.6 and 5.6.1.7, we see that deleting that potential NO_X outlier (vehicle number 3202) has virtually no effect on either regression line. The slope of the IM240 regression line decreases only 3.3 degrees, and the slope of the ASM regression line decreases less than half a degree.

Table 5.6.1.6
Effect on IM240 Regression Line
For NO_X Emissions
Of Deleting Vehicle 3202

	Based on All 52 Vehicles	Based on 51 Vehicles
Constant	-0.275563	-0.183932
Coefficient	0.738523	0.652265
R^2	64.5%	57.4%

Table 5.6.1.7
Effect on ASM Regression Line
For NO_X Emissions
Of Deleting Vehicle 3202

	Based on All 52 Vehicles	Based on 51 Vehicles
Constant	-0.013624	-0.003336
Coefficient	0.829714	0.816328
R^2	70.8%	60.1%

Six vehicles (vehicle numbers: 3172, 3200, 3212, 3239, 3240, and 3244) exhibited large decreases in lane NO_X emissions, but little if any change in FTP NO_X emissions. These six had a number of factors in common:

- All six had low as-received FTP HC (for five of the six $HC \leq 0.37$, and $HC = 0.59$ for the sixth), CO ($CO \leq 3.47$), and NO_X ($NO_X \leq 2.34$).

- All six had low as-received lane-IM240 HC ($HC \leq 0.29$) and CO ($CO \leq 3.33$), but high lane-IM240 NO_X ($NO_X \geq 1.14$).

- All six had low as-received ASM composite HC ($HC \leq 0.24$) and CO ($CO \leq 4.53$).
    - -- Five of the six had as-received ASM composite $NO_X \geq 1.07$.
    - -- Four of the six had as-received ASM composite $NO_X \geq 1.58$.
    - -- Three of the six had as-received ASM composite $NO_X \geq 2.39$.
- All six had ambient temperatures between 61° and 80° F.

As previously noted, many vehicles exhibited little, if any, change in a particular pollutant (either HC, CO, or NO_X) because the initial (as-received) test results for that pollutant were relatively low (i.e., those vehicles had been recruited because one of the other two pollutants exceeded its cutpoint). The effects of including those vehicles in the analysis (which was done in the preceding analysis) is to increase the number of vehicles clustered near the origin (Figures 5.6.1.1 through 5.6.1.3) and, in the regression analysis (Tables 5.6.1.2 and 5.6.1.3), to increase the weighting applied to those points clustered near the origin. Thus, by restricting the analysis to only those vehicles that exceeded the as-received cutpoint for each pollutant , those two situations are eliminated. The three resulting data bases are:

1) the 32 (of the 52) vehicles that were recruited (and repaired) because their initial lane-IM240 exceeded the HC cutpoint of:

   Composite IM240 HC > 0.80 and Mode-2 IM240 HC > 0.50.

2) the 16 vehicles that were recruited (and repaired) because their initial lane-IM240 exceeded the CO cutpoint of:

   Composite IM240 CO > 15.00 and Mode-2 IM240 CO > 12.00.

3) the 30 vehicles that were recruited (and repaired) because their initial lane-IM240 exceeded the NO_X cutpoint of:

   Composite IM240 NO_X > 2.00.

As previously discussed, two vehicles (vehicles numbered 3211 and 3190) could be deleted from the "HC-Repaired" and from the "CO-Repaired" data bases due to questionable test results. Additionally, vehicle number 3202 could be deleted from the "NOx-Repaired" data base for similar reasons. Thus, in addition to performing regression analyses on the entire 52 car data base, we can also perform regressions on the 32/16/30 (HC/CO/NO_X) subsets, as well as, (after deleting the questionable vehicles) on the 30/14/29 car subsets. Within these various data sets, we performed 16 linear regressions, the results of which are summarized in Tables 5.6.1.8 through 5.6.1.10.

Table 5.6.1.8

Regression Lines of ΔHC for Short Tests Versus FTP

	------------ IM240 ------------			------------ ASM ------------		
	Based on All 52 Vehicles	Based on 32 Exceeding Initial HC	Based on 32 Minus Two	Based on All 52 Vehicles	Based on 32 Exceeding Initial HC	Based on 32 Minus Two
Constant	-.365173	-.932339	0.014741	.270944	0.371352	0.7929
Coefficient	1.41060	1.63036	0.958254	2.18967	2.14853	1.11862
R-Squared	81.9%	82.7%	63.3%	71.7%	67.2%	60.9%

Table 5.6.1.9

Regression Lines of ΔCO for Short Tests Versus FTP

	------------ IM240 ------------			------------ ASM ------------		
	Based on All 52 Vehicles	Based on 16 Exceeding Initial CO	Based on 16 Minus Two	Based on All 52 Vehicles	Based on 16 Exceeding Initial CO	Based on 16 Minus Two
Constant	4.64057	17.5097	-0.36712	5.71775	13.9744	13.4061
Coefficient	0.846373	0.611959	1.28527	1.08685	0.95755	0.962594
R-Squared	47.5%	18.7%	55.1%	79.5%	73.0%	74.1%

Table 5.6.1.10

Regression Lines of ΔNOx for Short Tests Versus FTP

	------------ IM240 ------------			------------ ASM ------------		
	Based on All 52 Vehicles	Based on 30 Exceeding Initial NOx	Based on 30 Minus One	Based on All 52 Vehicles	Based on 30 Exceeding Initial NOx	Based on 30 Minus One
Constant	-.275563	-.778908	-0.45849	-0.013624	0.209571	0.273927
Coefficient	0.738523	0.886525	0.733666	0.829714	0.763686	0.711124
R-Squared	64.5%	54.2%	39.9%	70.8%	62.3%	45.7%

Examining the slopes and y-intercepts (i.e., the "coefficient" and "constants" in Tables 5.6.1.8 through 5.6.1.10) of the 18 regression lines, we make the following observations:

- Limiting the analysis to only those vehicles whose initial lane-IM240 test exceeded the cutpoint for the pollutant being examined:

  -- had virtually no effect on the regression line predicting FTP HC changes based on ASM HC changes, and only a relatively small effect on the line predicting FTP CO changes based on ASM CO changes;

  -- had moderate effects on the two regression lines predicting FTP HC and CO changes based on IM240 HC and CO changes; and

  -- had only relatively small effects on the regression lines predicting FTP NOx changes based on ASM or IM240 NOx changes. Again, the effect was larger for the IM240 case.

- Deleting the one or two questionable vehicles prior to performing the regression analysis:

  -- produced only small effects in the two NOx cases (IM240 and ASM) and in the ASM CO case and

  -- produced substantial effects in the two HC cases and in the IM240 CO case.

In summary, this analysis indicates that the change in ASM scores before and after repairs correlates with changes in FTP emissions, about as well as for the IM240. However, because ASM cutpoints were not recommended by ASM proponents and EPA did not have cutpoints to use as repair targets, the contractor repairs were performed to attain IM240 scores that complied with the standard IM240 cutpoints. So the contractor repairs offer little insight into the primary question of whether vehicles repaired to pass an ASM test will be as effective as vehicles repaired to pass the IM240 test. The next two sections will further discuss repair issues.

5.6.2 Commercial repairs

5.6.2.1 Introduction

The purpose of this analysis was to compare the effects of commercial repairs, for vehicles that failed the Arizona I/M test, on IM240 and ASM after-repair test results. Experience has shown that commercial repairs geared to steady-state I/M tests have not met expectations for in-use emission reductions. Because vehicles are operated only at steady-state, repairs have been geared to reducing emissions at those operating conditions. As a result, emissions over the full range of operating conditions are often not effectively reduced, even when vehicles are repaired to pass a steady-state I/M test. This is one reason EPA has established a transient test for enhanced I/M. Since the IM240 requires vehicles to perform over a wide variety of real-world operating conditions, IM240-successful repairs must be effective in reducing emissions over a wide range of operating conditions.

By comparing the effects of commercial repairs on ASM and IM240 test results at selected cutpoints, an evaluation of the comparative repair effectiveness can be made. As discussed above, EPA analyzed the results of repairs performed to pass the Arizona I/M test to determine whether such repairs would significantly reduce ASM emissions without significantly reducing FTP emissions. Since the ASM test and the Arizona I/M test are somewhat similar in that they are steady-state tests, repairs for the Arizona I/M test may provide information on whether ASM-successful repair are as effective as IM240-effective repairs. The data show that successful repairs for the Arizona I/M test are more likely to be successful for the ASM test than for the IM240.

5.6.2.2 Database/Analysis

EPA's commercial repair program in Mesa consisted of offering incentives to owners of 1983 and newer vehicles that failed the Arizona I/M test, but were not needed or declined to participate in laboratory testing, to return to EPA's IM240 lane for after-repair ASM and IM240 tests. To receive their incentive, they were told to return with a receipt for commercial repairs. No instructions were given to owners regarding where or how to get their cars repaired, and owners were not compensated for the actual repair itself.

As of April 1, 1993, before- and after-repair data were available for 23 of these vehicles. One vehicle, #13239 (CR# 24) was removed from the database due to unacceptable speed deviations on its initial ASM test, leaving 22 vehicles available for analysis. For this analysis, five other vehicles were excluded because they continued to fail the Arizona test after repairs. The resulting database consisted of 17 successfully repaired, 1983 and newer vehicles.

Cutpoints were applied to the IM240 and ASM data to determine pass/fail status. The pass/fail determinations were then compared to evaluate the effects of commercial repairs. Three different cutpoint sets were used to make the comparisons. Since the Arizona test measures HC/CO only, the first comparisons involved only HC and CO criteria. Two additional comparisons were made which included NOx cutpoints. All three are listed below (Section 5.3 discusses the relevance of these cutpoints.):

- IM240 recommended cutpoints for HC/CO with ASM cutpoints that produce the highest IDRs at the same failure rate as the IM240 recommended cutpoints:

  IM240 - 0.80 / 15.0 + 0.50 / 12.0
  ASM - 1.00 / 8.0

- EPA recommended IM240 cutpoints including NOx with ASM cutpoints that produce the same 18% failure rate. These cutpoints are listed below:

  IM240 - 0.80 / 15.0 / 2.0 + 0.50 / 12.0
  ASM - 1.00 / 8.0 / 2.0

- ASM and IM240 cutpoints selected to achieve the highest IDRs possible while keeping the probable Ec rate below 5%. These cutpoints are listed below:

  IM240 - 0.30 / 9.0/ 1.7 + 0.19 / 7.0
  ASM - 0.40 / 8.0 / 1.5

For each set of cutpoints, a comparison of the initial and final test results were made. To evaluate the effects of repairs on a specific I/M test a vehicle must be identified by the I/M test for repairs. Thus, while the initial test result comparison allowed the identification ability of these two I/M tests to be compared, the final test result allows an evaluation of the relative repair effectiveness of the I/M tests. The data were restricted to vehicles which were identified by all tests for the comparison of final test results. Using these common vehicles allows the comparison of repair effects to be clearly illustrated.

The results, which are discussed in the next section, indicate that the IM240 is superior at identifying vehicles requiring repair and that for vehicles which initially fail both the IM240 and ASM, steady-state repairs are more likely to result in ASM passing scores than in IM240 passing scores.

5.6.2.3 Results/Conclusions

Initially, all 17 vehicles used in this analysis failed their initial Arizona I/M test. However, the IM240 and ASM identified slightly different sets of vehicles as needing repairs. Vehicles of interest are those that pass the initial IM240 and fail the initial ASM and those that fail the initial IM240 and pass the initial ASM.

As shown in Table 5.6.2-1, for the initial HC/CO only comparison, one car passed the IM240 and failed the ASM and four cars passed the ASM and failed the IM240 (see Appendix B for data listings). These errors-of-omission support the assertion made in Section 5.3 that the ASM is weaker than the IM240 at identifying malfunctioning vehicles with HC and/or CO emission problems.

Table 5.6.2-1
Initial Pass/Fail Status Comparison

HC/CO only Cutpoints			Common Failure Rate Cutpoints			Optimal IDR/Max Ec Cutpoints		
IM240 PASS	**ASM** PASS	3	**IM240** PASS	**ASM** PASS	2	**IM240** PASS	**ASM** PASS	1
IM240 FAIL	**ASM** PASS	4	**IM240** FAIL	**ASM** PASS	2	**IM240** FAIL	**ASM** PASS	2
IM240 PASS	**ASM** FAIL	1	**IM240** PASS	**ASM** FAIL	0	**IM240** PASS	**ASM** FAIL	0
IM240 FAIL	**ASM** FAIL	9	**IM240** FAIL	**ASM** FAIL	13	**IM240** FAIL	**ASM** FAIL	14

Vehicle 13504 (CR# 25) failed the ASM and Arizona test due to a CO problem which appears to occur only at idle operation. Because the IM240 driving cycle includes little idle operation, this vehicle was not identified by the IM240 HC/CO only cutpoints. An air/fuel mixture adjustment reduced emissions sufficiently to pass the HC/CO cutpoints for the ASM and Arizona tests. However, this vehicle did exhibit excessive NOx emissions that were identified by the addition of a NOx cutpoint. Incidentally, the fuel mixture adjustment did little to address or reduce this vehicle's NOx emissions on either the IM240 or the ASM.

In contrast to the IM240, which failed to identify only one vehicle, four vehicles passed the ASM HC/CO only cutpoints and failed the IM240 and Arizona cutpoints. Three of these vehicles are examples of ASM errors-of-omission and illustrate the superior identification ability of the IM240. The fourth vehicle failed NOx and will be discussed after the three that passed.

Vehicle 13471 (CR# 27) failed the Arizona and IM240 tests because of high CO emissions, but passed the ASM test. Vehicle 13125 (CR# 12) failed HC on both the IM240 and Arizona tests and was not identified by the ASM cutpoints. Vehicle 13202 (CR# 15) failed the HC and CO idle modes of the Arizona test. On the IM240, vehicle 13202 failed HC and NOx but passed CO due to the two-ways-to-pass algorithm. The ASM identified this vehicle for NOx emissions only.

The fourth vehicle that initially passed only the ASM test was vehicle 12771 (CR# 8). This vehicle exemplifies the weakness of steady-state I/M tests and is discussed in detail in Section 5.6.3. Vehicle 12771 failed CO on the loaded mode of the Arizona test but passed the CO cutpoint on both the IM240 and the ASM. However, the car failed NOx and HC on the IM240 and failed only NOx on the ASM. After repair, this car passed both the ASM and Arizona tests even when ASM cutpoints were tightened. These repairs did not sufficiently reduce emissions over the full operating range of the vehicle, demonstrated by the vehicle continuing to fail both HC (1.01 g/mi) and NOx (3.01 g/mi) on the IM240. This supports the assertion made in the introduction that repairs to pass a steady-state test may not be effective in reducing emissions over normal driving conditions and, therefore, do not effectively reduce in-use emissions.

To illustrate the effects of commercial repairs on ASM and IM240 after-repair test results, data were restricted to vehicles that failed both the initial ASM and IM240 (see Table 5.6.2-1). The results of these comparisons are graphically depicted in Figures 5.6.2-1 thru 5.6.2-3.

Figure 5.6.2-1
Commercial Repairs Passing ASM and IM240 Cutpoints
HC/CO only Comparison

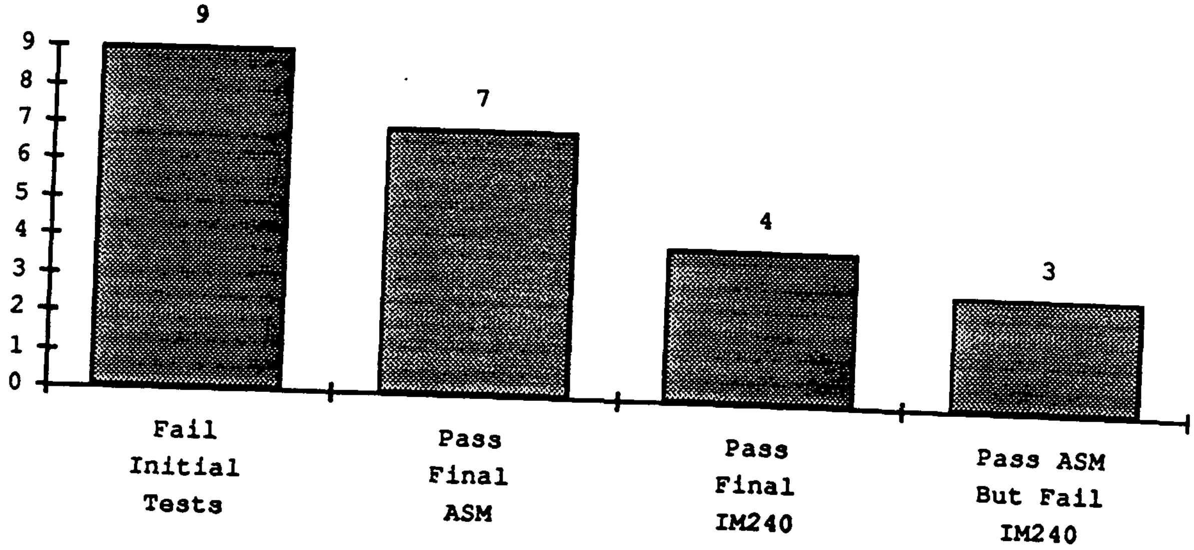


Figure 5.6.2-2
Commercial Repairs Passing ASM and IM240 Cutpoints
Common Failure Rate Comparison

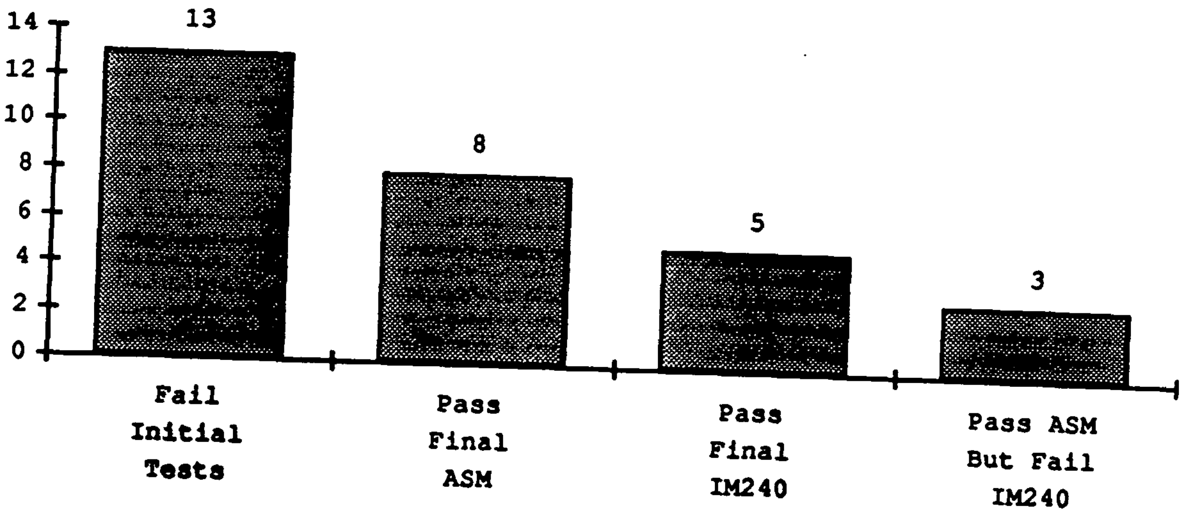
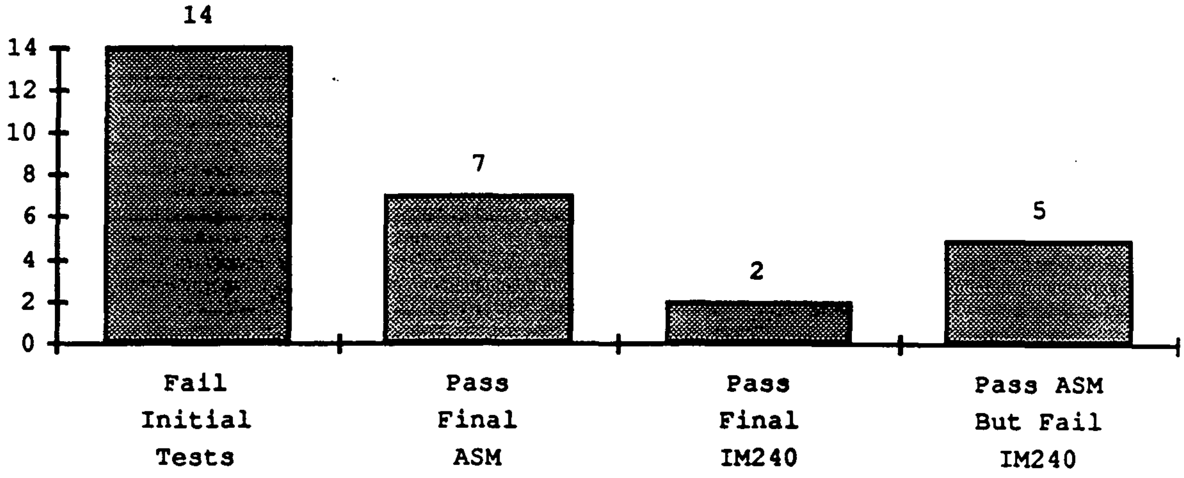


Figure 5.6.2-3
Commercial Repairs Passing ASM and IM240 Cutpoints
High Ec Comparison



These graphs show that vehicles can and will be repaired to pass the ASM test but will continue to fail the IM240.

For the first comparison using only HC and CO cutpoints, three vehicles passed the ASM but continued to fail the IM240. The second comparison added the NOx cutpoint which in combination with the HC/CO cutpoints produced the same failure rates for the IM240 and ASM. Again, three vehicles passed the ASM but continued to fail the IM240. For the comparison using the most stringent cutpoints for the IM240 and ASM, five vehicles passed the ASM but continued to fail the IM240. For all of these comparisons, there were no vehicles that failed the ASM and passed the IM240 after commercial repairs. This indicates that repairs which are sufficient to pass the ASM test are not necessarily sufficient to pass the IM240, indicating that the repair effectiveness of the IM240 is superior to that of the ASM.

Based on these results, repairs to pass the steady-state Arizona I/M test are significantly more effective at reducing ASM emission scores than IM240 emission scores. Although the sample of successful commercial repairs is small, these results indicate that the ASM test, if implemented, will result in significantly lower identification rates and emission reduction benefits than those of the IM240. A more detailed investigation of ASM emission reduction benefits is discussed in Section 5.6.3.

5.6.3 In-Use Emission Reductions from Real World Repairs

One of the concerns with any test is the ability of an observed reduction on the test to reflect real and permanent in-use reductions. Two particular concerns are (1) can unscrupulous mechanics find repair strategies that would allow a vehicle to temporarily pass the I/M test without resulting in permanent in-use reductions (i.e., temporary repairs would be undone after passing the test), and (2) is the test sufficiently imprecise such that honest, but insufficient, repairs would not be detected by the I/M retest.

Test Defeating Strategies

It is common knowledge that the current idle test can be, and is being, defeated by a variety of methods. Most can be used only in the privacy of a test-and-repair station. Some of the common ones that can be used in a test-only station include creating a vacuum leak to lean out the air-fuel ratio for CO failures, and raising the idle speed to create a similar effect. A logical question is, what is the likelihood that test defeating strategies can be developed by unscrupulous mechanics for the ASM or for the IM240 I/M tests.

On the surface, the ASM test appears easier to beat than the IM240 because of its steady-state nature and number of limited operating modes. In theory at least, the mechanic could employ a similar method to the idle test for ASM CO failures. The process would include creating a vacuum leak and disabling the feedback control system. Since it is assumed that most shops would have a dynamometer in an ASM I/M scenario, the mechanic would simply need to operate the vehicle on the dynamometer and adjust the leak until the car was under the cutpoints. Most likely the driveability of the car would be quite poor; however, it would only need sufficient driveability to drive to the test center and return, where the test beating repairs could be undone.

If the vehicle could drive to the test center, then it could certainly drive the steady-state test, since driveability is not required on the ASM, and emissions are not recorded during the transitions between ASM test modes. Conversely, the emissions are measured during driving transitions on the IM240, and the lack of driveability would require more throttle movement with a likely substantial increase in CO emissions. If misfire occurred during driving transitions because of the lean condition, the HC, and possibly NOx, would increase on the IM240, but would not on the ASM (because emissions are not measured during driving transitions).

Another potential test defeating strategy that could occur on the ASM for NOx failures deals with ignition timing. Retarding ignition timing has long been an approach to reducing NOx. Retarding the ignition timing excessively, however, reduces driveability. Once again, however, driveability is not required on the ASM. A severe loss in driveability on the IM240 would be expected to increase CO significantly, but would be expected to have little effect on the ASM CO levels.

Some may point out that many new cars do not have adjustable distributors, and others do not have distributors at all. Therefore, it would not be possible to retard the timing, so such a test defeating strategy would not exist on these cars. What many may not know is that all cars with non-adjustable distributors and those without distributors have a base timing mode that can be activated. Activation of base timing will severely retard the timing in most cases, and could be used to lower NOx emissions.

Since these are only a few of the less creative methods that might be attempted to defeat an ASM or IM240 test, it would be useful to verify if the theoretical potential really could occur. Currently there is no data on purposefully test defeating repairs. However, data from vehicles tested in Arizona and sent for commercial repair may shed some light on the potential for test defeating or improper repairs to be identified by either the ASM or the IM240.

In our commercial repair data base, twenty-two vehicles failed the Arizona I/M test which includes a steady-state loaded mode and an idle mode. All of these vehicles received a 4-mode ASM test and an IM240 test. The vehicle owners took the vehicles for commercial repair, and volunteered for repeat ASM and IM240 tests when they returned for their Arizona retest.

Five of the 22 vehicles were excluded from this analysis because their four-mode ASM emissions did not exceed the cutpoints of 1.0/8.0/2.0 (HC/CO/NOx). The resulting 17 vehicles represent the portion of the 22 car sample that would have failed a four-mode ASM test if that had been the official test. Note that this group of 17 vehicles represents a different portion of the sample of 22 commercially repaired vehicles than the 17 vehicles used for analysis in Section 5.6.2. The analysis in Section 5.6.2 excluded five vehicles that ultimately did not pass the Arizona I/M test after repairs. The analysis in this section excluded five vehicles that passed the initial ASM test, but included those vehicles that did not ultimately pass the Arizona I/M test after repairs.

The repairs conducted on the 17 vehicles are listed in Table 5.6.3-1. From these repairs and the resulting ASM and IM240 scores, the possibility of test defeating strategies can be evaluated. Note that the multiple repairs represent retest failures on the Arizona I/M test. Also, four of the 17 vehicles that initially failed the ASM test did not ultimately pass the Arizona I/M test.

The before and after repair emission results are graphically represented in Figures 5.6.3-1 though 5.6.3-3. From the repair data reported by the commercial garages (in Table 5.6.3-1), it is clear that many vehicles had the air-fuel ratio adjusted or received repairs that would likely affect air-fuel ratio. Many of the vehicles were feedback carbureted; however, this should make no difference for the purposes of evaluating the effect of air-fuel ratio on the test type. Only vehicles CR-07 and CR-16 had reported commercial repairs that would not likely affect air-fuel ratio (it was assumed that the "tune-up" repairs in Table.5.6.3-1, in some cases, could have involved adjustment of air-fuel ratio).

On these other vehicles, the degree of the effect on air-fuel ratio is unknown. But, from the CO emission results in Figure 5.6.3-2, it is clear that in general, a repair that resulted in reduced CO on the IM240 also reduced CO on the ASM. However, there are some exceptions. These are vehicles CR-10, and CR-25. Vehicle CR-10 failed the before and after IM240, failed the before-ASM, but passed the after-ASM. Whereas vehicle CR-25 passed the before and after IM240, failed the before-ASM, and passed the after-ASM.

Since CO is primarily a function of air-fuel ratio, the observation from these two vehicles is that the air-fuel ratio during the steady-state test can be different than the average over the transient test. To some extent, this observation also appears to be evident in the CO results for vehicles CR-03, CR-06, and CR-22 (see Figure 5.6.3-2). In the case of vehicle CR-10, the air-fuel ratio during steady-state operation is sufficiently lean after repairs to allow the vehicle to pass the ASM, but rich enough overall during transient driving to cause an IM240 failure. The opposite is apparently true for vehicle CR-25, where the before repair air-fuel ratio during steady-state is apparently sufficiently rich to cause an ASM failure, but lean enough during average driving to allow the vehicle to pass the IM240.

Certainly, the CO level can also be affected by the catalyst. But the catalyst was the same in all of these tests, so the catalyst effect should wash out. Also, catalyst efficiency can be somewhat gauged by HC levels as seen in Figure 5.6.3-1. The after repair HC levels on vehicle CR-10 clearly pass the ASM cutpoint. The after repair IM240 HC status parallels the CO status. In other words, based on the IM240 this vehicle was still broken, but was passed on the ASM. The HC levels on vehicle CR-25 were low for all IM240 and ASM tests. Based on IM240 results, this vehicle should not have been failed for HC or CO. However, vehicle CR-25 did have serious problems as evidenced by the NOx emissions in Figure 5.6.3-3.

The emission results on these two vehicles, reinforce the following point. Air-fuel ratio can affect the CO levels on both tests. In particular, the air-fuel ratio during a steady-state mode can be different than the overall ratio during transient operation. Therefore, it is likely that with willful intent, a mechanic could purposefully create a vacuum leak, and adjust it so that a car could pass the ASM, but not the IM240. Whereas the amount of leanness in vehicle CR-10 was not sufficient to pass CO on the IM240, it was sufficient to pass the ASM. Furthermore, the amount of leanness was not sufficient to cause vehicle CR-10 to fail either the IM240 or the ASM NOx cutpoints. Therefore, the results on vehicle CR-10 support the theoretical possibility that unscrupulous mechanics could, with proper adjustment of vacuum leaks, be able to adjust vehicles to temporarily pass the ASM CO without increasing the NOx emissions sufficiently to cause an ASM NOx failure. As indicated previously, the likelihood of such improper and temporary repairs would be exacerbated in a program where the ASM was the official test, because unscrupulous repair centers could conveniently maladjust a vehicle on a dynamometer to pass the steady-state modes of the ASM test.

Table 5.6.3-1

Vehicle Repairs

VEH.NO	1st Repair	2nd Repair	3rd Repair
CR-01	Adjusted air/fuel mixture on carburetor.	Rpred electrical short in harness from ECU to mix control.	
CR-02	Adjusted air/fuel mixture on carburetor.		
CR-03	Adjusted air/fuel mixture on carburetor. Replaced heat valve.		
CR-04	Repaired vacuum leak and adjust ignition timing.		
CR-05	Replaced O2 Sensor and performed TuneUp.		
CR-06	Rpl O2 ,plugs, cap and rotor, cleaned fuel injector	Adjusted Idle, air/fuel mixture, cleaned fuel injectors.	
CR-07	Rpl fan belt, plugs, fuel flt. Adj timing. Changed oil.	A one year waiver was granted for this vehicle.	
CR-08	Tune - up, replaced fuel filter, replaced air filter.		
CR-09	Adjusted emissions. Scoped and adjusted air/fuel mixture.		
CR-10	Adjusted air/fuel mixture and idle speed.	Adjusted air/fuel mixture and idle speed.	
CR-13	Adjusted air/fuel mixture, idle speed.		
CR-15	Replaced Oxygen sensor.		
CR-16	Set Ignition timing to manufacturer's specifications.		
CR-21	Tune-up,Rpl plugs, wires, distributor cap and rotor.	Performed Tune-up.	
CR-22	Checked proper operation of choke and repaired.	Scoped engine and adjusted carburetor.	Overhauled Carburetor.
CR-25	Adjusted air/fuel mixture and idle speed.	-	
CR-26	Performed basic tune up.		

Figure 5.6.3 - 1

Commercial Repair Effects

Change in HC Emissions on Cars
Failing ASM HC, CO, or NOx

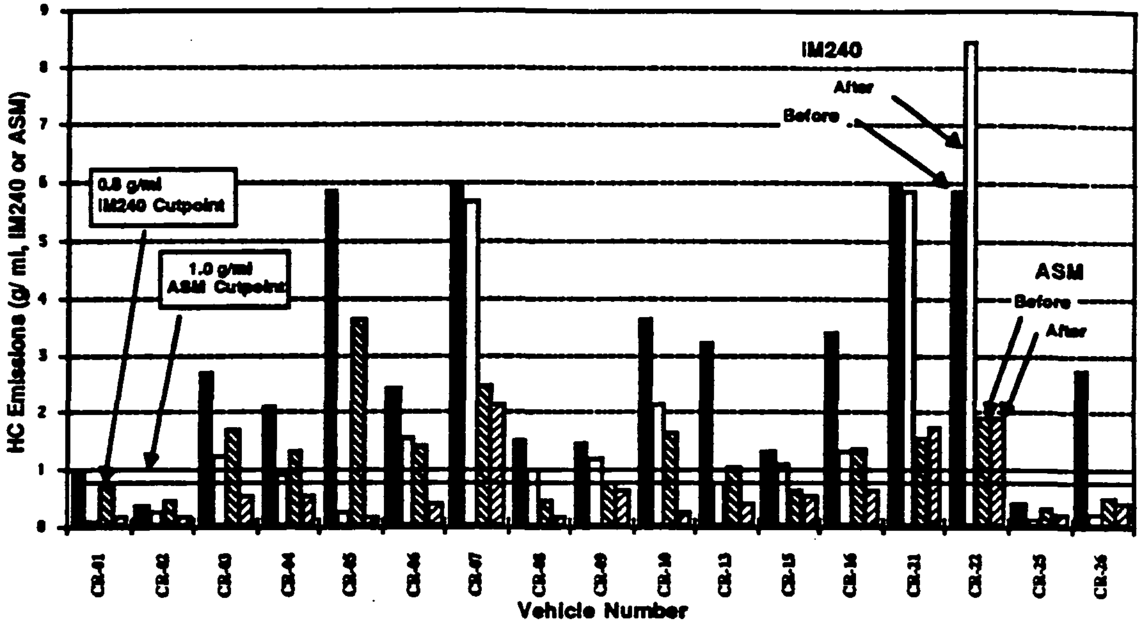


Figure 5.6.3 - 2

Commercial Repair Effects

Change in CO Emissions on Cars
Failing ASM HC, CO, or NOx

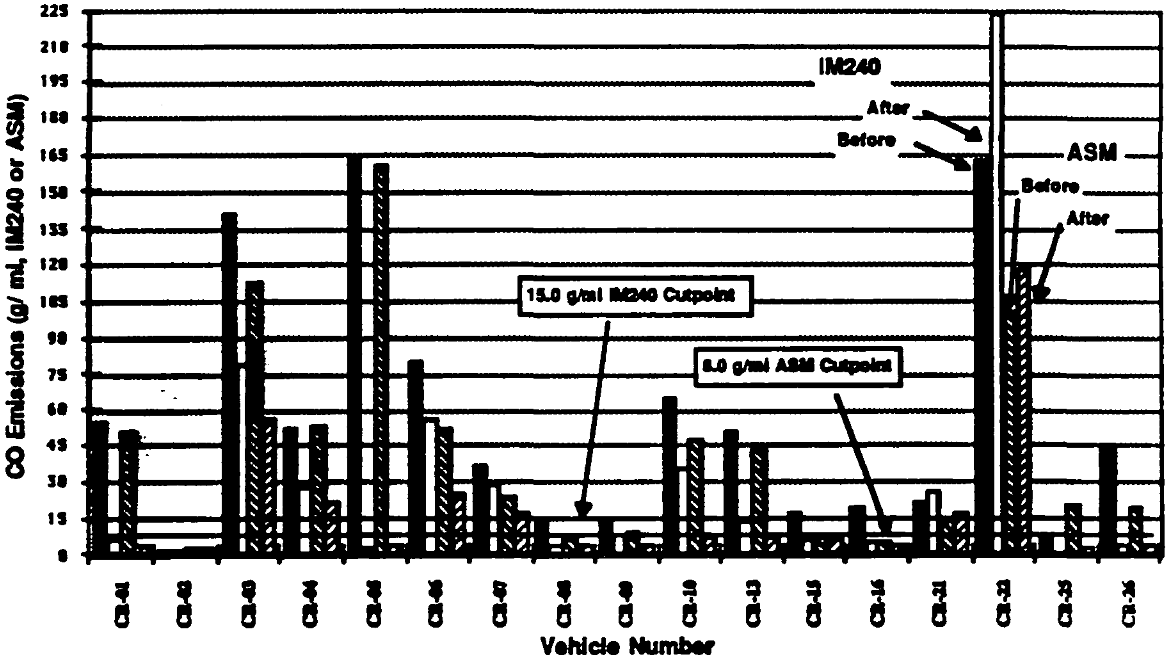
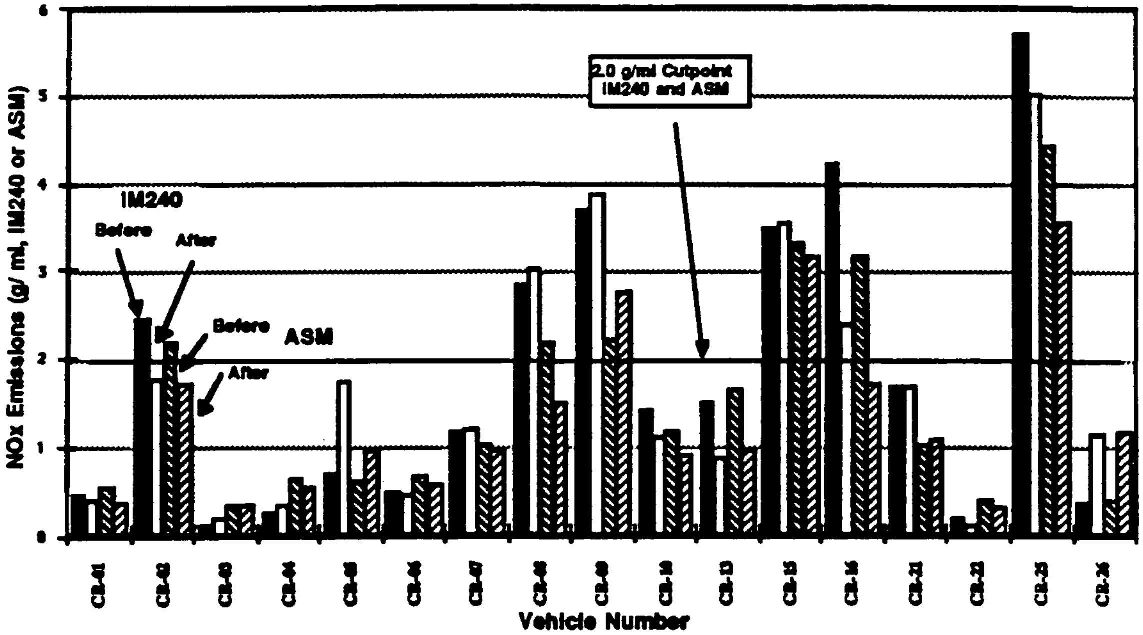


Figure 5.6.3-3

Commercial Repair Effects

Change in NOx Emissions on Cars Failing ASM HC, CO, or NOx



Insufficient Repairs

Another concern with an I/M test is the ability for the test to cause proper and sufficient repairs to be performed if the vehicle fails the I/M test. For this analysis, proper and sufficient repairs are considered to be repairs sufficient to pass the IM240 cutpoints. The commercial repair data used in the preceding section on test defeating strategies can also provide some insight into this issue.

Of interest is the comparison of test modes between the 4-mode ASM and the Arizona I/M test. Both have an idle mode, and both have a steady-state loaded mode. The Arizona loaded mode is similar to the ASM 2525 mode.

Using the general similarity of the test (i.e., idle and loaded modes), the general sufficiency of ASM repairs can be approximated by observing the results from vehicles used in the previous section that failed the initial ASM test and the initial Arizona I/M test. A case history on vehicle number CR-08, which initially failed the IM240 HC and NOx cutpoints (as well as the Arizona CO cutpoint and the ASM NOx cutpoint), illustrates the concern about the ability of the ASM test to cause proper and sufficient repairs to occur in-use.

After vehicle number CR-08 had failed the Arizona I/M test for CO on January 4, and had received initial tests on the IM240 and ASM, it was enlisted in the commercial repair program. Two weeks after the commercial repairs (January 14), the vehicle returned for its after-repair IM240, ASM, and Arizona I/M retest (and for the owner to obtain the recruitment incentive payment). At that time, it was discovered that two days after the initial I/M test (which was conducted on January 4), and following repairs (listed in Table 5.6.3-1), the repair center had taken the vehicle to another Arizona test lane for an I/M retest. At this other I/M lane, on January 6 the vehicle easily passed the Arizona cutpoints of 1.2% CO and 220 ppm HC. However, when retested on January 14 at the IM240 test lane, this vehicle failed the Arizona HC cutpoint by a wide margin (see Table 5.6.3-2). The owner was demonstrably upset (even though a valid Arizona passing certificate had been issued), and left the test center abruptly. However, the owner returned again in another two weeks (January 26). At this time, the vehicle passed all of the Arizona cutpoints. The owner did not divulge any information on corrections or repairs that may have occurred between January 14 and January 26.

Table 5.6.3-2

Test Data - Vehicle No. CR-08

			State Test				IM240			ASM		
			Loaded		Idle							
Date	Operation	Lane#	HC ppm	CO %	HC ppm	CO %	HC g/mi	CO g/mi	NOx g/mi	HC g/mi	CO g/mi	NOx g/mi
1/04/93	Lane IM240	2771	86	1.55	87	0.38	1.51	12.2	2.85	0.46	5.7	2.19
1/06/93	State Test	—	40	0.84	116	0.78	—	—	—	—	—	—
1/14/93	Lane IM240	2977	38	0.63	835	0.07	1.38	4.1	2.59	0.33	3.5	1.63
1/26/93	Lane IM240	3168	75	0.38	41	0.06	1.01	4.4	3.01	0.16	3.4	1.51

Several important aspects should be noted. First, while this vehicle failed the Arizona CO cutpoints, it passed CO on all ASM and IM240 tests. Also, while this vehicle passed HC in all of ASM tests, it failed HC on all of the IM240 tests. Further, after the first repair, this vehicle passed the ASM NOx cutpoints for all subsequent ASM tests, even though it failed the IM240 NOx cutpoints for all of the subsequent IM240 tests (as well as the initial IM240). The IM240 NOx actually increased slightly from the first test to the last.

The most pessimistic scenario on this vehicle is that once the vehicle failed the Arizona test for CO, the mechanic maladjusted the vehicle, took it to an I/M lane, where it passed, and then undid the maladjustments. These undid maladjustments were then observed on the January 14 Arizona retest. A more benign conclusion is that the mechanic performed incomplete repairs, but the repairs were ultimately sufficient to pass the Arizona test. Also, the repairs were sufficient to pass the ASM NOx cutpoints (HC and CO were always below the ASM cutpoints), while they were not sufficient to pass the IM240 NOx cutpoint, nor were they sufficient to pass the IM240 HC cutpoint. In fact, the ASM would not even have identified this vehicle as a high HC emitter.

Clearly, on this particular vehicle, commercial repairs were not sufficient to pass the IM240, but were sufficient to pass the ASM test.

Reviewing the data for all 17 vehicles that failed the initial ASM test, all of these vehicles, except CR-07, CR-21, and CR-22 eventually passed the Arizona HC I/M retest. Also, all vehicles, except these three vehicles and CR-06 eventually passed the Arizona CO I/M retest.

However, vehicles CR-03, CR-04, CR-06, CR-08, CR-09, CR-10, CR-15, and CR-16 which initially failed the IM240, continued to fail HC on the IM240 after all commercial repairs (see Figure 5.6.3-1). Further, after all commercial repairs, these same vehicles passed the ASM HC cutpoint (note CR-8, CR-9, and CR-15 passed the initial ASM test, see Figure 5.6.3-1). Given the similarities of the ASM and the Arizona test, these data suggest that the level of HC repair on the ASM would be similar to the current Arizona I/M test. This assumption on test similarity and stringency of repair effectiveness is further supported by the fact that the three vehicles that failed to pass the Arizona test after repairs (CR-7, CR-21, and CR-22) were also the only vehicles that failed the after-repair ASM test (see Table Figure 5.6.3-1).

Another method of looking at the ability of the ASM to enforce proper and sufficient repairs is to look at the test status of the ASM results before and after repairs relative to the before and after IM240 status. The test status for the 17 vehicles initially failing the ASM for at least one pollutant is listed in a truth-table format in Table 5.6.3-3 by pollutant (i.e., HC, CO, and NOx). The roughly square boxes in a diagonal row represent test results where the IM240 and ASM status before and after repair were identical. Deviations from the diagonal row, obviously represent results where the status differs between the IM240 and ASM. The fuzzy horizontal rectangular box in Table 5.6.3-3 highlights those vehicles which passed the ASM test after repair, but were still failing the IM240 for HC, CO, or NOx.

From the Table, a total of 11 vehicles continued to fail the IM240 HC cutpoint after repair. Of these 11 vehicles, 8 vehicles (or 73%) passed the ASM after repair (three of the eight also passed the initial ASM test). All eight vehicles also passed the Arizona HC cutpoint after repair. As previously mentioned, in the 11 vehicle sample that continued to fail the IM240 HC cutpoint, 100% of the vehicles that failed the Arizona HC cutpoint

(CR-07, CR-21, and CR-22), also failed the ASM HC cutpoint. Thus, every vehicle that continued to fail the Arizona HC cutpoint also continued to fail the ASM HC cutpoint. In other words, in this sample of commercial repairs, the ASM did not fail anymore retest vehicles than the Arizona I/M test.

CO test status represents somewhat of a mixed bag. Seven vehicles continued to fail the IM240 for CO after repair. Only one vehicle in this group of seven (or 14%) passed the ASM for CO after repair. This vehicle also passed the Arizona retest. In this seven vehicle sample that continued to fail the IM240 CO cutpoint, six vehicles continued to fail the ASM, and four vehicles (CR-06, CR-07, CR-21, and CR-22) failed the Arizona retest. In this case, the ASM found 2 more vehicles than the Arizona I/M retest after commercial repairs.

However, it should be noted, that four other vehicles had anomalous CO results. Two vehicles, CR-15 and CR-16 failed the initial IM240 for CO, passed the initial ASM, and subsequently passed both the IM240 and ASM for CO. Two other vehicles (CR-09 and CR-25), passed the initial IM240, failed the ASM for CO, and also subsequently passed both the IM240 and ASM retests. If the ASM was as good as the IM240 in identifying vehicles that should fail a retest (at the same overall failure rate), one might expect a random scatter on each side of the diagonal boxes, particularly for vehicles just marginally failing or passing (which all of these were, except CR-25). Even so, all of these vehicles also passed the Arizona CO retest. So they do not represent any additional retest failures following commercial repairs that the ASM would have found over the standard Arizona test. Also note, that these four vehicles initially failed and continued to fail the IM240 for HC or NOx, and that the commercial repairs reduced the IM240 CO levels in all cases.

A total of 5 vehicles in this sample of 17 continued to fail IM240 NOx after commercial repairs. Two of the five (or 40%) passed the ASM after repairs. The Arizona I/M test does not test for NOx, therefore, it is more difficult to judge the effectiveness of the ASM (using the Arizona test as a surrogate) to force proper and sufficient commercial repairs.

This analysis began with a concern about the ability of the ASM test to foster proper and sufficient commercial repairs following an I/M failure. Because of the general similarity of the Arizona I/M test to the ASM, it was expected that repairs targeted by the commercial repair industry towards the Arizona test would be similar to those that would be targeted towards the ASM, at least for HC and CO. Thus, if the ASM were more effective in forcing better repairs than the Arizona test, the ASM retest should fail more cars for a given pollutant than the Arizona retest. Further, if the ASM were very effective in forcing proper repairs, it would fail as many cars, for a given pollutant, as an IM240 retest.

The analysis shows that for this small sample, the ASM fails no more cars for HC after commercial repairs than the Arizona retest, and fails only twenty-seven percent of those that failed HC on the IM240 after repair. These results imply that the ASM test would not force the repair industry to make any more repairs for high HC emissions than the current Arizona test, and obviously, not as many HC repairs as the IM240. Therefore, the data from this sample suggest that the repair effectiveness credits for HC in the MOBILE model for commercial repairs on the ASM should be no greater than that currently given for existing basic I/M programs.

The analysis for CO retest failures, indicates that the ASM found two more vehicles than the Arizona test. The Arizona I/M retest found about 57 percent of the IM240 retest failures, and the ASM found about 86 percent of the retest failures. Thus in this small sample, it appears that an ASM retest would have forced the repair industry to make additional CO repairs over and above those that would have been required to pass the Arizona cutpoints, but again, not as many as the IM240 cutpoints would require. These results suggest that the repair effectiveness credits for CO in the MOBILE model for commercial repairs on the ASM should probably be given additional credit over that currently given for existing I/M programs. The additional credit would be approximately equal to 60 percent of the difference between that currently given for existing I/M programs and that given to I/M programs employing the IM240. However, given the potential ease that unscrupulous mechanics could defeat the CO portion of the ASM retest, assigning additional CO repair effectiveness credits in the model for ASM over those currently given for existing I/M programs would be difficult to rationalize at this time.

The analysis for NOx retest failures is somewhat hampered by the fact that the Arizona test only fails vehicles for HC and CO. Even though the repair industry was not repairing vehicles to an NOx standard, the IM240 and ASM retests after commercial repairs can be used to determine whether either retest would have forced the repair industry to make additional repairs. Clearly, both tests would have required some vehicles to get additional repairs for high NOx emissions. However, the results from this sample indicate that an ASM retest would only require 60 percent of the vehicles that failed the IM240 retest to get additional NOx repairs. Therefore, this result would suggest that the repair effectiveness credits for NOx in the MOBILE model for commercial repairs on the ASM should be about only sixty percent of that given for the IM240.

Table 5.6.3-3

Effect of Commercial Repairs on Test Status

IM240 Status	ASM Status			
	(Status Before Repair - Status After Repair)			
	Fail-Fail	Pass-Fail	Fail-Pass	Pass-Pass
Fail-Fail				
HC	CR-07, CR-21, CR-22	—	CR-03, CR-04, CR-06, CR-10, CR-16	CR-08, CR-09, CR-15
CO	CR-03, CR-06, CR-04, CR-07, CR-21, CR-22	—	CR-10	—
NOx	CR-9, CR-15, CR-25	—	CR-08, CR-16	—
Pass-Fail				
HC	—	—	—	—
CO	—	—	—	—
NOx	—	—	—	—
Fail-Pass				
HC	—	—	CR-05, CR-13	CR-01, CR-26
CO	—	—	CR-01, CR-05, CR-13, CR-26	CR-15, CR-16
NOX	—	—	CR-02	—
Pass-Pass				
HC	—	—	—	CR-02, CR-25
CO	—	—	CR-09, CR-25	CR-02, CR-8
NOx	—	—	—	CR-01, CR-03, CR-04, CR-05, CR-06, CR-07, CR-10, CR-13, CR-21, CR-22, CR-26

5.6.4 One-Mode Repairs on ASM

The objective of this analysis was to investigate the theoretical effects of targeting the ASM repairs to a single mode. That is, if it were possible for a mechanic to reduce the emissions sufficiently on a single mode while leaving the remaining three modes unaffected:

- Could an ASM failing vehicle, with such a repair, be made to pass the ASM composite cutpoint?

- What are the emission characteristics of such passing vehicles?

Examining the 106 laboratory test vehicles, we can determine whether the as-received NOx emissions met or exceeded an FTP NOx standard of 2.0 g/mi. Also, we can determine FTP HC/CO emission range. That is:

- Pass

  FTP HC ≤ 0.41 and CO ≤ 3.40 (g/mi)

- Marginal (Failing) Emitters

  FTP HC > 0.41 or CO > 3.40 (g/mi)
  and
  FTP HC ≤ 0.82 and CO ≤ 10.20 (g/mi)

- High Emitters

  FTP HC > 0.82 or CO > 10.20 (g/mi)
  and
  FTP HC ≤ 1.64 and CO ≤ 13.60 (g/mi)

- Very High Emitters

  FTP HC > 1.64 or CO > 13.60 (g/mi)
  and
  FTP HC ≤ 10.00 and CO ≤ 150.00 (g/mi)

- Super Emitters

  FTP HC > 10.00 or CO > 150.00 (g/mi)

Classifying the laboratory vehicles in this way produces ten strata; however, two of those strata are empty, and one stratum has only a single test vehicle. Using the weighting factors (Table 5.2.5.2), we can model the lane vehicles and characterize the emissions of that simulated lane sample of 2,071 1983 and new fuel-injected passenger cars. (Actually, the lane sample was 2,070 cars, the additional vehicle resulted from rounding off the estimated number of vehicles in those eight strata.) The distribution is given in the following table.

Fleet Distribution

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	27	36	10	18	1	808	934	96	143	6
NOx > 2.0	0	4	3	7	0	0	24	18	42	0

An ASM cutpoint of 1.00/8.0/2.0 (i.e., composite ASM HC ≤ 1.00, composite ASM CO ≤ 8.0, and composite ASM NOx ≤ 2.0) will fail 372 vehicles in that simulated lane fleet. The distribution of those 372 vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	3	6	5	12	1	54	144	30	72	6
NOx > 2.0	0	3	2	6	0	0	18	12	36	0

If mechanics were able to repair those 372 vehicles so that the emissions on the 2525 mode, the 50 mph mode, and the idle mode remained unchanged, but the emissions (HC, CO, and NOx) on the 5015 mode were reduced by 80 or 90 percent (the model yields the same result for each), then only 42 of those 372 would be able to pass the 1.00/8.0/2.0 cutpoint. Thus, a repair strategy that targeted only the 5015 mode would result in "successfully" repairing only about 11 percent of the originally failing vehicles. The distribution of those 42 passing vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0
Passing after Reducing 5015 Mode by 80 or 90%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	0	1	0	0	0	0	42	0	0	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

Rather than attempting to reduce the emissions on the 5015 mode by a flat percentage, the mechanic could target the typical emissions on the 5015 mode of vehicles whose ASM composite emissions pass the 1.00/8.0/2.0 cutpoint. Such a repair strategy would not change a single failing vehicle into a passing vehicle in our model.

If mechanics were able to repair those 372 vehicles so that the emissions (HC, CO, and NOx) on the 2525 mode were reduced by 80 percent (while the emissions on the other three modes remained unchanged), then only 30 of those 372 would be able to pass the 1.00/8.0/2.0 cutpoint. The distribution of those 30 "successfully" repaired vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0
Passing after Reducing 2525 Mode by 80%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	2	1	0	1	0	12	6	0	6	0
NOx > 2.0	0	1	0	0	0	0	6	0	0	0

Reducing the 2525 mode emissions by 90 percent would add 48 vehicles (42 marginal HC/CO emitters with NOx ≤ 2.0 and 6 very high HC/CO emitters with NOx > 2.0) to the 30 whose estimated ASM composite score would pass the cutpoint. Thus, a repair strategy that targeted only the 2525 mode would be successful on only 21 percent of the originally failing vehicles.

Rather than attempting to reduce the emissions on the 2525 mode by a flat percentage, the mechanic could target the typical emissions on the 2525 mode of vehicles whose ASM composite emissions pass the 1.00/8.0/2.0 cutpoint. Such a repair strategy would not change a single failing vehicle into a passing vehicle in our model.

If mechanics were able to repair those 372 vehicles so that the emissions (HC, CO, and NOx) on the 50 mph cruise mode were reduced by 80 percent (while the emissions on the other three modes remained unchanged), then 264 of those 372 would be able to pass the 1.00/8.0/2.0 cutpoint. The distribution of those 264 passing vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0
Passing after Reducing 50 mph Cruise Mode by 80%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	3	5	3	3	0	54	138	18	18	0
NOx > 2.0	0	2	2	2	0	0	12	12	12	0

Reducing the 50 mph cruise emissions by 90 percent would add 6 vehicles (all with very high HC/CO emitters and NOx > 2.0) to the 264 whose estimated ASM composite score would pass the cutpoint. Thus, a repair strategy that targeted only the 50 mph cruise mode would result in "successfully" repairing about 73 percent of the originally failing vehicles.

Rather than attempting to reduce the emissions on the 50 mph cruise mode by a flat percentage, the mechanic could target the typical emissions on the 50 mph cruise mode of vehicles whose ASM composite emissions pass the 1.00/8.0/2.0 cutpoint. Such a repair strategy would result in "successfully" repairing 162 (44%) of the originally failing vehicles. The distribution of those 162 passing vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0
Passing after Reducing 50 mph Cruise Mode to Nominal Score

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	1	2	4	2	0	42	84	24	12	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

If mechanics were able to repair those 372 vehicles so that the emissions (only HC and CO) on the idle mode were reduced by 80 or 90 percent (the model yields the same result for each) while the emissions on the other three modes remained unchanged, then only 96 of those 372 would be able to pass the 1.00/8.0/2.0 cutpoint. Thus, a repair strategy that targeted only the idle mode would result in "successfully" repairing only about one-fourth of the originally failing vehicles. The distribution of those 96 passing vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0

Passing after Reducing Idle Mode by 80 or 90%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	0	2	1	1	0	0	84	6	6	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

Rather than attempting to reduce the emissions on the idle mode by a flat percentage, the mechanic could target the typical emissions on the idle mode of vehicles whose ASM composite emissions pass the 1.00/8.0/2.0 cutpoint. Such a repair strategy would result in "successfully" repairing only 60 (16%) of the originally failing vehicles. The distribution of those 60 passing vehicles is given in the following table.

Fleet Distribution Failing 1.00/8.0/2.0

Passing after Reducing Idle Mode to Nominal Score

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	0	1	1	2	0	0	42	6	12	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

Tightening the ASM cutpoint from 1.00/8.0/2.0 to a more stringent cutpoint of 0.40/8.0/1.5 produces similar results in our model.

An ASM cutpoint of 0.40/8.0/1.5 will fail 587 vehicles in that simulated lane fleet. The distribution of those 587 vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	6	16	7	13	1	72	311	42	78	6
NOx > 2.0	0	4	3	6	0	0	24	18	36	0

As with the 1.00/8.0/2.0 cutpoint, single-mode repairs that reduced the 5015 mode emissions by 80 or 90 percent would succeed in "successfully" repairing only 108 (18 percent of the 587 failing vehicles) The distribution of those 108 vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5
Passing after Reducing 5015 Mode by 80 or 90%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	1	5	0	0	0	6	102	0	0	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

Rather than attempting to reduce the emissions on the 5015 mode by a flat percentage, the mechanic could target the typical emissions on the 5015 mode of vehicles whose ASM composite emissions pass the 0.40/8.0/1.5 cutpoint. Such a repair strategy would result in "successfully" repairing only 54 (16%) of the originally failing vehicles. The distribution of those 54 passing vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5
Passing after Reducing 5015 Mode to Nominal Score

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	1	2	0	0	0	6	48	0	0	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

If mechanics were able to repair those 587 vehicles so that the emissions on the 2525 mode were reduced by 80 percent (while the emissions on the other three modes remained unchanged), then only 138 of those 587 would be able to pass the 0.40/8.0/1.5 cutpoint. The distribution of those 138 vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5
Passing after Reducing 2525 Mode by 80%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	1	9	0	1	0	6	126	0	6	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

Reducing the 2525 mode emissions by 90 percent would add 12 vehicles (6 passing HC/CO with NOx ≤ 2.0 and 6 marginal HC/CO emitters with NOx > 2.0) to the 138 whose estimated ASM composite score would pass the cutpoint. Thus, a repair strategy that targeted only the 2525 mode would be successful on only about 26 percent of the originally failing vehicles.

Rather than attempting to reduce the emissions on the 2525 mode by a flat percentage, the mechanic could target the typical emissions on the 2525 mode of vehicles whose ASM composite emissions pass the 0.40/8.0/1.5 cutpoint. Such a repair strategy would result in "successfully" repairing only 102 (17%) of the originally failing vehicles. The distribution of those 102 passing vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5
Passing after Reducing 2525 Mode to Nominal Score

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	0	4	0	1	0	0	96	0	6	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

If mechanics were able to repair those 587 vehicles so that the emissions on the 50 mph cruise mode were reduced by 80 percent (while the emissions on the other three modes remained unchanged), then 365 of those 587 would be able to pass the 0.40/8.0/1.5 cutpoint. The distribution of those 365 passing vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5
Passing after Reducing 50 mph Cruise Mode by 80%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	6	12	4	2	0	72	251	24	12	0
NOx > 2.0	0	1	0	0	0	0	6	0	0	0

Reducing the 50 mph cruise emissions by 90 percent would add 12 vehicles (all with NOx > 2.0; 6 of which with marginal HC/CO and 6 with high HC/CO) to the 365 whose estimated ASM composite score would pass the cutpoint. Thus, a repair strategy that targeted only the 50 mph cruise mode would result in "successfully" repairing about 64 percent of the originally failing vehicles.

Rather than attempting to reduce the emissions on the 50 mph cruise mode by a flat percentage, the mechanic could target the typical emissions on the 50 mph cruise mode of vehicles whose ASM composite emissions pass the 0.40/8.0/1.5 cutpoint. Such a repair strategy would result in "successfully" repairing only 275 (47%) of the originally failing vehicles. The distribution of those 275 passing vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5
Passing after Reducing 50 mph Cruise Mode to Nominal Score

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	2	8	4	2	0	48	191	24	12	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

If mechanics were able to repair those 587 vehicles so that the emissions on the idle mode were reduced by 80 or 90 percent (the model yields the same result for each) while the emissions on the other three modes remained unchanged, then only 42 of those 587 would be able to pass the 0.40/8.0/1.5 cutpoint. Thus, a repair strategy that targeted only the idle mode would result in "successfully" repairing only about seven percent of the originally failing vehicles. The distribution of those 42 passing vehicles is given in the following table.

Fleet Distribution Failing 0.40/8.0/1.5

Passing after Reducing Idle Mode by 80 or 90%

	Laboratory Sample FTP HC/CO Emissions					Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	Highs	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	0	1	0	0	0	0	42	0	0	0
NOx > 2.0	0	0	0	0	0	0	0	0	0	0

Rather than attempting to reduce the emissions (only HC and CO) on the idle mode by a flat percentage, the mechanic could target the typical emissions on the idle mode of vehicles whose ASM composite emissions pass the 0.40/8.0/1.5 cutpoint. Such a repair strategy would have produced exactly the same result (i.e., 42 passing vehicles) as would reducing the idle emissions by a flat 80 or 90 percent.

From the preceding two examples (i.e., using cutpoints of 1.00/8.0/2.0 and 0.40/8.0/1.5), the only potentially effective "single-mode ASM repairs" are those repairs targeted at the 50 mph cruise mode (reducing emissions by 90%). However, the model predicts that those repairs would not be successful on 27 to 36 percent of the originally failing vehicles. The distributions, of those vehicles that are still failing the respective ASM cutpoint after repairs targeted on the 50 mph cruise mode (reducing emissions by 90%), are given in the following table.

Still Failing 0.40/8.0/1.5

After Reducing 50 mph Cruise Mode by 90%

	Still Failing Cutpoint of 1.00/8.0/2.0 Simulated Lane Fleet FTP HC/CO Emissions					Still Failing Cutpoint of 0.40/8.0/1.5 Simulated Lane Fleet FTP HC/CO Emissions				
	Pass	Marginal	High	V. High	Super	Pass	Marginal	High	V. High	Super
NOx ≤ 2.0	0	6	12	54	6	0	60	18	66	6
NOx > 2.0	0	6	0	18	0	0	12	12	36	0

From the preceding table, we can see that the vehicles that the model predicts will continue to exceed the respective ASM cutpoints, even after single-mode repairs targeted at the 50 mph cruise mode, are among the highest emitters in the simulated lane fleet.

5.7 Purge Analyses

5.7.1 Introduction

In purge testing, the concern is not that too many malfunctioning vehicles will pass a test. Instead, the major concern is too many properly functioning vehicles will fail a test that attempts to replace a test with real-world driving behavior with a few steady-state modes. These steady-state modes may not provide some vehicles with the opportunity to purge. Thus, the purpose of this section was to compare the canister purge system false failure rates (errors-of-commission or Ecs) for the ASM and IM240. The data indicate that the IM240 is significantly less likely to falsely fail vehicles for purge than the ASM.

Vehicle evaporative emissions contribute significantly to the VOC inventory. Because vehicle fuel tanks and carburetors must vent to atmosphere for proper vehicle operation, carbon canisters are added to collect hydrocarbon molecules which would otherwise escape. Because the carbon canister has a finite capacity, which if exceeded, allows hydrocarbons to escape, the canister must be kept purged of stored hydrocarbon molecules. The evaporative control system includes a purge system which draws stored hydrocarbons into the engine where they are burned.

Most properly functioning canister purge systems do not purge constantly; instead, most only purge when their ECM computer algorithms call for purge. Driveability or emission problems accompany purge that initiates during unfavorable conditions, so purge algorithms are designed to take advantage of opportune conditions. The purge algorithms are known to vary widely from model to model. So, the main problem for an I/M test is to provide vehicle operation that will coincide with the conditions necessary to induce the system to activate canister purge. EPA has found that some vehicles only purge during accelerations or decelerations, which is problematic for steady state tests such as the ASM and could result in falsely failing vehicles with purge systems that are properly functioning.

Also, some vehicles have timers that don't allow purge for several minutes after the engine is started or a specified operating temperature is reached, so all else being equal, the longer the test duration, the lower the probability of purge false failures. This also makes the test order important, since the test that was performed second is more likely to achieve purge than the initial test. This is one reason the test procedure in our study in Mesa required the test order to be reversed each time another car was tested and why the engine was restarted just before each test.

The IM240 purge flow was summed over the full IM240. The ASM purge flow was measured and summed over the full four modes of the ASM including transient segments of the ASM cycle, in contrast to the ASM exhaust emissions, which were only measured during the four ASM steady-state modes. Because the flow measuring equipment is the same for both transient and steady-state tests, it was practical to measure purge flow on the ASM during the three accelerations and the single deceleration needed to complete the four ASM modes.

5.7.2 The Database

The database for the lane purge analysis was restricted to vehicles that met all of the following criteria:

- as-received purge data were available for both the IM240 and the ASM,
- the test order was known,
- and the data passed the purge QC criteria (see Appendix C).

The resulting database consisted of 1170 vehicles. Of these, 577 received the IM240 first and 593 received the ASM test first. The comparisons made for this analysis included failure rate comparisons, and comparisons of vehicles for which the ASM and IM240 purge status did not agree, or "false failures". In addition, these comparisons were made for data stratified by test order. The standard used for these comparisons was 1.0 liter/test.

5.7.3 The Results

The results of the failure rate comparisons are as follows:

- Overall purge failure rates:
  - The IM240 failed 7.43% (87 vehicles).
  - The ASM failed 11.45% (134 vehicles).

- Initial test failure rates:
  - The IM240.1st failed 6.93% (40 vehicles).
  - The ASM.1st failed 11.13% (66 vehicles).

- Second test failure rates:
  - The IM240.2nd failed 7.92% (47 vehicles).
  - The ASM.2nd failed 11.79% (68 vehicles).

These higher failure rates for the ASM raise the question of whether the ASM correctly identified non-purging vehicles that the IM240 missed, or whether the ASM incorrectly failed vehicles. Passing the IM240 purge test requires either that purge actually occurs or that the measurement system falsely indicate that purge is occurring. Since the ASM and IM240 were run with the same measurement system, and results were reported electronically without human intervention, it is not conceivable that a measurement error made some cars pass the IM240 and fail the ASM. Consequently, the ASM-fail/IM240-pass cars must be considered improper fails by the ASM, and vice versa, with a possibility that test order was a contributing factor in specific cases despite the engine restart for both tests. However, since the sample has essentially an equal number of each test order, test order should not be a relevant factor overall.

The next set of statistics implies that both the ASM and the IM240 falsely fail vehicles, but the ASM falsely fails more vehicles.

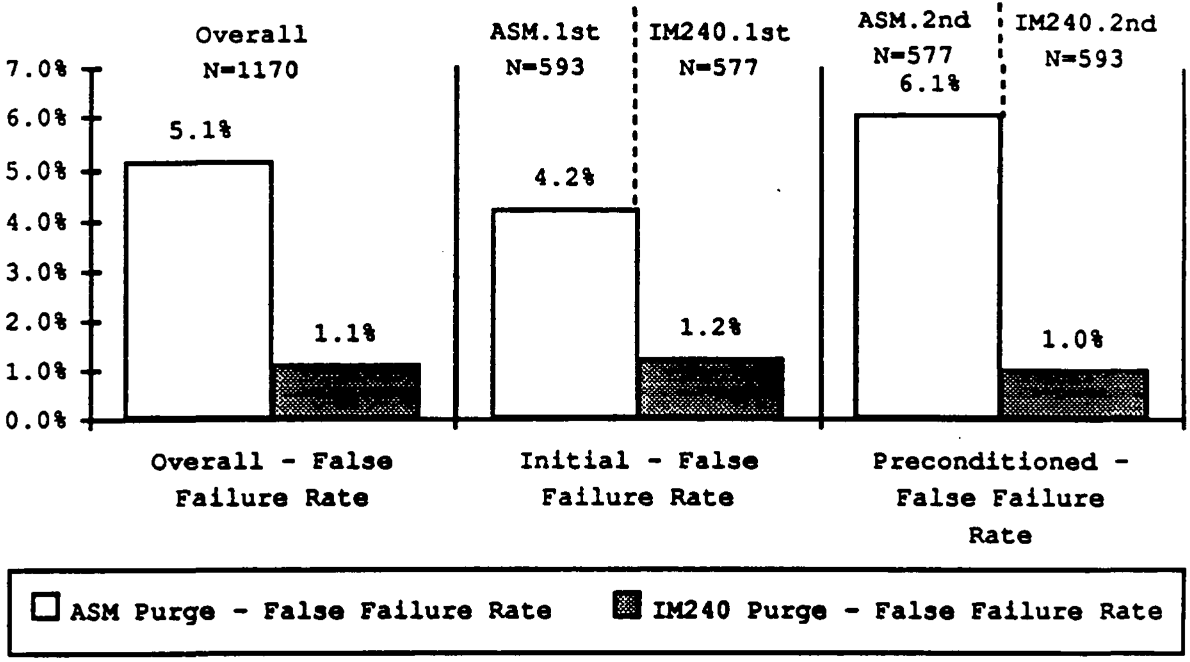
- Overall false failure rates (fails one test but not the other):
  - 1.1% or 13 vehicles failed the IM240 but passed the ASM.
  - 5.13% or 60 vehicles failed the ASM but passed the IM240.

- False failures on initial test:
  - The IM240.1st falsely failed 1.21% (7 vehicles).
  - The ASM.1st falsely failed 4.22% (25 vehicles).

- False failures on second test:
  - The IM240.2nd falsely failed 1.01% (6 vehicles).
  - The ASM.2nd falsely failed 6.07% (35 vehicles).

Figure 5.7.1 graphically illustrates the comparison of false failure rates.

Figure 5.7.1
Comparison of False Failure Rates for IM240 purge vs ASM purge



The most relevant comparison is the initial tests (ASM.1st & IM240.1st) because they are more representative of the conditions and vehicle preconditioning expected in official I/M programs than the preconditioned tests. The purge results for the initial tests were similar to the overall results; the ASM.1st's false failure rate was 3 percentage points higher than for the IM240.1st.

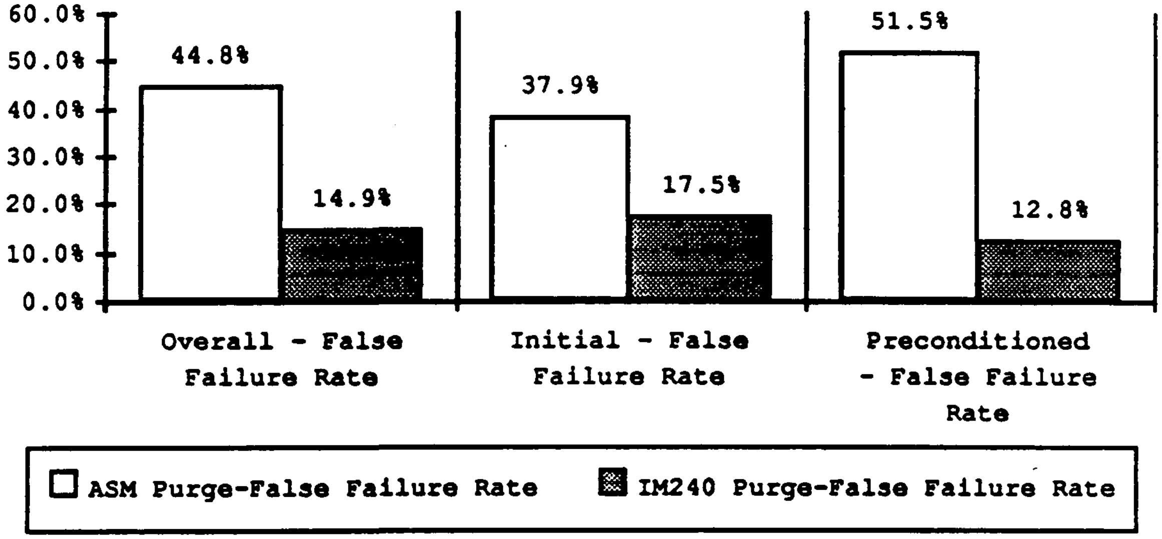
With a 3 to 4% false failure rate, the ASM purge test could cause severe problems to I/M programs in the form of frustrated consumers and skeptical mechanics.

As discussed in the introduction, test order was expected to be important because the test that was performed second would be more likely to achieve purge than the test that was performed first. Contrary to expectations, however, the ASM.2nd exhibited a 0.63% increase in failure rate and a 1.85% increase in false failures when compared to the ASM.1st. The the IM240.2nd also produced a higher failure rate (+1.0%) than the IM240.1st, but the IM240.2nd's false failures decreased 0.2% compared to the IM240.1st.

In addition, the false failure rate for the IM240.2nd is markedly better than for the ASM.2nd when viewed as a percentage of failures. Figure 5.7.2

shows that the false failure rate dropped from 17.5% of the failing IM240.1st vehicles to 12.8% of the failing IM240.2nd vehicles. In contrast, the false failure rate increased to 51.5% of the ASM.2nd failing vehicles from 37.9% of the ASM.1st failing vehicles. So although the false failure rate for both tests is expected to decrease further if the engine restart is avoided before performing the second-chance test, these data suggest that retesting is more effective in reducing IM240 false failures than ASM false failures.

Figure 5.7.2
False Failure Rates as a Percentage of Failures for IM240 purge vs ASM purge



Overall, 74 vehicles failed both the ASM and IM240. The ASM falsely failed 60 additional vehicles while the IM240 falsely failed only 13 additional vehicles. As shown in Figure 5.7.2, 44.8% of the 134 vehicles failing the ASM purge were false failures compared to 14.9% of the 87 vehicles failing the IM240 purge. In addition, 37.9% (25 of 66) of the ASM.1st falsely failed compared to 17.5% (7 of 40) IM240.1st false failures. Of the 68 vehicles that failed the ASM.2nd 35 had purged on the IM240, so 51.5% of the ASM.2nd failures were false failures, whereas only 6 of the 47 vehicles that failed the IM240.2nd had purged on the preceding ASM, so 12.8% of the IM240.2nd failures were false failures.

These results indicate that the ASM error-of-commission rate will be intolerably high with one third to one half of failing vehicles being false failures. I/M programs could implement a second chance test immediately following the first test without shutting off the engine to reduce false failures. However, it is speculative whether this will significantly reduce the ASM false failure rate. Also, second-chance testing adds cost. Since the false failure rate increases from the ASM.1st to the ASM.2nd and decreases for the IM24.2nd compared to the IM240.1st (See Figure 5.7.2), the data indicates that second-chance testing may not be as effective for the ASM as for the IM240.

Second-chance testing costs will be lower for the IM240 because it fails fewer cars initially, thus, requiring fewer retests and some vehicles just do not purge during steady-state operation. For these vehicles, an alternate cycle such as the IM240 would be required. Dynamometer costs would then increase because inertia simulation is needed, but the more expensive IM240 exhaust measurement systems would not be needed.

In summary, the comparison of ASM purge and IM240 purge shows that the IM240 is superior in correctly identifying vehicles with malfunctioning purge systems. With false failure rates of 4 to 6% for the ASM (3 to 6 times higher than IM240 false failure rates), an additional second-chance test will be required. And since some vehicles simply do not purge on the ASM steady-state modes, even with purge measured during the accelerations between modes, an alternate cycle such as the IM240 may be required for retests. In conclusion, the ASM purge test is substantially less effective than the IM240 purge test.

5.8 IM240 Improvements and the Four-Mode IM240

The purpose of this section is to convey that refinements are possible which would make the IM240's performance a "moving-target," and to further reiterate why one sample should be used to develop the ASM-mode weighting factors and an independent sample used to evaluate the ASM's effectiveness.

EPA's recommended IM240 cutpoints of 0.80/15.0/2.0 + 0.50/12.0 represent a compromise between failing high emitting vehicles and not failing clean vehicles. As cutpoints are tightened, the IDRs generally increase at the expense of increasing the possibility of errors-of-commission. Increasing the power of the test (i.e., the ability to distinguish between malfunctioning and properly functioning vehicles) serves the public good, in that the high emitters not identified by the test are not repaired, so the cost of testing such vehicles is not rewarded by air quality improvements that accrue from identifying and repairing such vehicles. More tangible is that vehicle owner satisfaction and acceptance of I/M programs increase with lower errors-of-commission.

EPA is not content for all time with the absolute performance of the IM240 as now defined. Although in a relative sense, its performance is superior to any of the alternative I/M tests, it can be improved. Consider for example the IM240's 15 g/mi CO cutpoint. This is more than four times the FTP CO standard, and unlike the FTP which includes a cold start[9], the IM240 is to be performed on fully warmed up vehicles. So the errors of omission (vehicles which pass, but should not) are higher than if a more stringent CO standard were used. EPA testing has shown that tighter cutpoints will identify more high emitters, but also fail some properly functioning vehicles. Although the IM240 is considerably better than any alternative I/M test, in this regard, there is no question that its performance can be improved. The IM240's performance can be improved in two areas:

- Reduce the test-to-test variability so that cutpoints can be tightened without falsely failing clean vehicles.

- Use statistical techniques to improve the IM240's correlation with the FTP.

Such improvements will serve the public interest by increasing the air quality yield per test-dollar, so alternative tests should be evaluated against the state-of-the-art of IM240 testing rather than the IM240 performance, as it existed, when the I/M Rule was published. Proponents of alternative I/M tests may point out that if the IM240's performance, as it stood in November 1992, was good enough to meet the performance standard, then this performance standard should be the standard for alternative tests. While such a policy may indeed "level-the-playing-field" for alternative tests and is in fact what is allowed by EPA's I/M Rule, it is difficult to argue that this approach promotes the general welfare and should guide state and local decision-makers concerned as much about clean air as about meeting minimum requirements.

5.8.1 Reduce Test-to-Test Variability

Test-to-test variability is the primary reason why the IM240's cutpoints are so much less stringent than the FTPs. The FTP controls a number of variables that are widely known to affect a given vehicle's emissions. Some variables that are tightly controlled for FTPs were either more loosely controlled or not controlled in EPA's IM240 lane tests. These include, among others:

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[9] CO (and HC) emissions are considerably higher during warmup than during fully warmed-up operation.

- ambient temperature in the test cell
- humidity in the test cell
- engine temperature (FTP indirectly controls with preconditioning and ambient conditions)
- catalyst temperature (FTP indirectly controls with preconditioning and ambient conditions)
- vehicle operation prior to the emissions test (can affect emission control system timers for purge, air switching, etc., and other variables affecting emissions)
- evaporative canister loading (FTP indirectly controls with ambient conditions and vehicle operation during the 12 hours preceding the FTP emissions test)
- tire pressure
- speed excursions from the nominal speed (±2 mph on FTP vs. driver discretion for EPA's pilot IM240 testing to date)
- exhaust system backpressure (NOx can be adversely affected by a constant volume sampler if quality control is not adequate)
- fuel composition

EPA has already made improvements that I/M programs will be required to implement, but were not implemented during EPA's testing. For example, FTPs are voided if speed excursions from the nominal speed exceed ±2 mph. In contrast, much of EPA's data are from vehicles with speed excursions that exceed ±2 mph. In a committee that included I/M contractors, state I/M program officials, IM240 equipment manufacturers, and automobile manufacturers, a consensus was reached on requiring this tighter speed tolerance along with additional tighter controls that will reduce test-to-test variability[10].

There are also variables that can not be controlled, such as ambient temperature and canister loading, but can be compensated for to better distinguish between malfunctioning and properly functioning vehicles. Given enough data, computer algorithms can be developed that consider the more important variables and apply adjustment factors to the official IM240 test results.

Simplistic approaches such as setting tire pressure or providing second-chance tests for vehicles that are within 1.5 times the cutpoints seem costly to implement because additional I/M lanes and personnel are needed, but are judged to be cost effective since vehicles that should not fail but do, must be retested after "repairs" anyway.

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[10] Draft High-Tech Test Procedures, Quality Control Requirements, and Equipment Specifications, April 5, 1993.

More sophisticated algorithms utilizing sensors to measure variables like ambient temperature and catalyst temperature allow relationships to be developed and used to compute scores. These are more efficient because they can increase the power of the test without requiring additional I/M lanes and personnel. Developing these techniques will require substantial data. When the IM240 is implemented, much data will become available to allow development of such algorithms.

5.8.2 Statistical Techniques to Improve the IM240's Correlation With the FTP

Presently, the IM240 score constitutes the sum of the mass emissions divided by the distance accumulated. Because almost every second of operation is taken from various segments of the FTP, the two tests correlate better than any existing alternative I/M test. But their correlation can be improved using multiple regression. For example, the uncontrolled variables that attend IM240 tests probably make it appropriate to de-emphasize the initial operation of the IM240 in computing the score and emphasizing the later operation. The later operation is somewhat preconditioned by the initial operation. Also, the IM240 has a higher average speed than the FTP, so de-emphasizing the high speed portions should produce a better correlation with the FTP.

The data itself can be used to determine the more appropriate weighting through the use of regression techniques. For example, EPA divided the IM240 into four modes as follows:

Mode 1:	0-60 seconds
Mode 2:	61-119 seconds
Mode 3:	120-174 seconds
Mode 4:	175-239 seconds

As for the ASM, coefficients are developed by performing a multiple regression wherein the results from four modes are the independent variables and the FTP results is the dependent variable, which allows the data to determine the appropriate mode weighting.

EPA tried this using the only substantial database with the information needed (FTPs with IM240 4-mode results or second-by-second results), which happens to be the vehicles on which this report focuses. So the coefficients had to be developed on the same set of data to which they were applied. EPA condemns this practice, as discussed in Section 5.5, but having no alternative, the results are presented only to provide an indication of how the IM240's performance is enhanced through this approach.

Unfortunately, the legitimate performance increase gained by using multiple regression to determine appropriate mode weighting can not be isolated from the inappropriate application of these coefficients to the same vehicles from which they were developed. So the performance presented in Table 5.8.2 gives an overly optimistic view, but also reiterates that ASM-advocates who do not accept EPA's judgement that it is inappropriate to apply coefficients to the vehicles from which they were developed, should then compare the ASM performance with inter-linked coefficients to the IM240 also utilizing inter-linked coefficients.

The multiple regression was performed on the first 91 vehicles in the database only (this analysis was not repeated when additional data became available). The results are presented in Tables 5.8.1 and 5.8.2. The negative coefficients in Table 5.8.1 indicate that insufficient data is available for developing logical coefficients, which will compensate, to some degree for the inter-linked performance listed in Table 5.8.2.

Table 5.8.1
Coefficients Developed from
Multiple Regression of 4-Mode IM240 vs. FTP

Mode	**HC**	**CO**	**NOx**
Constant	0.03	-0.28	-0.02
1	-0.30	-0.18	-0.07
2	1.16	1.70	0.37
3	0.26	-0.01	0.02
4	0.09	-0.08	0.56
R^2	90.3%	86.0%	69.6%

Table 5.8.2 illustrates how the 4-Mode test improves the tradeoff between IDRs and Ec rates at equivalent failure rates.

Table 5.8.2
4-Mode IM240 Performance Versus Normal IM240

Fail Rate	IDRs						Ecs	
	HC		CO		NOx			
	4-Mode	Regular	4-Mode	Regular	4-Mode	Regular	4-Mode	Regular
12%	88%	88%	65%	63%	72%	75%	0.0%	0.4%
13%	90%	90%	66%	65%	75%	76%	0.0%	0.4%
14%	91%	91%	66%	66%	78%	78%	0.4%	0.7%
15%	92%	91%	66%	66%	75%	78%	0.4%	0.7%
19%	91%	93%	72%	68%	83%	82%	0.4%	1.4%
20%	94%	93%	72%	69%	86%	82%	0.4%	1.8%
23%	95%	93%	73%	69%	88%	83%	0.7%	3.9%

Notice the performance increase in that the IDRs increase and errors-of-commission decrease.

In conclusion, developers of alternative I/M tests should not consider the performance of the IM240 to be fixed. While better than any existing I/M tests, IM240 improvements are possible and desirable. EPA's mission to improve air quality and enhance the public welfare necessitates evaluating alternative tests, not against the performance of the IM240 as it was in November 1992 when the I/M Rule was published, but instead, against the state-of-the-art.

6. Test Programs by Other Organizations

6.1 Colorado Test Program

The Colorado Department of Health (CDH) completed an evaluation[11] comparing the FTP and the IM240 to the following eight I/M test modes, in the order the modes were performed:

- 35 mph road load
- 50 mph road load
- ASM 2545
- ASM 2525
- ASM 5015
- Idle test
- 2500 rpm

Their conclusions included the following:

> "The loaded mode [IM240] tests (both [93] second and 240 second] identify significantly more of the excessively emitting vehicles and more of the excess emissions than do any of the steady-state tests. They also have fewer errors of commission and less sensitivity to differences between FTP and short test emission levels. With no other consideration, either the 95 second or the 240 second version of the [IM240] would be the clear choice for the most accurate and effective identification of excessively emitting vehicles."

6.2 California Test Program

EPA has received a preliminary analysis[12] from the California Air Resources Board (CARB) comparing the ASM5015 and the ASM2525 to the IM240. The CARB analysis looks favorably on the ASM modes and concludes that the ASM tests are as effective as the IM240. However, there are significant concerns with CARB's data. These concerns include the following:

- The CARB database is not representative of the newer fleet.

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[11] Ragazzi, et al.

[12] Draft Memorandum from Jeff Long, Manager, Analysis Section to Mark Carlock, Chief, Motor Vehicle Analysis Section, "Comparison of Excess Emissions Identified by IM240, ASM5015 and ASM2525 Tests," California Air Resources Board, not dated, received April 15, 1993.

- CARB's testing is not representative of actual I/M testing.
- All of CARB's tests were preconditioned.
- CARB's ASM equations, when applied to EPA's data, demonstrate poor performance.

EPA is preparing a separate document that will consider CARB's ASM test program in more detail.

7. Test Costs Comparison

Supporters of the ASM have frequently suggested that it would be a more cost-effective test than the IM240, given that the equipment cost is significantly lower. As Table 5.12.1 shows, the equipment package for the ASM series, with purge and pressure testing, does have a lower total cost than the IM240, purge, and pressure equipment package.

Table 7.1
Equipment Costs for the ASM Series and IM240

IM240		ASM	
Equipment	Cost	Equipment	Cost
Pressure Rig	$600	Pressure Rig	$600
Purge Meter	$500	Purge Meter	$500
VDA	$1,000	VDA	$1,000
Dynamometer	$25,000	Dynamometer	$20,000
CVS & Analyzers	$79,000[13]	BAR90 & NOx Bench	$19,000
Total	$106,100		$41,100

These figures reflect the most recent cost information that EPA has received from industry. EPA has published previous estimates of the per vehicle costs of ASM and IM240 testing in "I/M Costs, Benefits, and Impacts," in November, 1992. EPA found, and independent analyses confirmed, that equipment costs, when spread over the useful life of the equipment, constitute a relatively small portion of the per vehicle cost of an I/M test; labor and overhead costs are considerably higher. In analyzing the current average per vehicle inspection cost in a centralized program of $8.50, EPA estimated that equipment accounted for 21¢, labor for 96¢, 82¢ went to defray construction costs, the state oversight fee averaged $1.25, and the remaining $5.26 went to cover various overhead costs (for a full discussion of EPA's cost estimation assumptions and methodology the reader is referred to Sections 5.2 and 5.3 of "I/M Costs, Benefits, and Impacts," contained in Appendix H). Current testing stations have an average peak capacity of 25 vehicles per hour and enough stations are constructed to avoid long lines on peak demand days. Given the typical pattern of owners' choices about when to come for inspections, this results in an average actual throughput of 12.5 vehicles per hour which

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[13] Letter from Kenneth W. Thomas, Marketing Manager, I/M Systems, Horiba Instruments Incorporated, to Bill Pidgeon, U.S. Environmental Protection Agency, April 7, 1973 and Quotation from Scott P. Corrunker, Sales Engineer, Combined Fluid Products Company to Dan Sampson, U.S. Environmental Protection Agency, January 27, 1993. These are attached as Appendices J and K.

translates into 39,000 vehicles per year per lane, and costs are spread over a multi-year period, five years in most cases.

Throughput is the most critical variable in estimating costs since it determines the size of the inspection station network needed for a given area and the number of vehicles over which costs for each lane are spread. Inspection lanes usually have more than one position, with different parts of the inspection performed at each one. Hence, throughput is governed not by the time required to perform the total test sequence, but by the time required at the longest position. Whether the test sequence consists of the IM240 with purge and pressure testing or the ASM with purge and pressure testing, the longest part of the sequence is the tailpipe emissions test.

The combined IM240 and purge test takes approximately three minutes (using fast-pass and fast-fail) to perform on the average. Allowing an additional minute to maneuver the vehicle onto the dynamometer and otherwise prepare the vehicle for testing the total time at the longest position is estimated to be four minutes. This translates into a peak lane capacity of 15 vehicles per hour and an average actual throughput of 7.5 vehicles per hour. The ASM consists of four modes lasting 40 seconds each with a few seconds in between to change speed. This works out to approximately three minutes per test. Allowing, again, an additional minute to maneuver the vehicle onto the dynamometer and otherwise prepare it for testing, the total test time is about four minutes, hence, the throughput rates for the ASM is the same as for the IM240. Average throughput for both tests is 7.5 vehicles per hour. Assuming that stations operate 60 hours per week, 52 weeks per year, and costs are spread over a five year period, then equipment costs are spread over a total of 117,000 vehicles.

The optimum lane configuration for both tests is a three position lane staffed by three inspectors. Consequently, as shown in "I/M Costs, Benefits, and Impacts," staff, infrastructure and overhead costs are essentially the same for both tests. The only difference is in the cost of equipment. Table 5.12.2 shows the estimated per vehicle costs for performing the ASM and the IM240. The costs are derived using the same methodology and assumptions as in Appendix H. Overhead costs for IM240 and ASM tests are estimated by factoring the overhead for current centralized programs by the change in throughput. Equipment, and construction costs are obtained by dividing those costs over the total vehicle traffic in a five year period. Staff costs are obtained by dividing inspectors' hourly wages ($6.00) by the average number of vehicles inspected in a hour. State oversight costs are estimated at $1.75 per vehicle but could vary depending upon the intensity of the state oversight program; they would not vary between the two test types.

Despite the difference between the costs of the equipment packages required for the two tests, the total cost per vehicle, factoring in all necessary costs involved in a testing program, differs very little between the two tests. In a high volume test program the per vehicle cost difference is estimated at 74¢; the per vehicle cost for the ASM is about 5 percent less than for the IM240.

Table 7.2

Cost Components and Cost per Vehicle for the ASM and IM240

IM240		ASM
$2.40	Inspection Staff	$2.40
$1.75	State Oversight	$1.75
$1.39	Test Equipment	$0.65
$1.71	Building Modification/Construction	$1.71
$9.12	Other Overhead	$9.12
$16.37	Total Cost Per Test	$15.63

8. Evaluation of the Adequacy of the ASM for Enhanced I/M Programs

8.1 Introduction

The preceding chapters show that the four-mode ASM test is not equivalent to the IM240 on a per-car basis. Even if ASM cutpoints are selected so that the same number of cars are failed, they will represent a smaller portion of the fleet's excess emissions, and the cars will not be repaired as effectively as if the IM240 were used for reinspection after repair. However, to some extent this loss of emission reduction can be compensated for by improving other I/M program features to make them more stringent than would otherwise be required to meet the emission reduction performance standard in EPA's rule for enhanced I/M programs. Among these other features are the inspection of heavy-duty gasoline-fueled vehicles, the use of the ASM test for all 1981 and newer vehicles rather than just the 1986 and newer vehicles which are assumed to be tested with the IM240 in the model I/M program, a higher failure rate for pre-1981 vehicles, purge testing for more model years than in the model program, and more comprehensive tampering inspections.

Whether these improvements are enough to offset the loss of benefit from the ASM is the decisive question that determines whether areas subject to the enhanced I/M program requirement can rely on ASM testing instead of IM240 testing. Also of interest is whether it is possible to use the ASM and still operate a biennial program. To answer these questions, EPA examined annual and biennial scenarios in which the ASM cutpoints were made as stringent as EPA believes is consistent with good engineering practice and the possible offsetting program improvements were made as large as EPA considers reasonably possible. If this hypothetical best-possible ASM program cannot satisfy the enhanced I/M performance standard, then no ASM program can.

Regarding best-possible ASM cutpoints, EPA has assumed that the failure rate associated with the most stringent IM240 cutpoints for which EPA has provided emission reduction credits is the limit of good engineering practice in an I/M program. These IM240 HC/CO/NOx cutpoints are 0.6/10.0/1.5, compared to the 0.8/20.0/2.0 used in the model enhanced I/M program. The ASM cutpoints that matched this failure rate in the full Mesa lane sample were 0.40/8.0/1.8. These ASM cutpoints can be expected to produce a higher error of commission rate than the 0.6/20.0/2.0 IM240 cutpoints, but in the interest of exploring the limits of ASM testing, EPA assumed that this did not make them unacceptable. EPA calculated MOBILE5a I/M credits for these ASM cutpoints, using the same basic approach as originally used for the IM240 credits. We then used MOBILE5a with these credits and appropriate assumptions for the offsetting program improvements to determine the overall benefit of a best-possible hypothetical ASM program. Further description of this process follows.

8.2 MOBILE5a Analysis

The I/M credits for the ASM test procedure were determined using the identification rate from the Arizona test sample. The laboratory sample was weighted as described in Section 5.2.5.8 to reverse the effect of the recruitment bias. The fraction of total emissions identified by the ASM test with best-possible cutpoints and the IM240 test with its standard cutpoints were determined for that sample*. Using the IM240 results for the Arizona sample, the ASM identification rates were converted to a fraction of the IM240 results. These fractions were then used in the I/M credit model to adjust the IM240 identification rates used in MOBILE 5 to represent the effect of the ASM test.

For repair effects, based on current information, EPA can only give the ASM test the same repair effect as the 2500/Idle test procedure for HC and CO. For NOx, the ASM test was temporarily assumed to have the same repair effect as the IM240 test procedure using a 2.0 NOx cutpoint, the nearest available to the 1.8 ASM cutpoint. At this time, we made this temporary assumption for NOx so that the ASM program can be analyzed for all three pollutants even though the repair effectiveness problems found for HC and CO appear to be similar for NOx. Unlike HC and CO, there is no set of alternative repair effectiveness numbers available that could be used since steady-state tests have never been used for NOx control in the past.

Using the ASM credit set described above, we proceeded to perform MOBILE5a runs for four separate I/M program scenarios: a no-I/M run, an enhanced I/M performance standard run, and two ASM runs, one assuming an annual testing program, and the other, a biennial program. All four scenarios assume national default inputs for the local area parameter record - including vehicle registration mix, ambient temperature, average VMT, fuel RVP, average speed, etc. - and cover evaluation years ranging from 2000 to 2011. Depending on the ozone classification, states must show in the 1993 SIP that the I/M program selected meets the performance standard in these evaluation years.

Both ASM runs were identical, with the exception of the above-noted difference in test frequency. The other program parameters assumed for the

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* For convenience in calculations, MOBILE5a I/M credits for a particular test and cutpoints are developed starting with the total emissions identification rate, rather than the excess emission identification rate used in earlier sections, to more readily display the relative effectiveness of tests. The difference does not affect the final result.

ASM runs include a program start year of 1983, a test-only network, and ASM testing of model year 1981 and later light-duty vehicles and light-duty trucks. The ASM runs also assumed evaporative system purge and pressure testing, and visual inspection of the catalyst, inlet restrictor, gas cap, air pump, EGR, tailpipe lead test, and PCV system on all 1971 and later model year vehicles. Full purge benefits were given for ASM testing, since ASM purge testing will fail virtually all cars that would fail the IM240 test. A pre-1981 stringency of 40% was assumed, along with a 3% waiver rate and a 96% program compliance rate.

Once these MOBILE5a runs were complete, we compared the results for the enhanced I/M performance standard run and the ASM runs with the no I/M case to determine what percent reduction was required to meet the performance standard and what reductions could be expected from the annual and biennial ASM programs modeled. The results are shown in Table 8.1.

Table 8.1
MOBILE5a Emission Factors and Reductions from ASM Testing

	VOC			CO			NOx*		
	g/m	Redux	OK?	g/m	Redux	OK?	g/m	Redux	OK?
2000 No I/M	2.88						2.27		
Enhanced Performance Standard	1.96	32.0%					1.97	13.5%	
Maximum Annual ASM	2.00	30.5%	NO				1.93	15.0%	YES
Maximum Biennial ASM	2.07	27.9%	NO				1.96	13.9%	YES
2001 No I/M				22.23					
Enhanced Performance Standard				13.98	37.1%				
Maximum Annual ASM				15.08	32.1%	NO			
Maximum Biennial ASM				15.79	29.0%	NO			
2003 No I/M	2.66						2.10		
Enhanced Performance Standard	1.68	36.6%					1.77	15.8%	
Maximum Annual ASM	1.81	31.8%	NO				1.76	16.3%	YES
Maximum Biennial ASM	1.87	29.4%	NO				1.78	15.0%	NO
2006 No I/M	2.52						2.02		
Enhanced Performance Standard	1.53	39.2%					1.67	17.2%	
Maximum Annual ASM	1.71	32.3%	NO				1.67	17.0%	NO
Maximum Biennial ASM	1.76	30.1%	NO				1.70	15.7%	NO
2008 No I/M	2.47						1.97		
Enhanced Performance Standard	1.47	40.3%					1.62	17.8%	
Maximum Annual ASM	1.66	32.6%	NO				1.63	17.4%	NO
Maximum Biennial ASM	1.72	30.4%	NO				1.66	16.1%	NO
2011 No I/M	2.39						1.94		
Enhanced Performance Standard	1.39	41.8%					1.58	18.8%	
Maximum Annual ASM	1.60	33.1%	NO				1.60	17.6%	NO
Maximum Biennial ASM	1.65	30.9%	NO				1.62	16.3%	NO

* With temporary assumption for NOx repair benefits, as described in text.

By comparing the ASM results to the performance standard, we conclude that neither the maximum annual nor the maximum biennial ASM program would meet the performance standard for HC or CO for any of the milestone years. For NOx, the biennial ASM program with the temporary assumption for NOx repair benefits meets the performance standard in 2000, but misses it for each successive milestone, while the annual ASM program meets the performance standard through the 2003 milestone.

These NOx results include a caveat, however. The degree to which the ASM NOx benefit in the table exceeds the performance standard is quite small. If the percent NOx repair benefit for ASM testing is anything less than 90% (i.e., 13.5%/15.0%) as good as for IM240 testing, the Maximum Annual ASM program will not meet the NOx performance standard in 2000. The corresponding "actual values" for the Maximum Biennial ASM program in 2000 and the Maximum Annual ASM program in 2003 are 98% (13.5%/13.8%) and 97% (15.8%/16.2%), respectively. While EPA for the present reserves judgment on exactly how much NOx repair benefit is lost with ASM testing, (while we consider a test program to further explore this question) it is clear from Section 5.3 that the loss is certainly at least 10%. Thus, ASM testing cannot meet the performance standard for any pollutant for any milestone date, and therefore is not an acceptable test in any enhanced I/M program.

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Appendix A: Test Procedures

Test Procedure to Evaluate the Acceleration Simulation Mode and the Emissions Measurement Capabilities of a BAR90 Certified Analyzer With An Integrated Fuel Cell Type NO Analyzer

1.0 Objectives

The objective of this ASM test project was to collect data to compare the effectiveness of a four-mode steady-state test procedure as an alternative I/M test to the IM240. Emissions and canister purge flow data were collected using the following vehicle operating modes:

- Two Acceleration Simulation Modes (5015 and 2525)

- A 50 mph steady state mode at road load

- An idle mode in Drive

- An idle mode in Neutral

These modes will subsequently be referred to as the ASM test. The same data were collected for the IM240 test.

The lower cost of the emissions measurement equipment is the salient feature that makes the ASM attractive to its proponents. Therefore, EPA made ASM emissions measurements using a certified BAR90 analyzer (for HC, CO, and CO_2) with an integrated NO analyzer of the fuel cell type for NO measurements. For the IM240 a CVS-based emissions measurement system was used.

Canister purge flow measurements were made with the same 0-50 liter per minute for both the ASM and IM240.

The testing was carried out in two locations, a single I/M lane in an official Arizona I/M station and at a laboratory owned by Automotive Testing Laboratories (ATL). Both were located in Mesa, Arizona.

2.0 Phoenix Lane Procedure

The following is a description of the I/M lane procedures.

- This procedure was restricted to 1983 and newer light duty vehicles with fuel injection, when available. Carbureted 1983 & newer vehicles were tested when fuel injected vehicles were unavailable.

Pre-1983 light duty vehicles were tested only when 1983 and newer vehicles were unavailable.

- Each light duty vehicle received:

  1. The ASM test that included the following modes in the sequence listed:

     - ASM5015 with purge,
     - ASM2525 with purge,
     - 50 mph at road load, with purge,
     - idle test (automatic transmissions in drive),
     - idle test (automatic transmissions in neutral) for the first 50 cars. Car 51 and subsequent cars will not get the 5th mode.

These four or five modes will be referred to as the ASM series.

2. An IM240 with purge.

3. A pressure test.

4. An Arizona State I/M test.

2.1 Procedure Sequence

- In general all odd numbered vehicles got the IM240 as the initial test and all even numbered vehicles got the ASM as the initial test.

- Data collected included a number 1 or 2 in a field named "Test.Order" to designate whether the ASM series procedure was run first or second. Discrepancies between the Test.Order entry and even/odd vehicle numbers are resolved by relying on the Test.Order entry, as this was ATL's primary means to identify test order.

2.2 Measurement Equipment

- For the ASM series, a certified BAR90 HC/CO/CO_2 exhaust emission analyzer was used to measure HC, CO, and CO_2, with an integrated NO analyzer using a fuel cell sensor. ATL only acquired a NO analyzer/BAR90 analyzer combination that provided second-by-second data for HC, CO, CO_2, and NO. The data output for the ASM test went to 3-1/2 inch floppy discs that included run number, time (sec), mode number, vehicle speed, purge flow, NO (ppm), HC (ppm), CO2 (%), CO (%), actual torque, required torque, actual horsepower and required horsepower.

- A 50 liter/min Sierra flow meter was used to measure total canister purge flow. The flow meter system output was the cumulative second-by-second data for total flow recorded on the 3-1/2" floppy discs discussed above.

- For the IM240, normal measurements with the CVS system continued at the lane. The data collected included time (sec), bag number, ambient measurements, NOx (grams/second), HC (g/sec), CO_2 (g/sec), CO (g/sec), and purge in standard liters.

2.3 Procedure Details

- An electric Clayton dynamometer was used for both the IM240 and the ASM series. The dynamometer horsepower settings for the ASMs were as follows:
  - 5015 HP = (ETW / 250)
  - 2525 HP = (ETW / 300)
  - 50 Mph HP = Road Load

  The horsepower and inertia weight settings for the IM240 were as normally performed. The minimum inertia weight setting (2,000 lbs.) was used for the ASMs.

- Manual transmission vehicles were tested in second gear for both the ASM5015 and the ASM2525. The 50 mph road load mode used the top non-overdrive gear, typically 4th gear on a 5-speed, 4th gear on a 4-speed, and 3rd gear on a 3-speed. Drivers used a lower gears for vehicles that were lugging.

- The engine was shut off prior to the IM240 and the ASM5015 (as will normally be done by I/M programs to connect the purge meter), regardless of which procedure was performed first, and restarted just prior to initiating these procedures. The engine was not shut off between ASM modes, and the vehicle was accelerated from the current mode up to the next mode speed, without first returning to zero.

- The ASM emission sampling period and the canister purge flow measurement period were as follows:

1. Each ASM mode was initiated after the vehicle speed had achieved the nominal speed (15, 25, or 50 mph, and 0 mph idle) ±2 mph. Once up to speed, emissions sampling of one second average concentrations continued for 40 seconds. Emission scores for HC, CO, CO2 and NO were reported for each second. Emissions scores for the first 10 seconds of each mode were ignored to allow the dynamometer to stabilize and to allow for transport time to the analyzers.

2. The purge flow reported was the second by second cumulative flow over the entire ASM cycle, including transient accelerations. The nominal acceleration rate was 3.3 mph/sec., with a minimum acceleration rate of 1.8 mph/sec and a maximum of 4.3 mph/sec. The table below lists the minimum, nominal, and maximum acceleration times used to accelerate from one mode to another. For example, the table shows that the time to accelerate from 25 mph to 50 mph should be 7.6 seconds., but can take as long as 13.9 seconds., and as little as 5.8 seconds. The zero to 60 mph time is provided to indicate how the specified acceleration times relate to a commonly known reference of vehicle performance. ATL used a video driver's aid with the nominal acceleration rate.

		Time to Accelerate from-to:			
	Acceleration Rate (mph/sec)	0-15 mph (secs)	15-25 mph (secs)	25-50 mph (secs)	0-60 mph (secs)
Minimum	4.3	3.5	2.3	5.8	14.0
Nominal	3.3	4.5	3.0	7.6	18.2
Maximum	1.8	8.3	5.6	13.9	33.3

- During the accelerations between modes, the dynamometer load setting did not exceed road load. This was specified to enhance the opportunity for canister purge during the ASM accelerations. The combination of the ASM load and the base 2,000 lb. inertia may load some vehicles to heavily to allow purge to initiate.

3.0 Lab Recruitment

Light duty vehicles that received all of the lane tests (IM240, ASM series, and Arizona I/M test), were recruited for testing at ATL's laboratory. Cars were categorized as passing or failing using the IM240 cutpoints in the table below:

Phoenix Lane IM240 Cutpoints for Lab Procurement

Model Years	HC g/mile	CO g/mile	NOx g/mile
1983+	>0.80	>15.0	>2.0

The following table provides the laboratory recruitment goals for the pass/fail categories listed as a percentage of the total number of cars recruited to the lab for this task. The initial recruitment target was 100 vehicles.

Phoenix Lab Recruitment Goals Using Lane IM240 Categories

Model Years	HC/CO Pass	HC/CO Fail	NOx Pass	NOx Fail
1986+	15%	15%	15%	15%
1983-85	10%	10%	10%	10%

4.0 Commercial Repair Recruitment

Owners of vehicles that failed the Arizona I/M test, and received and IM240/ASM series, were offered $50 to return to the lane for after-repair tests. These vehicle owners were only offered this incentive if they refused to participate in the laboratory testing program or if their vehicles were not needed for laboratory recruitment. Recruiting vehicles for laboratory tests was a higher priority than for commercial repair participation.

The owners were informed that they must return with repair receipts indicating repairs by a commercial establishment with itemized labor and parts costs to qualify for the $50 incentive. ATL included either the original receipts or copies in the vehicle test packets that ATL provided to EPA. In addition, ATL provided summarized comments and data for these vehicles on electronic disk.

Vehicles returning after commercial repairs followed the same procedures.

5.0 Lab Procedure

The lab procedure is summarized in Attachment 1, so this section will only add explanations to the procedure listed in Attachment 1.

5.1 Two Groups

The vehicles recruited to the lab were separated into two groups:

1. Those whose initial lane test was the IM240 and were repaired to IM240 targets. For the vehicles in this group, the IM240 always precedes the ASM series (see Attachment 1).

2. Those whose initial lane test was the ASM series and were repaired to ASM targets. There were not enough data to set ASM repair targets, so IM240 targets were used for both groups. For the vehicles in this group, however, the ASM series always preceded the IM240 (see Attachment 1).

5.2 Repair Targets

The repair targets were to achieve 0.80/15.0/2.0 on the IM240 for both the ASM-targeted group and the IM240-targeted group. Initially, repair targets were to be provided to ATL for the ASM targeted group to replace the IM240 targets. However, due to time and data constraints this proved impossible.

For the initial repair attempt, the mechanic was only aware of the lane IM240 score for both vehicle groups (initial lane test: ASM or IM240). For subsequent repair attempts, the mechanics were only be aware of lane and lab IM240 scores. FTP scores were not provided to the mechanics for either group.

Repairs were limited to $1,000.

5.3 Laboratory Test Equipment

Due to time and financial constraints, EPA was unable to develop lab ASM capability. The IM240 and FTP were measured with a CVS system. Modal or second-by-second CVS capability was not available at the laboratory.

Appendix A: Attachment 1

ASM/IM240 Lab Procedure

Revision Date: 10/21/92
Number tested =
Recruitment: 1983+ fuel injected only.
Repairs: Get IM240 Indolene to .8/15/2.0. The mechanic should only be aware of IM240 scores for the IM240 targetted repairs. $1,000 repair limit/car - catalyst if necessary, aftmrkt preferred.

Develop explanations for any IM240 failures that pass FTP, while veh is still at lab.

Tank Fuel

On-Road Warmup
Tank Fuel IM240

9.0 RVP Indolene As-Received

LA-4 Prep cycle @ 80°F
No Diurnal
FTP Exhaust
No Hot Soak
IM240 Indolene (with purge if available)

Repair to get IM240 Indolene to .8/15/2.0. The mechanic should only be aware of IM240 scores - not FTP scores, and only perform minimum repairs necessary to achieve targets.

Report After-First-Repair Indolene IM240 regardless of outcome. Mechanic will only be aware of lane IM240 score for first repair, not lab tank fuel score.

Continue repairs if necessary. Don't perform FTP until .8/15/2.0 is achieved.

9.0 RVP Indolene After-Repair to IM240 0.8/15/2.0

3 LA-4 Prep cycles @ 80°F for all vehicles
Top off to 40% fill - don't drain.
FTP Exhaust
IM240 Indolene RM1 (w/purge if available)

Stop repairs even if failing FTP.

Indolene Lane Tests For Vehicles Whose Initial Lane Test Was IM240

On-Road Warmup
Lane Indolene IM240
ASM Series

Indolene Lane Tests Procedure for Vehicles Whose Initial Lane Test Was ASM Series

On-Road Warmup
ASM Series
Lane Indolene IM240

Appendix B

Data Listings

I. Cutpoint Table Analyses Laboratory Recruited Vehicles

Vehicle Information					**FTP Scores**			**IM240 SCORES**					**ASM**		
								Composites			Bag 2 score		Composite Scores		
Veh#	**Run#**	**Test**	**Date**	**Order**	**HC**	**CO**	**NOx**	**HC**	**CO**	**NOx**	**HC2**	**CO2**	**ASM HC**	**ASM CO**	**ASM NOx**
3148	1672	TST17	921030	IM240.2nd	0.11	1.1	0.97	0.03	1.3	0.55	0.04	1.1	0.13	3.8	0.51
3149	1685	TST17	921102	IM240.1st	0.2	2.3	0.2	0.21	2.8	1.19	0.16	2.2	0.19	3.3	0.77
3150	1692	TST17	921030	IM240.2nd	2.43	82.9	0.59	1.44	32.6	0.95	0.79	14.7	1.40	72.5	0.56
3151	1696	TST17	921102	IM240.2nd	0.34	3.5	5.81	0.2	2.0	4.54	0.1	2.7	0.47	3.3	2.09
3152	1709	TST17	921103	IM240.1st	0.18	3.6	1.01	0.12	2.8	1.34	0.09	2.6	0.10	4.0	0.35
3154	1739	TST17	921103	IM240.1st	0.31	6.2	1.04	0.34	4.4	2.24	0.23	3.4	0.31	8.2	1.70
3155	1735	TST17	921103	IM240.1st	3.25	46.7	0.26	2.77	24.1	1.2	2.06	17.2	0.43	5.8	0.50
3156	1726	TST17	921104	IM240.2nd	0.31	6.7	1.07	0.45	6.1	2.07	0.45	6.2	0.19	3.8	1.04
3157	1747	TST17	921104	IM240.1st	1.7	14.3	2.14	2.84	34.7	2.95	2.26	15.7	1.59	11.3	2.56
3158	1753	TST17	921104	IM240.1st	0.15	2.6	0.85	0.16	2.4	2.44	0.07	1.6	0.11	2.9	0.90
3159	1752	TST17	921105	IM240.2nd	1.11	74.2	0.31	0.75	41.2	0.49	0.83	49.2	0.57	38.8	1.01
3160	1749	TST17	921105	IM240.1st	0.29	3.0	1.26	0.21	2.8	2.27	0.18	2.6	0.15	3.4	1.31
3161	1754	TST17	921105	IM240.2nd	0.28	5.1	1.7	0.24	4.1	2.42	0.23	4.6	0.16	5.8	2.04
3162	1777	TST17	921106	IM240.1st	0.35	3.7	1.25	0.77	6.7	3.08	0.35	2.9	0.11	3.1	1.05
3165	1810	TST17	921106	IM240.2nd	1.96	13.2	2.5	1.59	7.3	2.48	1.5	6.9	0.40	4.7	1.14
3169	1677	TST17	921109	IM240.1st	1.04	15.0	0.96	0.85	14.2	0.98	0.79	14.7	1.68	17.3	0.74
3170	1879	TST17	921109	IM240.1st	0.42	7.2	1.16	0.34	7.6	2.02	0.24	6.6	0.16	3.9	1.32
3171	1891	TST17	921118	IM240.1st	0.15	3.2	0.52	0.1	2.3	0.46	0.07	2.8	0.12	2.9	1.07
3172	1895	TST17	921120	IM240.1st	0.16	3.3	0.73	0.12	2.1	3.3	0.09	1.8	0.21	3.6	0.61
3173	1804	TST17	921111	IM240.2nd	0.37	6.7	0.82	0.18	3.7	0.84	0.13	2.9	0.11	2.9	0.91
3174	1688	TST17	921111	IM240.2nd	0.74	16.3	1.88	0.76	19.3	2.5	0.62	16.6	0.31	9.8	2.03
3175	1907	TST17	921120	IM240.1st	0.4	13.1	0.46	0.9	47.8	0.63	1.04	59.7	0.20	12.9	0.84
3178	1965	TST17	921118	IM240.1st	0.2	1.6	0.82	0.09	1.8	0.72	0.08	1.6	0.20	3.3	0.64
3179	1966	TST17	921220	IM240.2nd	2.9	77.6	2.06	1.84	55.9	1.6	1.71	54.3	2.44	89.0	2.10
3180	2005	TST17	921123	IM240.1st	0.96	9.8	1.22	1.33	8.5	2.34	1.09	5.9	0.16	3.6	0.68
3181	2015	TST17	921120	IM240.1st	0.2	3.4	0.48	0.13	1.2	0.69	0.1	1.3	0.22	3.3	0.77
3182	2019	TST17	921120	IM240.1st	1.47	26.2	1.12	1.53	18.0	1.36	1.44	17.5	1.07	22.1	2.16
3183	2024	TST17	921124	IM240.2nd	3.13	66.3	0.7	1.29	26.0	0.85	1.01	20.6	1.92	34.8	1.59
3184	2128	TST17	921125	IM240.2nd	0.3	3.0	0.48	0.14	3.5	0.52	0.15	2.9	0.34	4.4	1.09
3185	2130	TST17	921125	IM240.2nd	0.43	7.4	1.27	0.33	7.7	1.32	0.31	7.7	0.74	11.8	2.86
3186	2152	TST17	921125	IM240.2nd	0.19	2.3	0.17	0.15	1.4	0.17	0.19	1.7	0.18	3.9	0.31
3187	2131	TST17	921127	IM240.1st	0.26	2.3	0.66	0.23	2.7	1.42	0.18	2.5	0.12	3.5	0.87
3188	2160	TST17	921127	IM240.2nd	4.49	17.8	0.2	4.02	14.4	0.1	3.21	14.2	3.78	15.1	0.31

I. Cutpoint Table Analyses Laboratory Recruited Vehicles

Vehicle Information					**FTP Scores**			**IM240 SCORES**					**ASM**		
								Composites			**Bag 2 score**		**Composite Scores**		
Veh#	**Run#**	**Test**	**Date**	**Order**	**HC**	**CO**	**NOx**	**HC**	**CO**	**NOx**	**HC2**	**CO2**	**ASM HC**	**ASM CO**	**ASM NOx**
3189	2165	TST17	921127	IM240.1st	0.4	5.9	1.24	0.17	3.2	1.41	0.15	3.1	0.12	4.1	1.33
3190	2161	TST17	921201	IM240.1st	13.07	42.0	0.56	7.06	24.8	0.79	5.77	23.1	4.27	12.7	0.80
3191	2164	TST17	921130	IM240.2nd	0.32	3.3	0.56	0.17	3.5	0.45	0.18	3.6	0.22	4.4	0.62
3192	1995	TST17	921130	IM240.1st	0.49	6.3	0.53	0.5	8.7	0.76	0.41	9.0	0.42	6.6	0.92
3193	2176	TST17	921130	IM240.2nd	0.61	5.0	0.97	0.86	6.6	1.33	0.72	5.6	0.41	3.4	2.79
3194	2202	TST17	921201	IM240.2nd	2.29	47.1	1.92	1.42	20.2	1.69	1.39	20.4	1.04	43.2	2.16
3195	2200	TST17	921202	IM240.2nd	0.51	5.8	0.66	0.21	3.5	0.9	0.2	3.7	0.19	3.3	1.27
3196	2230	TST17	921201	IM240.2nd	2.87	26.5	5.81	2.73	13.9	5.1	2.54	13.7	1.49	15.9	5.88
3197	2238	TST17	921201	IM240.2nd	1.29	3.5	2.42	0.99	8.3	2.66	0.88	8.7	0.86	7.7	2.97
3198	2198	TST17	921201	IM240.2nd	1.77	10.2	1.8	1.51	8.5	2.04	1.31	8.2	1.07	7.4	2.50
3199	2244	TST17	921203	IM240.2nd	0.53	10.9	1.53	0.3	9.6	1.15	0.25	9.1	0.37	4.1	1.74
3200	2245	TST17	921203	IM240.1st	0.59	0.3	0.69	0.29	1.6	2.49	0.27	1.5	0.13	2.9	1.58
3201	2237	TST17	921202	IM240.1st	0.94	19.7	1.72	1.15	8.8	1.82	0.52	6.0	0.19	4.5	1.08
3202	2273	TST17	921203	IM240.1st	0.5	7.5	7.56	0.23	3.6	7.88	0.2	3.2	0.17	3.1	6.51
3203	2261	TST17	921203	IM240.1st	0.96	6.4	4.17	0.74	5.9	4.37	0.71	6.3	0.41	3.6	4.61
3204	2280	TST17	921203	IM240.2nd	0.34	6.4	0.47	0.16	4.1	0.45	0.15	3.4	0.15	3.3	0.57
3205	2302	TST17	921204	IM240.2nd	0.33	5.6	0.89	0.17	4.1	0.9	0.16	4.2	0.28	4.6	1.57
3206	2317	TST17	921207	IM240.1st	0.51	10.2	0.34	0.28	5.4	0.58	0.26	6.2	0.29	8.2	0.57
3207	2319	TST17	921207	IM240.1st	3.33	87.3	0.92	3.22	77.3	0.97	3.19	79.3	2.19	70.8	1.04
3208	2324	TST17	921207	IM240.2nd	2.38	113.4	0.31	1.87	74.4	0.41	1.83	71.9	1.59	73.7	0.73
3209	2326	TST17	921207	IM240.2nd	0.2	2.5	0.53	0.11	2.1	0.6	0.12	2.6	0.17	4.3	0.67
3210	2337	TST17	921207	IM240.1st	1.4	20.3	1.21	1.04	13.0	2.98	0.9	13.2	0.55	7.2	3.65
3211	2330	TST17	921207	IM240.2nd	0.48	10.8	0.57	1.42	93.1	0.53	1.94	129.3	0.63	64.9	0.58
3212	2352	TST17	921208	IM240.2nd	0.37	3.9	1.11	0.15	1.5	5.15	0.15	1.7	0.26	4.7	4.04
3213	2368	TST17	921208	IM240.2nd	0.33	4.3	0.93	0.54	19.6	1.17	0.59	24.7	0.16	3.0	0.55
3214	2369	TST17	921208	IM240.1st	1.15	12.9	2.5	2.01	23.4	2.96	1.83	21.4	0.85	6.6	2.03
3216	2379	TST17	921210	IM240.1st	0.3	3.2	0.65	0.96	14.8	1.04	0.12	0.9	0.47	7.1	0.55
3217	2376	TST17	921209	IM240.2nd	0.8	9.7	2.02	0.53	6.5	2.22	0.54	7.4	0.31	4.5	2.06
3218	2419	TST17	921210	IM240.1st	0.2	2.7	0.3	0.1	1.2	0.87	0.08	1.0	0.33	3.3	0.72
3219	2416	TST17	921210	IM240.2nd	0.33	4.0	0.78	0.23	4.0	0.81	0.2	3.1	0.38	4.0	0.89
3220	2424	TST17	921210	IM240.2nd	1.22	12.9	1.56	1.05	13.3	1.78	0.95	14.1	1.05	6.9	1.99
3221	2451	TST17	921211	IM240.2nd	0.39	4.5	0.57	0.35	4.0	0.8	0.27	3.5	0.36	3.6	0.60
3222	2435	TST17	921211	IM240.1st	0.32	4.7	0.64	0.15	3.0	1	0.09	2.1	0.77	3.2	0.76

I. Cutpoint Table Analyses Laboratory Recruited Vehicles

Vehicle Information					FTP Scores			IM240 SCORES					ASM		
								Composites			Bag 2 score		Composite Scores		
Veh#	Run#	Test	Date	Order	HC	CO	NOx	HC	CO	NOx	HC2	CO2	ASM HC	ASM CO	ASM NOx
3223	2440	TST17	921211	IM240.2nd	0.53	4.4	0.93	0.37	4.3	1.16	0.35	4.1	0.48	4.1	1.03
3224	2441	TST17	921215	IM240.1st	1.8	21.4	3.23	1.15	10.3	4.47	0.93	9.5	2.36	18.9	3.28
3225	2446	TST17	921214	IM240.2nd	0.57	5.7	0.77	0.19	7.9	1.33	0.18	6.3	0.76	8.3	1.07
3226	2447	TST17	921214	IM240.1st	0.31	3.7	0.99	0.19	3.2	1.59	0.18	3.1	0.30	4.3	1.44
3227	2449	TST17	921214	IM240.1st	0.42	7.6	1.25	0.23	1.4	1.82	0.15	1.2	0.37	3.2	0.80
3228	2450	TST17	921214	IM240.2nd	0.44	19.9	0.8	0.09	3.4	0.61	0.09	2.7	0.29	3.9	0.62
3229	2453	TST17	921214	IM240.1st	0.3	4.4	0.43	0.11	2.7	0.88	0.07	2.9	0.29	3.0	0.76
3230	2445	TST17	921215	IM240.1st	0.41	4.0	0.12	1.04	8.2	0.78	0.41	6.8	0.74	4.5	0.34
3231	2463	TST17	921216	IM240.1st	0.04	3.7	0.2	0.11	1.4	0.25	0.09	1.5	0.19	3.2	0.38
3232	2464	TST17	921216	IM240.2nd	0.18	3.2	0.18	0.33	11.3	0.75	0.44	15.4	0.34	12.8	0.84
3233	2469	TST17	921216	IM240.1st	0.24	2.0	0.28	0.13	1.2	0.21	0.09	0.5	0.26	2.9	0.34
3234	2470	TST17	921216	IM240.2nd	0.25	2.9	0.94	0.16	2.6	1.41	0.17	2.5	0.27	3.4	1.19
3235	2479	TST17	921217	IM240.1st	0.38	2.4	0.34	0.82	6.4	1.8	0.5	5.0	0.70	4.1	0.93
3236	2483	TST17	921217	IM240.1st	0.73	8.6	1.84	1.04	13.9	4.01	1.06	14.6	0.56	5.5	3.03
3237	2488	TST17	921217	IM240.2nd	0.33	3.0	0.28	0.22	2.3	0.19	0.14	1.3	0.31	3.4	0.35
3238	2489	TST17	921217	IM240.1st	0.35	2.3	0.35	0.27	4.7	0.43	0.23	5.3	0.39	3.7	0.40
3239	2490	TST17	921217	IM240.2nd	0.24	1.5	0.72	0.03	0.5	2.4	0.02	0.1	0.28	3.0	1.07
3240	2492	TST17	921217	IM240.2nd	0.27	2.7	1.14	0.07	1.5	2.55	0.06	1.2	0.20	3.0	2.55
3241	2496	TST17	921218	IM240.2nd	0.3	5.5	0.83	0.19	3.4	1.11	0.11	1.8	0.16	3.0	0.87
3242	2499	TST17	921218	IM240.1st	0.39	5.8	1.91	1.05	13.7	3.34	0.71	9.2	0.16	3.7	0.98
3243	2507	TST17	921218	IM240.1st	0.67	8.5	2.18	0.81	7.6	3.38	0.55	6.9	0.40	5.5	2.58
3244	2516	TST17	921218	IM240.2nd	0.22	3.1	0.47	0.09	3.5	2.34	0.09	3.9	0.16	3.8	2.39
3245	2529	TST17	921218	IM240.1st	0.56	4.7	1.63	0.49	4.2	4.52	0.48	4.4	0.19	3.6	1.99
3246	2563	TST17	921221	IM240.2nd	0.33	8.6	1.29	0.42	11.1	2.02	0.52	12.0	0.50	5.4	2.08
3247	2548	TST17	921221	IM240.2nd	0.84	11.4	1.99	0.69	13.5	3.78	0.6	13.1	0.53	6.5	3.09
3248	2830	TST17	930112	IM240.2nd	0.39	3.3	1.51	0.21	2.5	2.55	0.15	2.1	0.15	3.1	2.05
3249	2835	TST17	930112	IM240.1st	0.2	3.8	2.25	0.15	4.6	3.56	0.15	4.9	0.12	4.0	1.97
3250	2845	TST17	930113	IM240.1st	1.55	5.1	1.06	1.57	8.0	1.38	1.27	5.9	0.93	2.9	1.09
3251	2914	TST17	930114	IM240.2nd	1.31	16.9	4.26	0.25	3.6	5.25	0.25	4.2	0.59	5.8	3.46
3252	2945	TST17	930114	IM240.1st	1.03	12.5	1.34	0.99	8.8	1.76	0.85	8.5	0.96	8.4	1.69
3254	3080	TST17	930128	IM240.2nd	1.87	35.9	1.16	2.26	28.6	1.5	2	31.6	0.34	6.3	0.99
3255	3174	TST17	930129	IM240.2nd	0.18	1.3	0.23	0.1	0.8	0.14	0.12	0.9	0.16	3.1	0.38
3256	3208	TST17	930202	IM240.2nd	0.23	2.5	0.26	0.1	0.7	0.19	0.12	0.8	0.25	3.2	0.42

I. Cutpoint Table Analyses Laboratory Recruited Vehicles

Vehicle Information					**FTP Scores**			**IM240 SCORES**					**ASM**		
								Composites			Bag 2 score		Composite Scores		
Veh#	**Run#**	**Test**	**Date**	**Order**	**HC**	**CO**	**NOx**	**HC**	**CO**	**NOx**	**HC2**	**CO2**	**ASM HC**	**ASM CO**	**ASM NOx**
3257	3213	TST17	930202	IM240.1st	1.26	8.6	0.9	1.92	10.6	1.55	1.48	9.4	0.27	4.6	1.03
3259	3250	TST17	930209	IM240.2nd	1.94	15.0	0.53	1.5	9.3	0.88	1.15	8.3	0.26	4.6	1.22
3260	3438	TST17	930216	IM240.2nd	0.2	3.0	0.66	0.11	3.4	0.85	0.12	3.7	0.23	3.0	1.46
3261	3475	TST17	930216	IM240.1st	0.72	12.5	0.37	0.91	19.1	0.69	0.79	19.3	0.48	11.8	0.76
3262	3480	TST17	930217	IM240.2nd	0.34	3.7	1.88	0.19	3.7	2.26	0.17	3.4	0.16	3.3	1.56
3264	3519	TST17	930218	IM240.1st	1.36	20.3	1.06	2.16	20.1	1.65	1.44	16.0	0.54	5.6	1.55
3265	3530	TST17	930223	IM240.2nd	2.7	14.8	2.59	2.49	9.9	3.32	2.22	9.1	1.81	5.5	2.84

II. Contractor Repair Data

Vehicle Information					FTP Scores			IM240 SCORES					ASM		
								Composites			Bag 2 score		Composite Scores		
Veh#	Run#	Test	Date	Order	HC	CO	NOx	HC	CO	NOx	HC2	CO2	ASM HC	ASM CO	ASM NOx
3150	1692	TST17	921028	IM240.2nd	2.43	82.9	0.59	1.44	32.6	0.95	0.79	14.7	1.35	86.9	0.62
3150	1924	TST2	921113	IM240.2nd	0.45	7.6	0.95	0.19	2.8	1.40	0.21	3.2	0.18	3.4	0.95
3151	1696	TST17	921028	IM240.2nd	0.34	3.5	5.81	0.20	2.0	4.52	0.10	2.7	0.36	3.6	3.19
3151	2145	TST27	921123	IM240.2nd	0.28	3.3	0.88	0.14	7.4	0.87	0.16	10.3	0.09	2.9	0.66
3154	1739	TST17	921030	IM240.1st	0.31	6.2	1.04	0.34	4.4	2.24	0.23	3.4	0.24	7.3	1.46
3154	1923	TST2	921113	IM240.1st	0.30	5.2	1.15	0.32	4.7	1.59	0.23	3.7	0.23	5.4	1.87
3155	1735	TST17	921030	IM240.1st	3.25	46.7	0.26	2.77	24.1	1.20	2.06	17.2	0.34	6.0	0.50
3155	1901	TST2	921106	IM240.1st	0.35	3.3	0.37	0.30	4.5	0.75	0.37	5.8	0.22	4.9	0.66
3156	1726	TST17	921029	IM240.2nd	0.31	6.7	1.07	0.45	6.1	2.07	0.45	6.2	0.15	3.7	1.04
3156	1926	TST2	921113	IM240.2nd	0.27	7.0	1.12	0.16	4.5	1.16	0.12	4.1	0.15	3.5	1.12
3157	1747	TST17	921030	IM240.1st	1.70	14.3	2.14	2.84	34.7	2.95	2.26	15.7	0.95	11.1	2.56
3157	2025	TST2	921118	IM240.1st	0.24	2.4	0.53	0.04	1.3	0.28	0.05	1.4	0.13	2.9	0.61
3159	1752	TST17	921030	IM240.2nd	1.11	74.2	0.31	0.74	40.3	0.48	0.83	49.2	0.48	32.9	0.88
3159	2032	TST2	921118	IM240.2nd	0.28	7.6	0.13	0.12	4.6	0.14	0.10	4.4	0.13	5.3	0.39
3160	1749	TST17	921030	IM240.1st	0.29	3.0	1.26	0.21	2.8	2.26	0.18	2.6	0.13	3.4	1.31
3160	1925	TST2	921113	IM240.1st	0.30	3.7	1.49	0.16	1.4	1.87	0.15	1.6	0.19	6.8	1.98
3165	1810	TST17	921103	IM240.2nd	1.96	13.2	2.50	1.58	7.3	2.48	1.50	6.9	0.39	5.6	1.50
3165	2141	TST27	921123	IM240.2nd	0.29	1.3	0.98	0.08	0.4	0.96	0.09	0.5	0.09	3.0	1.01
3169	1677	TST17	921027	IM240.1st	1.04	15.0	0.96	0.85	14.1	0.97	0.79	14.7	0.57	16.7	0.68
3169	1927	TST2	921113	IM240.1st	0.34	1.3	1.81	0.27	0.5	1.43	0.23	0.5	0.26	5.7	1.04
3172	1895	TST18	921106	IM240.1st	0.16	3.3	0.73	0.13	2.1	3.30	0.09	1.8	0.11	3.3	0.51
3172	2335	TST2	921203	IM240.1st	0.15	2.0	0.52	0.04	0.8	0.44	0.05	0.7	0.09	3.2	0.41
3174	1688	TST17	921028	IM240.2nd	0.74	16.3	1.88	0.76	19.3	2.50	0.62	16.6	0.20	9.0	1.81
3174	2174	TST2	921124	IM240.2nd	0.19	4.6	1.06	0.14	6.6	1.37	0.08	3.4	0.08	3.1	1.18

II. Contractor Repair Data

Vehicle Information					**FTP Scores**			**IM240 SCORES**					**ASM**		
								Composites			**Bag 2 score**		**Composite Scores**		
Veh#	**Run#**	**Test**	**Date**	**Order**	**HC**	**CO**	**NOx**	**HC**	**CO**	**NOx**	**HC2**	**CO2**	**ASM HC**	**ASM CO**	**ASM NOx**
3175	1907	TST17	921106	IM240.1st	0.40	13.1	0.46	0.90	47.8	0.63	1.04	59.7	0.17	12.9	0.84
3175	2364	TST2	921204	IM240.1st	0.42	7.9	0.71	0.43	9.6	0.60	0.48	12.0	0.08	4.1	0.54
3179	1966	TST17	921116	IM240.2nd	2.90	77.6	2.06	1.84	55.9	1.60	1.71	54.3	1.48	89.0	2.10
3179	2206	TST2	921125	IM240.2nd	0.22	4.1	1.18	0.07	2.1	1.37	0.09	2.7	0.13	3.0	1.53
3180	2005	TST17	921118	IM240.1st	0.96	9.8	1.22	1.33	8.5	2.34	1.09	5.9	0.15	3.6	0.68
3180	2433	TST27	921209	IM240.1st	0.69	8.8	0.74	0.57	4.8	1.12	0.30	3.7	0.36	3.8	0.84
3183	2024	TST17	921118	IM240.2nd	3.13	66.3	0.70	1.29	26.0	0.85	1.01	20.6	1.11	35.3	1.59
3183	2288	TST2	921201	IM240.2nd	0.25	3.2	1.21	0.17	8.1	1.13	0.20	10.9	0.10	3.1	1.26
3188	2160	TST17	921124	IM240.2nd	4.49	17.8	0.20	4.02	14.4	0.10	3.21	14.2	3.61	18.2	0.32
3188	2382	TST27	921207	IM240.2nd	0.63	5.1	0.54	0.13	2.7	0.66	0.11	2.7	0.16	3.5	0.76
3190	2161	TST17	921124	IM240.1st	13.07	42.0	0.56	7.06	24.8	0.79	5.77	23.1	3.70	12.8	0.80
3190	2456	TST27	921210	IM240.1st	0.19	0.6	0.82	0.10	2.7	0.66	0.10	3.6	0.19	2.9	0.68
3196	2230	TST17	921127	IM240.2nd	2.87	26.5	5.81	2.73	13.9	5.10	2.55	13.6	1.21	15.8	5.88
3196	2511	TST27	921214	IM240.2nd	0.34	1.2	0.83	0.16	1.1	0.94	0.17	1.3	0.16	2.9	1.15
3197	2238	TST17	921127	IM240.2nd	1.29	3.5	2.42	0.99	8.3	2.66	0.88	8.7	0.60	7.8	2.97
3197	2432	TST27	921208	IM240.2nd	0.14	1.7	0.22	0.00	0.3	0.07	0.00	0.3	0.21	3.1	0.30
3198	2198	TST17	921125	IM240.2nd	1.77	10.2	1.80	1.51	8.5	2.04	1.31	8.2	0.86	7.4	2.50
3198	2431	TST27	921208	IM240.2nd	0.18	1.9	0.05	0.05	0.8	0.03	0.06	1.1	0.32	4.6	0.29
3200	2245	TST17	921128	IM240.1st	0.59	0.3	0.69	0.29	1.6	2.47	0.27	1.5	0.13	2.9	1.58
3200	2457	TST27	921210	IM240.1st	0.62	1.6	0.42	0.44	0.3	0.80	0.38	0.3	0.45	2.9	0.53
3201	2237	TST17	921127	IM240.1st	0.94	19.7	1.72	1.15	8.8	1.82	0.52	6.0	0.17	4.7	1.22
3201	2388	TST27	921207	IM240.1st	0.47	4.1	1.11	0.49	5.8	1.11	0.31	3.7	0.27	4.4	0.77
3202	2273	TST17	921201	IM240.1st	0.50	7.5	7.56	0.23	3.6	7.88	0.20	3.2	0.18	3.2	8.60
3202	2487	TST27	921211	IM240.1st	0.42	7.1	1.25	0.25	7.2	1.66	0.25	8.8	0.31	4.1	1.16

II. Contractor Repair Data

Vehicle Information					FTP Scores			IM240 SCORES					ASM		
								Composites			Bag 2 score		Composite Scores		
Veh#	**Run#**	**Test**	**Date**	**Order**	**HC**	**CO**	**NOx**	**HC**	**CO**	**NOx**	**HC2**	**CO2**	**ASM HC**	**ASM CO**	**ASM NOx**
3203	2261	TST17	921130	IM240.1st	0.96	6.4	4.17	0.74	5.9	4.37	0.71	6.3	0.27	3.4	3.52
3203	2569	TST2	921217	IM240.1st	0.75	5.7	1.30	0.87	11.1	1.32	0.82	13.6	0.47	3.9	1.49
3207	2319	TST17	921203	IM240.1st	3.33	87.3	0.92	3.20	76.9	0.97	3.19	79.3	1.50	70.8	1.04
3207	2459	TST27	921210	IM240.1st	0.44	2.7	1.11	0.29	2.0	1.35	0.35	2.0	0.41	3.4	1.31
3208	2324	TST17	921203	IM240.2nd	2.38	113.4	0.31	1.86	74.3	0.41	1.83	71.9	1.24	73.7	0.73
3208	2468	TST27	921211	IM240.2nd	0.22	1.7	0.96	0.02	0.9	0.61	0.02	0.7	0.22	2.9	0.62
3210	2337	TST17	921203	IM240.1st	1.40	20.3	1.21	1.03	12.9	2.97	0.90	13.2	0.35	6.6	3.17
3210	2643	TST2	921222	IM240.1st	0.34	1.2	0.34	0.12	0.5	0.12	0.10	0.5	0.29	3.5	0.38
3211	2330	TST17	921203	IM240.2nd	0.48	10.8	0.57	1.42	93.1	0.53	1.94	129.3	0.67	75.2	0.63
3211	2461	TST27	921210	IM240.2nd	0.38	2.8	0.50	0.04	1.4	0.83	0.02	0.7	0.71	68.9	0.43
3212	2352	TST17	921204	IM240.2nd	0.37	3.9	1.11	0.15	1.5	5.15	0.15	1.7	0.24	4.7	4.04
3212	2494	TST27	921212	IM240.2nd	0.33	3.7	1.05	0.14	2.9	0.83	0.13	2.8	0.14	3.3	0.93
3213	2368	TST17	921205	IM240.2nd	0.33	4.3	0.93	0.54	19.6	1.17	0.59	24.7	0.14	3.0	0.55
3213	2493	TST27	921212	IM240.2nd	0.30	4.1	0.78	0.13	1.1	1.03	0.12	1.3	0.18	2.9	0.66
3214	2369	TST17	921205	IM240.1st	1.15	12.9	2.50	2.00	23.2	2.94	1.83	21.4	0.69	6.6	2.03
3214	2518	TST27	921214	IM240.1st	0.15	1.6	0.32	0.11	1.2	0.39	0.09	0.9	0.20	3.1	0.51
3217	2376	TST17	921205	IM240.2nd	0.80	9.7	2.02	0.53	6.5	2.22	0.54	7.4	0.23	4.2	1.80
3217	2515	TST27	921214	IM240.2nd	0.67	8.7	1.36	0.79	18.9	1.54	0.89	24.7	0.28	3.9	1.71
3220	2424	TST17	921208	IM240.2nd	1.22	12.9	1.56	1.05	13.3	1.78	0.95	14.0	0.73	6.3	1.70
3220	2570	TST2	921217	IM240.2nd	0.24	1.6	0.57	0.03	0.5	0.44	0.03	0.6	0.12	2.9	0.48
3224	2441	TST17	921209	IM240.1st	1.80	21.4	3.23	1.15	10.3	4.47	0.93	9.5	1.03	16.4	3.28
3224	2680	TST2	921224	IM240.1st	0.20	1.4	0.36	0.04	1.0	0.06	0.05	1.0	0.20	3.1	0.29
3236	2483	TST17	921211	IM240.1st	0.73	8.6	1.84	1.04	13.9	4.01	1.06	14.6	0.47	5.5	3.03
3236	2608	TST2	921221	IM240.1st	0.15	2.6	0.53	0.08	1.7	0.66	0.08	1.5	0.16	3.0	0.99

II. Contractor Repair Data

Vehicle Information					FTP Scores			IM240 SCORES					ASM		
								Composites			Bag 2 score		Composite Scores		
Veh#	**Run#**	**Test**	**Date**	**Order**	**HC**	**CO**	**NOx**	**HC**	**CO**	**NOx**	**HC2**	**CO2**	**ASM HC**	**ASM CO**	**ASM NOx**
3239	2490	TST17	921211	IM240.2nd	0.24	1.5	0.72	0.03	0.5	2.40	0.02	0.1	0.20	3.0	1.07
3239	2646	TST2	921222	IM240.2nd	0.30	1.0	0.85	0.07	1.4	0.96	0.02	0.4	0.28	2.9	0.84
3240	2492	TST17	921212	IM240.2nd	0.27	2.7	1.14	0.07	1.5	2.52	0.06	1.2	0.16	3.0	2.55
3240	2678	TST2	921224	IM240.2nd	0.26	2.6	1.23	0.15	5.4	1.18	0.17	6.6	0.17	3.1	1.30
3242	2499	TST17	921214	IM240.1st	0.39	5.8	1.91	1.05	13.7	3.34	0.71	9.2	0.15	3.7	0.98
3242	2663	TST2	921223	IM240.1st	0.15	1.4	0.38	0.15	6.7	0.51	0.18	9.0	0.18	3.2	0.40
3243	2507	TST17	921214	IM240.1st	0.67	8.5	2.18	0.81	7.6	3.38	0.55	6.9	0.33	5.5	2.58
3243	2670	TST2	921223	IM240.1st	0.21	1.8	0.27	0.24	4.0	0.42	0.20	4.1	0.32	3.7	0.44
3244	2516	TST17	921214	IM240.2nd	0.22	3.1	0.47	0.09	3.5	2.34	0.09	3.9	0.13	3.8	2.39
3244	2671	TST2	921223	IM240.2nd	0.25	3.8	0.42	0.11	5.3	0.38	0.11	5.7	0.29	3.7	0.52
3245	2529	TST17	921215	IM240.1st	0.56	4.7	1.63	0.49	4.2	4.52	0.48	4.4	0.13	3.6	1.99
3245	2679	TST2	921224	IM240.1st	0.11	0.6	0.35	0.04	0.4	0.31	0.03	0.4	0.15	3.0	0.42
3247	2548	TST17	921216	IM240.2nd	0.84	11.4	1.99	0.69	13.5	3.78	0.60	13.1	0.47	7.2	3.66
3247	2681	TST2	921224	IM240.2nd	0.12	0.8	0.35	0.04	0.7	0.25	0.03	0.6	0.21	3.1	0.36
3248	2830	TST17	930106	IM240.2nd	0.39	3.3	1.51	0.21	2.5	2.53	0.15	2.1	0.13	3.1	2.05
3248	3105	TST27	930121	IM240.2nd	0.27	1.5	0.33	0.03	1.3	0.20	0.03	1.2	0.11	2.9	0.50
3249	2835	TST17	930107	IM240.1st	0.20	3.8	2.25	0.15	4.5	3.51	0.15	4.9	0.10	4.0	1.97
3249	3056	TST27	930119	IM240.1st	0.18	1.6	0.69	0.16	4.0	0.89	0.19	4.9	0.12	3.3	0.96
3250	2845	TST17	930107	IM240.1st	1.55	5.1	1.06	1.52	7.8	1.35	1.26	5.9	0.63	2.9	1.09
3250	3183	TST27	930127	IM240.1st	0.68	1.5	1.20	0.25	0.2	1.37	0.21	0.2	0.30	2.9	1.06
3252	2945	TST17	930113	IM240.1st	1.03	12.5	1.34	0.99	8.8	1.76	0.85	8.4	0.52	8.4	1.69
3252	3192	TST27	930127	IM240.1st	0.12	1.1	0.17	0.13	1.5	0.27	0.12	1.9	0.20	4.0	0.52
3257	3213	TST17	930128	IM240.1st	1.26	8.6	0.90	1.92	10.6	1.55	1.48	9.4	0.25	4.6	1.03
3257	3637	TST27	930225	IM240.1st	0.70	3.9	0.26	0.48	2.5	0.11	0.55	2.7	0.29	3.8	0.31

II. Contractor Repair Data

Vehicle Information					FTP Scores			IM240 SCORES					ASM		
								Composites			Bag 2 score		Composite Scores		
Veh#	**Run#**	**Test**	**Date**	**Order**	**HC**	**CO**	**NOx**	**HC**	**CO**	**NOx**	**HC2**	**CO2**	**ASM HC**	**ASM CO**	**ASM NOx**
3259	3250	TST17	930201	IM240.2nd	1.94	15.0	0.53	1.50	9.3	0.88	1.15	8.3	0.23	4.6	1.22
3259	3518	TST2	930217	IM240.2nd	0.23	3.5	0.74	0.11	2.0	0.95	0.10	1.8	0.22	3.4	0.96
3261	3475	TST17	930212	IM240.1st	0.72	12.5	0.37	0.91	19.1	0.68	0.79	19.3	0.34	11.8	0.76
3261	3581	TST2	930222	IM240.1st	0.60	8.1	0.79	0.45	11.5	0.79	0.41	12.4	0.18	3.4	0.63
3264	3519	TST17	930217	IM240.1st	1.36	20.3	1.06	2.16	20.1	1.66	1.44	16.0	0.49	5.6	1.55
3264	3671	TST29	930226	IM240.1st	0.49	4.9	1.05	0.33	3.7	0.96	0.23	3.3	0.13	3.3	1.20
3265	3530	TST17	930217	IM240.2nd	2.70	14.8	2.59	2.49	9.9	3.31	2.21	9.1	1.22	5.5	2.84
3265	3704	TST27	930310	IM240.2nd	0.10	0.7	0.11	0.01	0.4	0.07	0.01	0.3	0.10	2.9	0.26

III. Commercial Repair Data

Vehicle Information						Arizona I/M Test				IM240 Scores					ASM		
						Loaded Mode		Idle Mode		Composite			Bag 2 Score		Composite Scores		
CR#	**Veh#**	**Run#**	**Test**	**Date**	**Order**	**HC**	**CO**	**HC**	**CO**	**HC**	**CO**	**NOx**	**HC2**	**CO2**	**ASM HC**	**ASM CO**	**ASM NOx**
1	11898	1898	TST17	921106	IM240.2nd	70	2.15	26	0.18	1.00	55.1	0.48	1.28	66.60	0.68	49.8	0.56
1	11898	1906	TST19	921106	IM240.2nd	116	2.97	43	0.09	0.59	33.3	0.63	0.71	36.40	0.23	8.2	0.60
1	11898	2012	TST20	921118	IM240.2nd	1	0	1	0	0.09	5.7	0.42	0.11	7.80	0.17	3.4	0.37
2	12636	2636	TST17	921222	IM240.2nd	70	0.02	545	0.11	0.36	1.6	2.45	0.30	2.10	0.41	3.1	2.17
2	12636	2662	TST19	921223	IM240.2nd	39	0.02	140	0.02	0.27	1.7	1.78	0.21	2.20	0.16	2.9	1.71
3	12644	2644	TST17	921222	IM240.2nd	260	6.88	45	0.01	2.69	140.9	0.11	2.75	144.80	1.66	112.0	0.35
3	12644	2720	TST19	921230	IM240.2nd	14	0	13	0	1.21	79.6	0.20	1.36	92.10	0.51	56.0	0.33
8	12771	2771	TST17	930104	IM240.1st	86	1.55	87	0.38	1.51	12.2	2.86	1.32	9.50	0.46	5.7	2.19
8	12771	2977	TST19	930114	IM240.1st	38	0.63	835	0.07	1.38	4.1	2.59	1.16	4.30	0.33	3.5	1.63
8	12771	3168	TST20	930126	IM240.1st	75	0.38	41	0.06	1.01	4.4	3.01	0.91	4.30	0.16	3.4	1.51
6	12794	2794	TST17	930105	IM240.2nd	51	0.11	455	7.03	2.43	80.2	0.50	2.68	99.80	1.41	51.9	0.68
6	12794	2975	TST19	930114	IM240.1st	298	10	480	7.21	2.09	72.5	0.39	2.19	86.50	1.27	61.0	0.49
6	12794	3137	TST20	930125	IM240.1st	46	0.15	106	1.44	1.55	55.8	0.47	1.69	68.00	0.40	24.4	0.57
10	12798	2798	TST17	930105	IM240.2nd	279	2.53	152	2.29	3.64	64.6	1.41	3.54	65.60	1.62	46.8	1.18
10	12798	3049	TST19	930119	IM240.1st	229	0.54	122	0.06	2.36	20.1	2.08	2.32	23.50	1.15	15.9	1.59
10	12798	3064	TST20	930119	IM240.2nd	100	0.15	141	0.29	2.14	35.8	1.13	1.72	34.60	0.28	6.9	0.89
4	12853	2853	TST17	930107	IM240.1st	201	4.33	637	7.41	2.08	52.3	0.28	2.02	56.60	1.29	52.5	0.63
4	12853	2861	TST19	930108	IM240.1st	81	0.95	12	0	0.90	27.9	0.36	0.91	29.50	0.54	20.4	0.55
5	12863	2863	TST17	930108	IM240.1st	433	8.72	1540	10	5.86	164.3	0.72	5.58	170.30	3.65	160.2	0.62
5	12863	2901	TST19	930111	IM240.1st	7	0	10	0	0.25	2.8	1.76	0.14	2.80	0.17	3.2	0.97
7	12968	2968	TST17	930113	IM240.2nd	397	1.58	466	1.79	6.00	37.0	1.19	5.10	35.30	2.45	23.3	1.02
7	12968	2976	TST19	930114	IM240.2nd	177	2.16	427	0.83	5.69	29.7	1.22	4.85	28.40	2.14	16.3	0.97
9	12981	2981	TST17	930114	IM240.1st	108	1.46	27	0.03	1.46	15.0	3.71	1.31	12.50	0.78	9.1	2.20
9	12981	2988	TST19	930114	IM240.1st	78	0.37	43	0.14	1.20	7.9	3.88	1.12	8.10	0.62	4.1	2.75

III. Commercial Repair Data

Vehicle Information						Arizona I/M Test				IM240 Scores					ASM		
						Loaded Mode		Idle Mode		Composite			Bag 2 Score		Composite Scores		
CR#	Veh#	Run#	Test	Date	Order	HC	CO	HC	CO	HC	CO	NOx	HC2	CO2	ASM HC	ASM CO	ASM NOx
11	13084	3084	TST17	930120	IM240.2nd	15	0.02	1517	0.01	1.16	7.8	0.20	1.13	7.50	0.19	3.0	0.35
11	13084	3104	TST19	930121	IM240.2nd	13	0	370	4.7	0.12	2.2	0.60	0.09	1.90	0.30	3.5	0.83
14	13124	3124	TST17	930122	IM240.2nd	111	1.42	17	0	0.41	11.1	0.52	0.44	12.80	0.29	7.8	1.04
14	13124	3181	TST19	930127	IM240.2nd	6	0.01	12	0	0.13	2.4	1.44	0.14	2.80	0.28	3.2	2.45
12	13125	3125	TST17	930122	IM240.1st	110	0.34	853	0.09	1.06	10.7	1.77	0.93	9.70	0.48	4.3	1.21
12	13125	3129	TST19	930122	IM240.1st	74	0.41	16	0	1.08	15.1	1.26	0.81	10.60	0.29	3.5	0.82
13	13146	3146	TST17	930126	IM240.2nd	117	1.91	84	0.14	3.25	50.7	1.51	2.87	46.50	1.03	42.2	1.64
13	13146	3156	TST19	930126	IM240.2nd	40	0.16	26	0	0.80	13.5	0.89	0.66	11.40	0.38	6.2	0.96
15	13202	3202	TST17	930128	IM240.2nd	129	0.97	712	10	1.33	16.8	3.50	1.22	8.40	0.62	6.3	3.32
15	13202	3231	TST19	930129	IM240.1st	112	0.36	178	0.63	1.11	6.3	3.55	1.08	6.00	0.52	5.4	3.16
21	13263	3263	TST17	930201	IM240.1st	172	0.99	673	2.49	6.02	21.4	1.68	5.42	20.00	1.52	12.8	1.01
21	13263	3379	TST19	930205	IM240.1st	93	0.5	601	0.75	5.74	17.5	1.65	5.20	16.10	1.01	9.2	1.15
21	13263	3561	TST20	930219	IM240.1st	303	1.24	46	0.02	5.87	25.5	1.69	5.35	23.60	1.71	16.3	1.08
16	13306	3306	TST17	930203	IM240.2nd	191	0.45	428	1.84	3.42	19.6	4.25	2.89	16.00	1.35	4.8	3.16
16	13306	3310	TST19	930203	IM240.2nd	73	0.26	75	0.58	1.34	4.9	2.40	1.24	3.60	0.61	4.0	1.72
22	13349	3349	TST17	930204	IM240.1st	251	8.68	115	3.28	5.88	162.5	0.20	5.22	141.30	1.90	100.4	0.39
22	13349	3381	TST19	930205	IM240.1st	194	6.97	125	3.22	4.85	145.7	0.25	4.25	121.10	1.12	73.2	0.38
22	13349	3453	TST20	930211	IM240.1st	71	1.89	54	0.36	1.84	25.9	1.13	1.48	22.90	0.45	17.8	0.77
22	13349	3548	TST21	930218	IM240.1st	261	9.51	185	3.89	8.48	224.2	0.12	7.44	199.50	1.89	118.2	0.32
23	13375	3375	TST17	930205	IM240.1st	136	0.38	132	2.81	0.09	1.2	0.78	0.07	1.00	0.20	3.5	0.45
23	13375	3388	TST19	930208	IM240.2nd	7	0	2	0	0.03	0.3	0.84	0.02	0.30	0.22	3.7	0.53
27	13471	3471	TST17	930212	IM240.1st	10	1.61	1	0	0.24	35.0	0.21	0.22	37.00	0.14	7.2	0.34
27	13471	3757	TST19	930316	IM240.1st	12	0.01	4	0	0.17	3.3	1.33	0.17	4.50	0.18	3.1	0.45

III. Commercial Repair Data

Vehicle Information						Arizona I/M Test				IM240 Scores					ASM		
						Loaded Mode		Idle Mode		Composite			Bag 2 Score		Composite Scores		
CR#	**Veh#**	**Run#**	**Test**	**Date**	**Order**	**HC**	**CO**	**HC**	**CO**	**HC**	**CO**	**NOx**	**HC2**	**CO2**	**ASM HC**	**ASM CO**	**ASM NOx**
25	13504	3504	TST17	930216	IM240.2nd	49	0.01	150	3.02	0.41	6.7	5.73	0.33	4.30	0.31	19.3	4.44
25	13504	3511	TST19	930216	IM240.1st	23	0	5	0	0.13	0.2	5.04	0.13	0.20	0.19	2.9	3.54
26	13616	3616	TST17	930224	IM240.2nd	189	0.19	349	10	2.77	44.8	0.37	2.58	37.30	0.50	18.7	0.41
26	13616	3680	TST19	930301	IM240.2nd	25	0.04	11	0	0.22	3.9	1.15	0.18	3.80	0.38	3.9	1.16

TST17 - Initial Test
TST19 - After 1st Repair
TST20 - After 2nd Repair
TST21 - After 3rd Repair

ASM/IM240 Phoenix Lane Data Request Form

Please Fax or Mail Your Data Requests to:

Attn: William M. Pidgeon
U. S. Environmental Protection Agency
2565 Plymouth Road
Ann Arbor, MI 48105-2425

Phone #: (313) 668-4416
Fax #: (313) 668-4497

Requestor: ______________________

Organization: ______________________

Phone #: ____________

Fax #: ____________

Mailing Address: ______________________

____

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Specify Disk Format (3.5 inch only)	☐ IBM ☐ Mac
☐ High Density	☐ Low Density

Specify File Format:

☐ Text ASCII File (tab separated)
☐ CSV ASCII File (comma separated)
☐ SYLK File
☐ Lotus File (.WKS)*
☐ Excel File (v2.1)*

*Note: Oldest available formats were chosen for maximum compatibility. These formats should be compatible with newer versions.

Appendix C:

QC Steps for ASM Analysis Database

The Phoenix lane data used in these analyses were reported to EPA by the testing contractor as total values (concentrations, mass, or flow) for the entire test mode as well as in second-by-second form. The following automated quality control (QC) checks were performed by EPA on the data. Tests that were flagged by one (or more) of these QC checks were then manually verified.

Second by Second ASM Tolerance Checks:

- Speed Tolerance - ± 15% of nominal speed for Modes 1,2,3. Allowed tolerance to be exceeded for less than 3 seconds in duration. Also checked Idle for Modes 4,5

- Mode Length - Checked to ensure that each mode contained at least 20 and not more than 30 "stable" seconds.

- Hp/Torque Tolerance - Compared required and actual horsepower (Hp) and Torque and flagged differences > ±10% for at least 5 seconds.

  All vehicles with test weights above 4000 pounds exceeded this tolerance because of the capacity of the dynamometer. These cars were not removed from these analyses. Smaller vehicles exceeding this tolerance were removed.

- Calculated average concentrations and cumulative purge for all ASM modes. Average concentrations were calculated as the average concentration from second 10 to second 39 of each mode. The first 10 seconds of each mode were ignored to allow for the dynamometer stabilization and exhaust transport time. Vehicles with less than 30 seconds per mode were noted and vehicles with less than 20 seconds per mode were excluded. Purge values were calculated as the total purge in liters over the entire ASM including transient accelerations.

Second by Second IM240 Tolerance Checks:

- Speed Tolerance - ± 4 mph at ± 1 sec of nominal speed. Allowed tolerance to be exceeded for less than 3 seconds in duration. Also speeds exceeding 70 mph, and less than 0 mph were flagged.

- Background Concentration Tolerances - Flagged background readings outside the following ranges:

  $1.8 < HC < 10.0$ (ppm)
  $-10.0 < CO < 30.0$ (ppm)
  $-0.5 < NO_x < 1.25$ (ppm)
  $0.0 < CO_2 < 0.15$ (percent)

- Test Length - Checked to ensure that the full 240 seconds were present.

- Distance Tolerance - Flagged distance > ± 5% of nominal distance

  Bag 1: 0.532 < dist 1 < 0.588
  Bag 2: 1.393 < dist 2 < 1.469

- Fuel Economy Tolerance - Flagged fuel economies < 10 mpg and >50 mpg

- Sample Continuity and Integrity - Ensured that the sampling was continuous (i.e., sec(I) = I for I = 1 to 240) and that gram and concentration values were non-zero (HC, CO and CO_2 cannot all be zero for fuel economy calculations or dilution factors).

  Non-zero concentrations were not mandatory for the Phoenix data because second by second concentrations received were calculated, not measured. The calculated concentrations were based on the reported grams per second results. These vehicles were still flagged for low concentrations but were not removed from the analyses for this reason.

- Comparison of composite and bag results calculated from the second by second data with composite and bags results received from ATL. Differences of > 10% were flagged.

Purge Flow Data QC

- Comparison of second-by-second purge flow to the reported cumulative purge flow and pass/fail status reported by ATL. All significant differences were flagged.

- Vehicles exhibiting a non-zero constant purge rate for more than 20 seconds and at various speeds were flagged. Purge data was rounded to nearest 0.01 liter/second prior to processing.

Bag FTP Tolerance Checks:

- The ratios of corresponding emissions (HC, CO, and NO_x) and fuel economy for each of the three bags that were not within expected ranges were flagged.

- The temperatures, barometric pressures, and distances that were not within expected ranges were flagged.

Bag IM240 Tolerance Checks:

- Bag-1 emissions (HC, CO, and NO_x) and fuel economy were compared to the corresponding Bag-2 results (based on regression analyses previously performed on the Indiana data). All significant differences were flagged.

- The Bag-1 and Bag-2 fuel economies were also compared to the test weight. All fuel economy values that were not within an expected range (based on test weight) were flagged.

- The Bag-1 and Bag-2 distances not with the following ranges were flagged:

$$\text{Bag 1:}\quad 0.545 \le \text{dist } 1 \le 0.586$$
$$\text{Bag 2:}\quad 1.365 \le \text{dist } 2 \le 1.435$$

Bag IM240/FTP Tolerance Checks:

- For the laboratory recruited vehicles, the composite IM240 emissions (HC, CO, and NO_x) and fuel economy were compared to the corresponding FTP results (based on regression analyses previously performed on the Indiana data). All significant differences were flagged.

Dynamometer Loading Tolerance Checks:

- The test weights and horsepower settings had to be within 10% for all tests performed on each vehicle.

Excluded Data Summary

This section of Appendix C details the vehicles excluded from the various databases.

Purge Analysis - 1725 of the 1758 lane tests contained the necessary data to be included into this analysis. Of these 153 were removed because of a malfunctioning purge meter, 184 tests were repeat tests for vehicles previously tested and were removed, 5 cars had purge flow status fields which indicated missing data, 95 additional vehicles had no indication of test order and were removed, and 118 of the remaining vehicles exhibited non-zero constant purge rates over varied vehicle speeds and were removed. The result was a database of 1170 lane tested vehicles.

Cutpoint Table Analysis - This analysis required laboratory FTP data. Therefore, only lab recruited vehicles were considered for this analysis. Of the 127 recruited vehicles, 17 did not receive initial ASM tests and one (veh# 3258) did not receive an as-received FTP. Of the remaining 109 vehicles one vehicle (veh# 2177) was removed because the ambient FTP temperature exceeded allowable tolerances, one vehicle (veh# 3253) was removed due to extremely low HC emissions at the lane caused by a flame-out in the FID HC analyzer, and veh# 3164 was removed due to unacceptable speed deviations on its initial ASM test. The resulting database contained 106 lab recruited vehicles.

Commercial Repair Analysis - Of the 27 vehicles recruited for this program only 23 had completed after repair tests at the time of this analysis. One vehicle, #13239 (CR# 24) was removed from the database due to unacceptable speed deviations on its initial ASM test, leaving 22 vehicles available for analysis. For the analysis of Section 5.6.2, 5 vehicles failed to pass the Arizona state test on the subsequent retest and were removed. The resulting database used for this analysis consisted of 17 vehicles which received "successful" commercial repairs. For the commercial repair analysis of Section 5.6.3, only vehicles initially failing ASM cutpoints were included. The result was 17 vehicles. Commercial repairs did not have to be successful for this analysis and the two data sets contained slightly different cars.

Regression Coefficient Analysis - For this analysis all lab recruited vehicles and commercial repair vehicles were removed from the analysis to prevent the application of coefficients to data used to develop those coefficients. Therefore, 1422 of the 1758 vehicles were considered for inclusion into this analysis. Ten vehicles were removed because the composite IM240 data was not available. The following vehicles were removed because there was insufficient second by second data to calculate composite IM240 results:

Run #	Reason for Removal
1027	Test has only 93 seconds
1855	Missing second by second
2231	Test has only 93 seconds
3066	Sampling Discontinuity
3077	Sampling Discontinuity
3079	Sampling Discontinuity
3081	Sampling Discontinuity

Of the 1405 remaining vehicles, 1192 passed all QC tolerances. Purge tolerances were not considered for this analysis. The following table lists the QC tolerances checks for which vehicles were removed from this analysis.

Tolerance Flagged	**Number of Vehicles**
ASM Speed	8
Short ASM Mode	2
ASM Horsepower	10
IM240 Speed	14
IM240 Fuel Economy	4
IM240 Background	163
IM240 Sample	18

Note: 1405 minus the above vehicles does not equal 1192 because some vehicles exceeded more than one tolerance

Six hundred and eight (608) of the 1192 tests remaining received the IM240 second and were chosen for this analysis.

Appendix D

IM240 Cutpoint Tables

Appendix D: IM240 Cutpoint Tables

IM240	Cutpoints	Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Composite + Mode 2	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
12%	1.20 / 20.0 / 2.5 + 0.75 / 16.0	343	5286	253	86.2%	61.5%	74.0%	257	0	0.0%	0	0.0%
13%	1.00 / 20.0 / 2.4 + 0.62 / 16.0	351	5419	262	88.2%	63.1%	76.5%	275	0	0.0%	0	0.0%
13%	1.00 / 20.0 / 2.5 + 0.62 / 16.0	348	5342	257	87.4%	62.2%	74.9%	263	0	0.0%	0	0.0%
13%	1.20 / 18.0 / 2.5 + 0.75 / 14.4	347	5422	258	87.2%	63.1%	75.5%	275	0	0.0%	0	0.0%
13%	1.20 / 15.0 / 2.5 + 0.75 / 12.0	347	5422	258	87.2%	63.1%	75.5%	275	0	0.0%	0	0.0%
13%	1.20 / 20.0 / 2.4 + 0.75 / 16.0	347	5363	258	87.0%	62.4%	75.5%	269	0	0.0%	0	0.0%
14%	0.80 / 20.0 / 2.5 + 0.50 / 16.0	362	5627	263	90.9%	65.5%	76.8%	293	0	0.0%	0	0.0%
14%	1.00 / 12.0 / 2.4 + 0.62 / 9.6	357	5548	262	89.6%	64.6%	76.5%	293	0	0.0%	0	0.0%
14%	1.20 / 12.0 / 2.4 + 0.75 / 9.6	357	5548	262	89.6%	64.6%	76.5%	293	0	0.0%	0	0.0%
14%	1.00 / 12.0 / 2.5 + 0.62 / 9.6	356	5548	262	89.3%	64.6%	76.5%	287	0	0.0%	0	0.0%
14%	1.20 / 12.0 / 2.5 + 0.75 / 9.6	356	5548	262	89.3%	64.6%	76.5%	287	0	0.0%	0	0.0%
14%	1.00 / 18.0 / 2.4 + 0.62 / 14.4	353	5478	262	88.7%	63.8%	76.5%	287	0	0.0%	0	0.0%
14%	1.00 / 15.0 / 2.4 + 0.62 / 12.0	353	5478	262	88.7%	63.8%	76.5%	287	0	0.0%	0	0.0%
14%	1.00 / 18.0 / 2.5 + 0.62 / 14.4	352	5478	262	88.4%	63.8%	76.5%	281	0	0.0%	0	0.0%
14%	1.00 / 15.0 / 2.5 + 0.62 / 12.0	352	5478	262	88.4%	63.8%	76.5%	281	0	0.0%	0	0.0%
14%	1.00 / 20.0 / 2.3 + 0.62 / 16.0	351	5429	266	88.2%	63.2%	77.7%	293	12	0.6%	0	0.6%
14%	1.20 / 18.0 / 2.3 + 0.75 / 14.4	348	5432	263	87.4%	63.2%	76.7%	298	12	0.6%	0	0.6%
14%	1.20 / 15.0 / 2.3 + 0.75 / 12.0	348	5432	263	87.4%	63.2%	76.7%	298	12	0.6%	0	0.6%
14%	1.20 / 18.0 / 2.4 + 0.75 / 14.4	348	5422	258	87.4%	63.1%	75.5%	281	0	0.0%	0	0.0%
14%	1.20 / 15.0 / 2.4 + 0.75 / 12.0	348	5422	258	87.4%	63.1%	75.5%	281	0	0.0%	0	0.0%
14%	1.20 / 20.0 / 2.3 + 0.75 / 16.0	347	5373	263	87.0%	62.6%	76.7%	287	12	0.6%	0	0.6%
15%	0.60 / 20.0 / 2.4 + 0.37 / 16.0	365	5707	268	91.6%	66.5%	78.3%	316	6	0.3%	0	0.3%
15%	0.80 / 20.0 / 2.4 + 0.50 / 16.0	365	5704	268	91.6%	66.4%	78.3%	304	0	0.0%	0	0.0%
15%	0.80 / 18.0 / 2.4 + 0.50 / 14.4	365	5709	268	91.6%	66.5%	78.3%	310	0	0.0%	0	0.0%
15%	0.80 / 15.0 / 2.4 + 0.50 / 12.0	365	5709	268	91.6%	66.5%	78.3%	310	0	0.0%	0	0.0%
15%	0.80 / 12.0 / 2.4 + 0.50 / 9.6	365	5709	268	91.6%	66.5%	78.3%	310	0	0.0%	0	0.0%
15%	0.60 / 20.0 / 2.5 + 0.37 / 16.0	364	5707	268	91.3%	66.5%	78.3%	310	6	0.3%	0	0.3%
15%	0.60 / 18.0 / 2.5 + 0.37 / 14.4	364	5713	268	91.3%	66.5%	78.3%	316	6	0.3%	0	0.3%
15%	0.80 / 18.0 / 2.5 + 0.50 / 14.4	364	5709	268	91.3%	66.5%	78.3%	304	0	0.0%	0	0.0%
15%	0.60 / 15.0 / 2.5 + 0.37 / 12.0	364	5713	268	91.3%	66.5%	78.3%	316	6	0.3%	0	0.3%
15%	0.80 / 15.0 / 2.5 + 0.50 / 12.0	364	5709	268	91.3%	66.5%	78.3%	304	0	0.0%	0	0.0%
15%	0.60 / 12.0 / 2.5 + 0.37 / 9.6	364	5713	268	91.3%	66.5%	78.3%	316	6	0.3%	0	0.3%
15%	0.80 / 12.0 / 2.5 + 0.50 / 9.6	364	5709	268	91.3%	66.5%	78.3%	304	0	0.0%	0	0.0%
15%	1.00 / 12.0 / 2.3 + 0.62 / 9.6	357	5558	266	89.6%	64.7%	77.7%	310	12	0.6%	0	0.6%
15%	1.20 / 12.0 / 2.3 + 0.75 / 9.6	357	5558	266	89.6%	64.7%	77.7%	310	12	0.6%	0	0.6%

* see text in Section 5 for explanation

Appendix D: IM240 Cutpoint Tables

IM240	Cutpoints	Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Composite + Mode 2	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
15%	1.00 / 18.0 / 2.3 + 0.62 / 14.4	353	5489	266	88.7%	63.9%	77.7%	304	12	0.6%	0	0.6%
15%	1.00 / 15.0 / 2.3 + 0.62 / 12.0	353	5489	266	88.7%	63.9%	77.7%	304	12	0.6%	0	0.6%
15%	1.00 / 20.0 / 2.2 + 0.62 / 16.0	351	5431	273	88.2%	63.2%	79.7%	310	12	0.6%	0	0.6%
15%	1.20 / 20.0 / 2.1 + 0.75 / 16.0	349	5429	276	87.6%	63.2%	80.5%	316	12	0.6%	0	0.6%
15%	1.20 / 18.0 / 2.2 + 0.75 / 14.4	348	5434	269	87.4%	63.3%	78.7%	316	12	0.6%	0	0.6%
15%	1.20 / 15.0 / 2.2 + 0.75 / 12.0	348	5434	269	87.4%	63.3%	78.7%	316	12	0.6%	0	0.6%
15%	1.20 / 20.0 / 2.2 + 0.75 / 16.0	347	5375	269	87.0%	62.6%	78.7%	304	12	0.6%	0	0.6%
16%	0.80 / 20.0 / 2.2 + 0.50 / 16.0	365	5716	279	91.6%	66.6%	81.5%	340	12	0.6%	0	0.6%
16%	0.60 / 20.0 / 2.3 + 0.37 / 16.0	365	5718	272	91.6%	66.6%	79.5%	334	18	0.9%	0	0.9%
16%	0.80 / 20.0 / 2.3 + 0.50 / 16.0	365	5714	272	91.6%	66.5%	79.5%	322	12	0.6%	0	0.6%
16%	0.60 / 18.0 / 2.3 + 0.37 / 14.4	365	5723	272	91.6%	66.6%	79.5%	340	18	0.9%	0	0.9%
16%	0.80 / 18.0 / 2.3 + 0.50 / 14.4	365	5719	272	91.6%	66.6%	79.5%	328	12	0.6%	0	0.6%
16%	0.60 / 15.0 / 2.3 + 0.37 / 12.0	365	5723	272	91.6%	66.6%	79.5%	340	18	0.9%	0	0.9%
16%	0.80 / 15.0 / 2.3 + 0.50 / 12.0	365	5719	272	91.6%	66.6%	79.5%	328	12	0.6%	0	0.6%
16%	0.60 / 12.0 / 2.3 + 0.37 / 9.6	365	5723	272	91.6%	66.6%	79.5%	340	18	0.9%	0	0.9%
16%	0.80 / 12.0 / 2.3 + 0.50 / 9.6	365	5719	272	91.6%	66.6%	79.5%	328	12	0.6%	0	0.6%
16%	0.60 / 18.0 / 2.4 + 0.37 / 14.4	365	5713	268	91.6%	66.5%	78.3%	322	6	0.3%	0	0.3%
16%	0.60 / 15.0 / 2.4 + 0.37 / 12.0	365	5713	268	91.6%	66.5%	78.3%	322	6	0.3%	0	0.3%
16%	0.60 / 12.0 / 2.4 + 0.37 / 9.6	365	5713	268	91.6%	66.5%	78.3%	322	6	0.3%	0	0.3%
16%	1.00 / 12.0 / 2.1 + 0.62 / 9.6	359	5614	279	90.2%	65.4%	81.5%	340	12	0.6%	0	0.6%
16%	1.20 / 12.0 / 2.1 + 0.75 / 9.6	359	5614	279	90.2%	65.4%	81.5%	340	12	0.6%	0	0.6%
16%	1.00 / 12.0 / 2.2 + 0.62 / 9.6	357	5560	273	89.6%	64.7%	79.7%	328	12	0.6%	0	0.6%
16%	1.20 / 12.0 / 2.2 + 0.75 / 9.6	357	5560	273	89.6%	64.7%	79.7%	328	12	0.6%	0	0.6%
16%	1.00 / 10.0 / 2.4 + 0.62 / 8.0	357	5579	264	89.6%	65.0%	77.0%	340	42	2.0%	0	2.0%
16%	1.20 / 10.0 / 2.4 + 0.75 / 8.0	357	5579	264	89.6%	65.0%	77.0%	340	42	2.0%	0	2.0%
16%	1.00 / 10.0 / 2.5 + 0.62 / 8.0	356	5579	264	89.3%	65.0%	77.0%	334	42	2.0%	0	2.0%
16%	1.20 / 10.0 / 2.5 + 0.75 / 8.0	356	5579	264	89.3%	65.0%	77.0%	334	42	2.0%	0	2.0%
16%	1.00 / 18.0 / 2.0 + 0.62 / 14.4	356	5565	279	89.2%	64.8%	81.6%	340	12	0.6%	0	0.6%
16%	1.00 / 15.0 / 2.0 + 0.62 / 12.0	356	5565	279	89.2%	64.8%	81.6%	340	12	0.6%	0	0.6%
16%	1.00 / 18.0 / 2.1 + 0.62 / 14.4	356	5545	279	89.2%	64.6%	81.5%	334	12	0.6%	0	0.6%
16%	1.00 / 15.0 / 2.1 + 0.62 / 12.0	356	5545	279	89.2%	64.6%	81.5%	334	12	0.6%	0	0.6%
16%	1.00 / 20.0 / 1.9 + 0.62 / 16.0	354	5559	282	88.8%	64.7%	82.4%	340	12	0.6%	0	0.6%
16%	1.00 / 20.0 / 2.0 + 0.62 / 16.0	354	5505	279	88.8%	64.1%	81.6%	328	12	0.6%	0	0.6%
16%	1.00 / 20.0 / 2.1 + 0.62 / 16.0	354	5485	279	88.8%	63.9%	81.5%	322	12	0.6%	0	0.6%
16%	1.00 / 18.0 / 2.2 + 0.62 / 14.4	353	5491	273	88.7%	63.9%	79.7%	322	12	0.6%	0	0.6%

* *see text in Section 5 for explanation*

Appendix D: IM240 Cutpoint Tables

IM240	Cutpoints	Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Composite + Mode 2	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
16%	1.00 / 15.0 / 2.2 + 0.62 / 12.0	353	5491	273	88.7%	63.9%	79.7%	322	12	0.6%	0	0.6%
16%	1.20 / 18.0 / 2.0 + 0.75 / 14.4	351	5508	276	88.0%	64.1%	80.6%	334	12	0.6%	0	0.6%
16%	1.20 / 15.0 / 2.0 + 0.75 / 12.0	351	5508	276	88.0%	64.1%	80.6%	334	12	0.6%	0	0.6%
16%	1.20 / 18.0 / 2.1 + 0.75 / 14.4	351	5488	276	88.0%	63.9%	80.5%	328	12	0.6%	0	0.6%
16%	1.20 / 15.0 / 2.1 + 0.75 / 12.0	351	5488	276	88.0%	63.9%	80.5%	328	12	0.6%	0	0.6%
16%	1.20 / 20.0 / 1.9 + 0.75 / 16.0	349	5502	279	87.6%	64.1%	81.4%	334	12	0.6%	0	0.6%
16%	1.20 / 20.0 / 2.0 + 0.75 / 16.0	349	5449	276	87.6%	63.4%	80.6%	322	12	0.6%	0	0.6%
17%	0.80 / 20.0 / 2.0 + 0.50 / 16.0	367	5790	286	92.2%	67.4%	83.4%	358	12	0.6%	0	0.6%
17%	0.80 / 20.0 / 2.1 + 0.50 / 16.0	367	5770	285	92.2%	67.2%	83.3%	352	12	0.6%	0	0.6%
17%	0.80 / 18.0 / 2.1 + 0.50 / 14.4	367	5776	285	92.2%	67.2%	83.3%	358	12	0.6%	0	0.6%
17%	0.80 / 15.0 / 2.1 + 0.50 / 12.0	367	5776	285	92.2%	67.2%	83.3%	358	12	0.6%	0	0.6%
17%	0.80 / 12.0 / 2.1 + 0.50 / 9.6	367	5776	285	92.2%	67.2%	83.3%	358	12	0.6%	0	0.6%
17%	0.60 / 20.0 / 2.2 + 0.37 / 16.0	365	5720	279	91.6%	66.6%	81.5%	352	18	0.9%	0	0.9%
17%	0.60 / 18.0 / 2.2 + 0.37 / 14.4	365	5725	279	91.6%	66.7%	81.5%	358	18	0.9%	0	0.9%
17%	0.80 / 18.0 / 2.2 + 0.50 / 14.4	365	5721	279	91.6%	66.6%	81.5%	346	12	0.6%	0	0.6%
17%	0.60 / 15.0 / 2.2 + 0.37 / 12.0	365	5725	279	91.6%	66.7%	81.5%	358	18	0.9%	0	0.9%
17%	0.80 / 15.0 / 2.2 + 0.50 / 12.0	365	5721	279	91.6%	66.6%	81.5%	346	12	0.6%	0	0.6%
17%	0.60 / 12.0 / 2.2 + 0.37 / 9.6	365	5725	279	91.6%	66.7%	81.5%	358	18	0.9%	0	0.9%
17%	0.80 / 12.0 / 2.2 + 0.50 / 9.6	365	5721	279	91.6%	66.6%	81.5%	346	12	0.6%	0	0.6%
17%	0.80 / 10.0 / 2.4 + 0.50 / 8.0	365	5740	270	91.6%	66.8%	78.8%	358	42	2.0%	0	2.0%
17%	0.80 / 10.0 / 2.5 + 0.50 / 8.0	364	5740	270	91.3%	66.8%	78.8%	352	42	2.0%	0	2.0%
17%	1.00 / 12.0 / 1.9 + 0.62 / 9.6	359	5688	282	90.2%	66.2%	82.4%	358	12	0.6%	0	0.6%
17%	1.20 / 12.0 / 1.9 + 0.75 / 9.6	359	5688	282	90.2%	66.2%	82.4%	358	12	0.6%	0	0.6%
17%	1.00 / 12.0 / 2.0 + 0.62 / 9.6	359	5634	279	90.2%	65.6%	81.6%	346	12	0.6%	0	0.6%
17%	1.20 / 12.0 / 2.0 + 0.75 / 9.6	359	5634	279	90.2%	65.6%	81.6%	346	12	0.6%	0	0.6%
17%	1.00 / 10.0 / 2.3 + 0.62 / 8.0	357	5589	268	89.6%	65.1%	78.2%	358	54	2.6%	0	2.6%
17%	1.20 / 10.0 / 2.3 + 0.75 / 8.0	357	5589	268	89.6%	65.1%	78.2%	358	54	2.6%	0	2.6%
17%	1.00 / 18.0 / 1.9 + 0.62 / 14.4	356	5618	282	89.3%	65.4%	82.4%	352	12	0.6%	0	0.6%
17%	1.00 / 15.0 / 1.9 + 0.62 / 12.0	356	5618	282	89.3%	65.4%	82.4%	352	12	0.6%	0	0.6%
17%	1.20 / 18.0 / 1.9 + 0.75 / 14.4	351	5562	279	88.0%	64.8%	81.4%	346	12	0.6%	0	0.6%
17%	1.20 / 15.0 / 1.9 + 0.75 / 12.0	351	5562	279	88.0%	64.8%	81.4%	346	12	0.6%	0	0.6%
18%	0.40 / 20.0 / 2.4 + 0.25 / 16.0	371	5923	276	93.0%	69.0%	80.7%	382	6	0.3%	0	0.3%
18%	0.40 / 18.0 / 2.4 + 0.25 / 14.4	371	5923	276	93.0%	69.0%	80.7%	382	6	0.3%	0	0.3%
18%	0.40 / 15.0 / 2.4 + 0.25 / 12.0	371	5923	276	93.0%	69.0%	80.7%	382	6	0.3%	0	0.3%
18%	0.40 / 12.0 / 2.4 + 0.25 / 9.6	371	5923	276	93.0%	69.0%	80.7%	382	6	0.3%	0	0.3%

* see text in Section 5 for explanation

Appendix D: IM240 Cutpoint Tables

IM240	Cutpoints	Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Composite + Mode 2	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
18%	0.40 / 20.0 / 2.5 + 0.25 / 16.0	370	5923	276	92.8%	69.0%	80.7%	376	6	0.3%	0	0.3%
18%	0.40 / 18.0 / 2.5 + 0.25 / 14.4	370	5923	276	92.8%	69.0%	80.7%	376	6	0.3%	0	0.3%
18%	0.40 / 15.0 / 2.5 + 0.25 / 12.0	370	5923	276	92.8%	69.0%	80.7%	376	6	0.3%	0	0.3%
18%	0.40 / 12.0 / 2.5 + 0.25 / 9.6	370	5923	276	92.8%	69.0%	80.7%	376	6	0.3%	0	0.3%
18%	0.60 / 20.0 / 1.9 + 0.37 / 16.0	367	5847	288	92.2%	68.1%	84.2%	382	18	0.9%	0	0.9%
18%	0.80 / 20.0 / 1.9 + 0.50 / 16.0	367	5844	288	92.2%	68.0%	84.2%	370	12	0.6%	0	0.6%
18%	0.80 / 18.0 / 1.9 + 0.50 / 14.4	367	5849	288	92.2%	68.1%	84.2%	376	12	0.6%	0	0.6%
18%	0.80 / 15.0 / 1.9 + 0.50 / 12.0	367	5849	288	92.2%	68.1%	84.2%	376	12	0.6%	0	0.6%
18%	0.80 / 12.0 / 1.9 + 0.50 / 9.6	367	5849	288	92.2%	68.1%	84.2%	376	12	0.6%	0	0.6%
18%	0.50 / 12.0 / 2.0 + 0.31 / 10.0	367	5799	286	92.2%	67.5%	83.4%	376	18	0.9%	0	0.9%
18%	0.60 / 12.0 / 2.0 + 0.38 / 10.0	367	5799	286	92.2%	67.5%	83.4%	376	18	0.9%	0	0.9%
18%	0.60 / 20.0 / 2.0 + 0.37 / 16.0	367	5794	286	92.2%	67.5%	83.4%	370	18	0.9%	0	0.9%
18%	0.60 / 18.0 / 2.0 + 0.37 / 14.4	367	5799	286	92.2%	67.5%	83.4%	376	18	0.9%	0	0.9%
18%	0.80 / 18.0 / 2.0 + 0.50 / 14.4	367	5796	286	92.2%	67.5%	83.4%	364	12	0.6%	0	0.6%
18%	0.60 / 15.0 / 2.0 + 0.37 / 12.0	367	5799	286	92.2%	67.5%	83.4%	376	18	0.9%	0	0.9%
18%	0.80 / 15.0 / 2.0 + 0.50 / 12.0	367	5796	286	92.2%	67.5%	83.4%	364	12	0.6%	0	0.6%
18%	0.60 / 12.0 / 2.0 + 0.37 / 9.6	367	5799	286	92.2%	67.5%	83.4%	376	18	0.9%	0	0.9%
18%	0.80 / 12.0 / 2.0 + 0.50 / 9.6	367	5796	286	92.2%	67.5%	83.4%	364	12	0.6%	0	0.6%
18%	0.50 / 12.0 / 2.1 + 0.31 / 10.0	367	5779	285	92.2%	67.3%	83.3%	370	18	0.9%	0	0.9%
18%	0.60 / 12.0 / 2.1 + 0.38 / 10.0	367	5779	285	92.2%	67.3%	83.3%	370	18	0.9%	0	0.9%
18%	0.60 / 20.0 / 2.1 + 0.37 / 16.0	367	5774	285	92.2%	67.2%	83.3%	364	18	0.9%	0	0.9%
18%	0.60 / 18.0 / 2.1 + 0.37 / 14.4	367	5779	285	92.2%	67.3%	83.3%	370	18	0.9%	0	0.9%
18%	0.60 / 15.0 / 2.1 + 0.37 / 12.0	367	5779	285	92.2%	67.3%	83.3%	370	18	0.9%	0	0.9%
18%	0.60 / 12.0 / 2.1 + 0.37 / 9.6	367	5779	285	92.2%	67.3%	83.3%	370	18	0.9%	0	0.9%
18%	0.80 / 10.0 / 2.3 + 0.50 / 8.0	365	5750	274	91.6%	66.9%	80.0%	376	54	2.6%	0	2.6%
18%	0.60 / 10.0 / 2.4 + 0.37 / 8.0	365	5744	270	91.6%	66.9%	78.8%	370	48	2.3%	0	2.3%
18%	0.60 / 10.0 / 2.5 + 0.37 / 8.0	364	5744	270	91.3%	66.9%	78.8%	364	48	2.3%	0	2.3%
18%	1.00 / 10.0 / 2.2 + 0.62 / 8.0	357	5591	274	89.6%	65.1%	80.2%	376	54	2.6%	0	2.6%
18%	1.20 / 10.0 / 2.2 + 0.75 / 8.0	357	5591	274	89.6%	65.1%	80.2%	376	54	2.6%	0	2.6%
19%	0.40 / 20.0 / 2.3 + 0.25 / 16.0	371	5933	281	93.0%	69.1%	81.9%	400	18	0.9%	0	0.9%
19%	0.40 / 18.0 / 2.3 + 0.25 / 14.4	371	5933	281	93.0%	69.1%	81.9%	400	18	0.9%	0	0.9%
19%	0.40 / 15.0 / 2.3 + 0.25 / 12.0	371	5933	281	93.0%	69.1%	81.9%	400	18	0.9%	0	0.9%
19%	0.40 / 12.0 / 2.3 + 0.25 / 9.6	371	5933	281	93.0%	69.1%	81.9%	400	18	0.9%	0	0.9%
19%	0.50 / 12.0 / 1.9 + 0.31 / 10.0	367	5853	288	92.2%	68.1%	84.2%	388	18	0.9%	0	0.9%
19%	0.60 / 12.0 / 1.9 + 0.38 / 10.0	367	5853	288	92.2%	68.1%	84.2%	388	18	0.9%	0	0.9%

* see text in Section 5 for explanation

Appendix D: IM240 Cutpoint Tables

IM240	Cutpoints	Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Composite + Mode 2	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
19%	0.50 / 12.0 / 1.8 + 0.31 / 10.0	367	5853	288	92.2%	68.1%	84.2%	388	18	0.9%	0	0.9%
19%	0.60 / 12.0 / 1.8 + 0.38 / 10.0	367	5853	288	92.2%	68.1%	84.2%	388	18	0.9%	0	0.9%
19%	0.60 / 18.0 / 1.9 + 0.37 / 14.4	367	5853	288	92.2%	68.1%	84.2%	388	18	0.9%	0	0.9%
19%	0.60 / 15.0 / 1.9 + 0.37 / 12.0	367	5853	288	92.2%	68.1%	84.2%	388	18	0.9%	0	0.9%
19%	0.60 / 12.0 / 1.9 + 0.37 / 9.6	367	5853	288	92.2%	68.1%	84.2%	388	18	0.9%	0	0.9%
19%	0.80 / 10.0 / 2.2 + 0.50 / 8.0	365	5752	281	91.6%	67.0%	82.0%	394	54	2.6%	0	2.6%
19%	0.60 / 10.0 / 2.3 + 0.37 / 8.0	365	5754	274	91.6%	67.0%	80.0%	388	60	2.9%	0	2.9%
19%	1.00 / 10.0 / 1.9 + 0.62 / 8.0	359	5688	282	90.2%	66.2%	82.4%	400	54	2.6%	0	2.6%
19%	1.20 / 10.0 / 1.9 + 0.75 / 8.0	359	5688	282	90.2%	66.2%	82.4%	400	54	2.6%	0	2.6%
19%	1.00 / 10.0 / 2.0 + 0.62 / 8.0	359	5665	281	90.2%	66.0%	82.1%	394	54	2.6%	0	2.6%
19%	1.20 / 10.0 / 2.0 + 0.75 / 8.0	359	5665	281	90.2%	66.0%	82.1%	394	54	2.6%	0	2.6%
19%	1.00 / 10.0 / 2.1 + 0.62 / 8.0	359	5645	281	90.2%	65.7%	82.0%	388	54	2.6%	0	2.6%
19%	1.20 / 10.0 / 2.1 + 0.75 / 8.0	359	5645	281	90.2%	65.7%	82.0%	388	54	2.6%	0	2.6%
20%	0.40 / 12.0 / 2.1 + 0.25 / 10.0	371	5952	287	93.0%	69.3%	83.9%	424	18	0.9%	0	0.9%
20%	0.40 / 12.0 / 2.0 + 0.25 / 10.0	371	5952	287	93.0%	69.3%	83.9%	424	18	0.9%	0	0.9%
20%	0.40 / 20.0 / 2.2 + 0.25 / 16.0	371	5935	287	93.0%	69.1%	83.9%	418	18	0.9%	0	0.9%
20%	0.40 / 18.0 / 2.2 + 0.25 / 14.4	371	5935	287	93.0%	69.1%	83.9%	418	18	0.9%	0	0.9%
20%	0.40 / 15.0 / 2.2 + 0.25 / 12.0	371	5935	287	93.0%	69.1%	83.9%	418	18	0.9%	0	0.9%
20%	0.40 / 12.0 / 2.2 + 0.25 / 9.6	371	5935	287	93.0%	69.1%	83.9%	418	18	0.9%	0	0.9%
20%	0.40 / 20.0 / 2.1 + 0.25 / 16.0	371	5952	287	93.0%	69.3%	83.9%	424	18	0.9%	0	0.9%
20%	0.40 / 18.0 / 2.1 + 0.25 / 14.4	371	5952	287	93.0%	69.3%	83.9%	424	18	0.9%	0	0.9%
20%	0.40 / 15.0 / 2.1 + 0.25 / 12.0	371	5952	287	93.0%	69.3%	83.9%	424	18	0.9%	0	0.9%
20%	0.40 / 12.0 / 2.1 + 0.25 / 9.6	371	5952	287	93.0%	69.3%	83.9%	424	18	0.9%	0	0.9%
20%	0.40 / 20.0 / 2.0 + 0.25 / 16.0	371	5952	287	93.0%	69.3%	83.9%	424	18	0.9%	0	0.9%
20%	0.40 / 18.0 / 2.0 + 0.25 / 14.4	371	5952	287	93.0%	69.3%	83.9%	424	18	0.9%	0	0.9%
20%	0.40 / 15.0 / 2.0 + 0.25 / 12.0	371	5952	287	93.0%	69.3%	83.9%	424	18	0.9%	0	0.9%
20%	0.40 / 12.0 / 2.0 + 0.25 / 9.6	371	5952	287	93.0%	69.3%	83.9%	424	18	0.9%	0	0.9%
20%	0.40 / 10.0 / 2.4 + 0.25 / 8.0	371	5923	276	93.0%	69.0%	80.7%	424	48	2.3%	0	2.3%
20%	0.40 / 10.0 / 2.5 + 0.25 / 8.0	370	5923	276	92.8%	69.0%	80.7%	418	48	2.3%	0	2.3%
20%	0.80 / 10.0 / 1.9 + 0.50 / 8.0	367	5849	288	92.2%	68.1%	84.2%	418	54	2.6%	0	2.6%
20%	0.50 / 11.0 / 2.0 + 0.31 / 9.0	367	5830	287	92.2%	67.9%	83.9%	424	60	2.9%	0	2.9%
20%	0.60 / 11.0 / 2.0 + 0.38 / 9.0	367	5830	287	92.2%	67.9%	83.9%	424	60	2.9%	0	2.9%
20%	0.50 / 10.0 / 2.0 + 0.31 / 8.0	367	5830	287	92.2%	67.9%	83.9%	424	60	2.9%	0	2.9%
20%	0.60 / 10.0 / 2.0 + 0.38 / 8.0	367	5830	287	92.2%	67.9%	83.9%	424	60	2.9%	0	2.9%
20%	0.60 / 10.0 / 2.0 + 0.37 / 8.0	367	5830	287	92.2%	67.9%	83.9%	424	60	2.9%	0	2.9%

* see text in Section 5 for explanation

Appendix D: IM240 Cutpoint Tables

IM240 Failure Rate	Cutpoints Composite + Mode 2	Excess Emissions Identified			Identification Rates			Fails	Errors of Commission	Ec Rate*	Discrepant Failures	Probable Ec Rate
		HC	CO	NOx	HC	CO	NOx					
20%	0.80 / 10.0 / 2.0 + 0.50 / 8.0	367	5826	287	92.2%	67.8%	83.9%	412	54	2.6%	0	2.6%
20%	0.50 / 11.0 / 2.1 + 0.31 / 9.0	367	5810	287	92.2%	67.6%	83.8%	418	60	2.9%	0	2.9%
20%	0.60 / 11.0 / 2.1 + 0.38 / 9.0	367	5810	287	92.2%	67.6%	83.8%	418	60	2.9%	0	2.9%
20%	0.50 / 10.0 / 2.1 + 0.31 / 8.0	367	5810	287	92.2%	67.6%	83.8%	418	60	2.9%	0	2.9%
20%	0.60 / 10.0 / 2.1 + 0.38 / 8.0	367	5810	287	92.2%	67.6%	83.8%	418	60	2.9%	0	2.9%
20%	0.60 / 10.0 / 2.1 + 0.37 / 8.0	367	5810	287	92.2%	67.6%	83.8%	418	60	2.9%	0	2.9%
20%	0.80 / 10.0 / 2.1 + 0.50 / 8.0	367	5807	287	92.2%	67.6%	83.8%	406	54	2.6%	0	2.6%
20%	0.60 / 10.0 / 2.2 + 0.37 / 8.0	365	5756	281	91.6%	67.0%	82.0%	406	60	2.9%	0	2.9%
21%	0.40 / 12.0 / 1.9 + 0.25 / 10.0	371	5975	288	93.1%	69.6%	84.2%	430	18	0.9%	0	0.9%
21%	0.40 / 12.0 / 1.8 + 0.25 / 10.0	371	5975	288	93.1%	69.6%	84.2%	430	18	0.9%	0	0.9%
21%	0.40 / 20.0 / 1.9 + 0.25 / 16.0	371	5975	288	93.1%	69.6%	84.2%	430	18	0.9%	0	0.9%
21%	0.40 / 18.0 / 1.9 + 0.25 / 14.4	371	5975	288	93.1%	69.6%	84.2%	430	18	0.9%	0	0.9%
21%	0.40 / 15.0 / 1.9 + 0.25 / 12.0	371	5975	288	93.1%	69.6%	84.2%	430	18	0.9%	0	0.9%
21%	0.40 / 12.0 / 1.9 + 0.25 / 9.6	371	5975	288	93.1%	69.6%	84.2%	430	18	0.9%	0	0.9%
21%	0.40 / 10.0 / 2.3 + 0.25 / 8.0	371	5933	281	93.0%	69.1%	81.9%	442	60	2.9%	0	2.9%
21%	0.50 / 12.0 / 1.7 + 0.31 / 10.0	368	6029	299	92.3%	70.2%	87.3%	430	18	0.9%	0	0.9%
21%	0.60 / 12.0 / 1.7 + 0.38 / 10.0	368	6029	299	92.3%	70.2%	87.3%	430	18	0.9%	0	0.9%
21%	0.50 / 12.0 / 1.6 + 0.31 / 10.0	368	6029	299	92.3%	70.2%	87.3%	430	18	0.9%	0	0.9%
21%	0.60 / 12.0 / 1.6 + 0.38 / 10.0	368	6029	299	92.3%	70.2%	87.3%	430	18	0.9%	0	0.9%
21%	0.50 / 11.0 / 1.9 + 0.31 / 9.0	367	5853	288	92.2%	68.1%	84.2%	430	60	2.9%	0	2.9%
21%	0.60 / 11.0 / 1.9 + 0.38 / 9.0	367	5853	288	92.2%	68.1%	84.2%	430	60	2.9%	0	2.9%
21%	0.50 / 10.0 / 1.9 + 0.31 / 8.0	367	5853	288	92.2%	68.1%	84.2%	430	60	2.9%	0	2.9%
21%	0.60 / 10.0 / 1.9 + 0.38 / 8.0	367	5853	288	92.2%	68.1%	84.2%	430	60	2.9%	0	2.9%
21%	0.50 / 11.0 / 1.8 + 0.31 / 9.0	367	5853	288	92.2%	68.1%	84.2%	430	60	2.9%	0	2.9%
21%	0.60 / 11.0 / 1.8 + 0.38 / 9.0	367	5853	288	92.2%	68.1%	84.2%	430	60	2.9%	0	2.9%
21%	0.50 / 10.0 / 1.8 + 0.31 / 8.0	367	5853	288	92.2%	68.1%	84.2%	430	60	2.9%	0	2.9%
21%	0.60 / 10.0 / 1.8 + 0.38 / 8.0	367	5853	288	92.2%	68.1%	84.2%	430	60	2.9%	0	2.9%
21%	0.60 / 10.0 / 1.9 + 0.37 / 8.0	367	5853	288	92.2%	68.1%	84.2%	430	60	2.9%	0	2.9%
22%	0.50 / 9.0 / 2.1 + 0.31 / 7.0	372	6124	309	93.5%	71.3%	90.3%	460	60	2.9%	0	2.9%
22%	0.60 / 9.0 / 2.1 + 0.38 / 7.0	372	6124	309	93.5%	71.3%	90.3%	460	60	2.9%	0	2.9%
22%	0.40 / 10.0 / 2.2 + 0.25 / 8.0	371	5935	287	93.0%	69.1%	83.9%	460	60	2.9%	0	2.9%
23%	0.50 / 9.0 / 1.9 + 0.31 / 7.0	372	6167	310	93.5%	71.8%	90.7%	472	60	2.9%	0	2.9%
23%	0.60 / 9.0 / 1.9 + 0.38 / 7.0	372	6167	310	93.5%	71.8%	90.7%	472	60	2.9%	0	2.9%
23%	0.50 / 9.0 / 1.8 + 0.31 / 7.0	372	6167	310	93.5%	71.8%	90.7%	472	60	2.9%	0	2.9%
23%	0.60 / 9.0 / 1.8 + 0.38 / 7.0	372	6167	310	93.5%	71.8%	90.7%	472	60	2.9%	0	2.9%

* see text in Section 5 for explanation

Appendix D: IM240 Cutpoint Tables

IM240	Cutpoints	Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Composite + Mode 2	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
23%	0.50 / 9.0 / 2.0 + 0.31 / 7.0	372	6144	310	93.5%	71.5%	90.4%	466	60	2.9%	0	2.9%
23%	0.60 / 9.0 / 2.0 + 0.38 / 7.0	372	6144	310	93.5%	71.5%	90.4%	466	60	2.9%	0	2.9%
23%	0.40 / 12.0 / 1.7 + 0.25 / 10.0	371	6151	299	93.2%	71.6%	87.3%	472	18	0.9%	0	0.9%
23%	0.40 / 12.0 / 1.6 + 0.25 / 10.0	371	6151	299	93.2%	71.6%	87.3%	472	18	0.9%	0	0.9%
23%	0.40 / 11.0 / 1.9 + 0.25 / 9.0	371	5975	288	93.1%	69.6%	84.2%	472	60	2.9%	0	2.9%
23%	0.40 / 10.0 / 1.9 + 0.25 / 8.0	371	5975	288	93.1%	69.6%	84.2%	472	60	2.9%	0	2.9%
23%	0.40 / 11.0 / 1.8 + 0.25 / 9.0	371	5975	288	93.1%	69.6%	84.2%	472	60	2.9%	0	2.9%
23%	0.40 / 10.0 / 1.8 + 0.25 / 8.0	371	5975	288	93.1%	69.6%	84.2%	472	60	2.9%	0	2.9%
23%	0.40 / 10.0 / 1.9 + 0.25 / 8.0	371	5975	288	93.1%	69.6%	84.2%	472	60	2.9%	0	2.9%
23%	0.40 / 11.0 / 2.1 + 0.25 / 9.0	371	5952	287	93.0%	69.3%	83.9%	466	60	2.9%	0	2.9%
23%	0.40 / 10.0 / 2.1 + 0.25 / 8.0	371	5952	287	93.0%	69.3%	83.9%	466	60	2.9%	0	2.9%
23%	0.40 / 11.0 / 2.0 + 0.25 / 9.0	371	5952	287	93.0%	69.3%	83.9%	466	60	2.9%	0	2.9%
23%	0.40 / 10.0 / 2.0 + 0.25 / 8.0	371	5952	287	93.0%	69.3%	83.9%	466	60	2.9%	0	2.9%
23%	0.40 / 10.0 / 2.1 + 0.25 / 8.0	371	5952	287	93.0%	69.3%	83.9%	466	60	2.9%	0	2.9%
23%	0.40 / 10.0 / 2.0 + 0.25 / 8.0	371	5952	287	93.0%	69.3%	83.9%	466	60	2.9%	0	2.9%
23%	0.50 / 11.0 / 1.7 + 0.31 / 9.0	368	6029	299	92.3%	70.2%	87.3%	472	60	2.9%	0	2.9%
23%	0.60 / 11.0 / 1.7 + 0.38 / 9.0	368	6029	299	92.3%	70.2%	87.3%	472	60	2.9%	0	2.9%
23%	0.50 / 10.0 / 1.7 + 0.31 / 8.0	368	6029	299	92.3%	70.2%	87.3%	472	60	2.9%	0	2.9%
23%	0.60 / 10.0 / 1.7 + 0.38 / 8.0	368	6029	299	92.3%	70.2%	87.3%	472	60	2.9%	0	2.9%
23%	0.50 / 11.0 / 1.6 + 0.31 / 9.0	368	6029	299	92.3%	70.2%	87.3%	472	60	2.9%	0	2.9%
23%	0.60 / 11.0 / 1.6 + 0.38 / 9.0	368	6029	299	92.3%	70.2%	87.3%	472	60	2.9%	0	2.9%
23%	0.50 / 10.0 / 1.6 + 0.31 / 8.0	368	6029	299	92.3%	70.2%	87.3%	472	60	2.9%	0	2.9%
23%	0.60 / 10.0 / 1.6 + 0.38 / 8.0	368	6029	299	92.3%	70.2%	87.3%	472	60	2.9%	0	2.9%
23%	0.50 / 12.0 / 1.5 + 0.31 / 10.0	368	6041	299	92.3%	70.3%	87.3%	472	18	0.9%	48	3.2%
23%	0.60 / 12.0 / 1.5 + 0.38 / 10.0	368	6041	299	92.3%	70.3%	87.3%	472	18	0.9%	48	3.2%
24%	0.50 / 8.0 / 2.1 + 0.31 / 6.0	376	6246	309	94.3%	72.7%	90.3%	502	60	2.9%	0	2.9%
24%	0.60 / 8.0 / 2.1 + 0.38 / 6.0	376	6246	309	94.3%	72.7%	90.3%	502	60	2.9%	0	2.9%
25%	0.40 / 9.0 / 1.9 + 0.25 / 7.0	376	6289	310	94.3%	73.2%	90.7%	514	60	2.9%	0	2.9%
25%	0.40 / 8.0 / 1.9 + 0.25 / 6.0	376	6289	310	94.3%	73.2%	90.7%	514	60	2.9%	0	2.9%
25%	0.50 / 8.0 / 1.9 + 0.31 / 6.0	376	6289	310	94.3%	73.2%	90.7%	514	60	2.9%	0	2.9%
25%	0.60 / 8.0 / 1.9 + 0.38 / 6.0	376	6289	310	94.3%	73.2%	90.7%	514	60	2.9%	0	2.9%
25%	0.40 / 9.0 / 1.8 + 0.25 / 7.0	376	6289	310	94.3%	73.2%	90.7%	514	60	2.9%	0	2.9%
25%	0.40 / 8.0 / 1.8 + 0.25 / 6.0	376	6289	310	94.3%	73.2%	90.7%	514	60	2.9%	0	2.9%
25%	0.50 / 8.0 / 1.8 + 0.31 / 6.0	376	6289	310	94.3%	73.2%	90.7%	514	60	2.9%	0	2.9%
25%	0.60 / 8.0 / 1.8 + 0.38 / 6.0	376	6289	310	94.3%	73.2%	90.7%	514	60	2.9%	0	2.9%

* see text in Section 5 for explanation

Appendix D: IM240 Cutpoint Tables

IM240	Cutpoints	Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Composite + Mode 2	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
25%	0.40 / 9.0 / 2.1 + 0.25 / 7.0	376	6266	310	94.3%	73.0%	90.4%	508	60	2.9%	0	2.9%
25%	0.40 / 8.0 / 2.1 + 0.25 / 6.0	376	6266	310	94.3%	73.0%	90.4%	508	60	2.9%	0	2.9%
25%	0.40 / 9.0 / 2.0 + 0.25 / 7.0	376	6266	310	94.3%	73.0%	90.4%	508	60	2.9%	0	2.9%
25%	0.40 / 8.0 / 2.0 + 0.25 / 6.0	376	6266	310	94.3%	73.0%	90.4%	508	60	2.9%	0	2.9%
25%	0.50 / 8.0 / 2.0 + 0.31 / 6.0	376	6266	310	94.3%	73.0%	90.4%	508	60	2.9%	0	2.9%
25%	0.60 / 8.0 / 2.0 + 0.38 / 6.0	376	6266	310	94.3%	73.0%	90.4%	508	60	2.9%	0	2.9%
25%	0.50 / 9.0 / 1.7 + 0.31 / 7.0	373	6343	321	93.6%	73.9%	93.8%	514	60	2.9%	0	2.9%
25%	0.60 / 9.0 / 1.7 + 0.38 / 7.0	373	6343	321	93.6%	73.9%	93.8%	514	60	2.9%	0	2.9%
25%	0.50 / 9.0 / 1.6 + 0.31 / 7.0	373	6343	321	93.6%	73.9%	93.8%	514	60	2.9%	0	2.9%
25%	0.60 / 9.0 / 1.6 + 0.38 / 7.0	373	6343	321	93.6%	73.9%	93.8%	514	60	2.9%	0	2.9%
25%	0.40 / 11.0 / 1.7 + 0.25 / 9.0	371	6151	299	93.2%	71.6%	87.3%	514	60	2.9%	0	2.9%
25%	0.40 / 10.0 / 1.7 + 0.25 / 8.0	371	6151	299	93.2%	71.6%	87.3%	514	60	2.9%	0	2.9%
25%	0.40 / 11.0 / 1.6 + 0.25 / 9.0	371	6151	299	93.2%	71.6%	87.3%	514	60	2.9%	0	2.9%
25%	0.40 / 10.0 / 1.6 + 0.25 / 8.0	371	6151	299	93.2%	71.6%	87.3%	514	60	2.9%	0	2.9%
25%	0.40 / 12.0 / 1.5 + 0.25 / 10.0	371	6163	299	93.2%	71.8%	87.3%	514	18	0.9%	48	3.2%
25%	0.50 / 11.0 / 1.5 + 0.31 / 9.0	368	6041	299	92.3%	70.3%	87.3%	514	60	2.9%	48	5.2%
25%	0.60 / 11.0 / 1.5 + 0.38 / 9.0	368	6041	299	92.3%	70.3%	87.3%	514	60	2.9%	48	5.2%
25%	0.50 / 10.0 / 1.5 + 0.31 / 8.0	368	6041	299	92.3%	70.3%	87.3%	514	60	2.9%	42	4.9%
25%	0.60 / 10.0 / 1.5 + 0.38 / 8.0	368	6041	299	92.3%	70.3%	87.3%	514	60	2.9%	42	4.9%
27%	0.40 / 9.0 / 1.7 + 0.25 / 7.0	376	6465	321	94.4%	75.3%	93.8%	556	60	2.9%	0	2.9%
27%	0.40 / 8.0 / 1.7 + 0.25 / 6.0	376	6465	321	94.4%	75.3%	93.8%	556	60	2.9%	0	2.9%
27%	0.50 / 8.0 / 1.7 + 0.31 / 6.0	376	6465	321	94.4%	75.3%	93.8%	556	60	2.9%	0	2.9%
27%	0.60 / 8.0 / 1.7 + 0.38 / 6.0	376	6465	321	94.4%	75.3%	93.8%	556	60	2.9%	0	2.9%
27%	0.40 / 9.0 / 1.6 + 0.25 / 7.0	376	6465	321	94.4%	75.3%	93.8%	556	60	2.9%	0	2.9%
27%	0.40 / 8.0 / 1.6 + 0.25 / 6.0	376	6465	321	94.4%	75.3%	93.8%	556	60	2.9%	0	2.9%
27%	0.50 / 8.0 / 1.6 + 0.31 / 6.0	376	6465	321	94.4%	75.3%	93.8%	556	60	2.9%	0	2.9%
27%	0.60 / 8.0 / 1.6 + 0.38 / 6.0	376	6465	321	94.4%	75.3%	93.8%	556	60	2.9%	0	2.9%
27%	0.50 / 9.0 / 1.5 + 0.31 / 7.0	373	6355	321	93.6%	74.0%	93.8%	556	60	2.9%	42	4.9%
27%	0.60 / 9.0 / 1.5 + 0.38 / 7.0	373	6355	321	93.6%	74.0%	93.8%	556	60	2.9%	42	4.9%
27%	0.40 / 11.0 / 1.5 + 0.25 / 9.0	371	6163	299	93.2%	71.8%	87.3%	556	60	2.9%	48	5.2%
27%	0.40 / 10.0 / 1.5 + 0.25 / 8.0	371	6163	299	93.2%	71.8%	87.3%	556	60	2.9%	42	4.9%
29%	0.30 / 12.0 / 2.1 + 0.19 / 10.0	377	6228	300	94.5%	72.5%	87.5%	598	60	2.9%	0	2.9%
29%	0.30 / 11.0 / 2.1 + 0.19 / 9.0	377	6228	300	94.5%	72.5%	87.5%	598	60	2.9%	0	2.9%
29%	0.30 / 10.0 / 2.1 + 0.19 / 8.0	377	6228	300	94.5%	72.5%	87.5%	598	60	2.9%	0	2.9%
29%	0.30 / 12.0 / 2.0 + 0.19 / 10.0	377	6228	300	94.5%	72.5%	87.5%	598	60	2.9%	0	2.9%

* see text in Section 5 for explanation

Appendix D: IM240 Cutpoint Tables

IM240	Cutpoints	Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Composite + Mode 2	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
29%	0.30 / 11.0 / 2.0 + 0.19 / 9.0	377	6228	300	94.5%	72.5%	87.5%	598	60	2.9%	0	2.9%
29%	0.30 / 10.0 / 2.0 + 0.19 / 8.0	377	6228	300	94.5%	72.5%	87.5%	598	60	2.9%	0	2.9%
29%	0.30 / 12.0 / 1.9 + 0.19 / 10.0	377	6228	300	94.5%	72.5%	87.5%	598	60	2.9%	0	2.9%
29%	0.30 / 11.0 / 1.9 + 0.19 / 9.0	377	6228	300	94.5%	72.5%	87.5%	598	60	2.9%	0	2.9%
29%	0.30 / 10.0 / 1.9 + 0.19 / 8.0	377	6228	300	94.5%	72.5%	87.5%	598	60	2.9%	0	2.9%
29%	0.30 / 12.0 / 1.8 + 0.19 / 10.0	377	6228	300	94.5%	72.5%	87.5%	598	60	2.9%	0	2.9%
29%	0.30 / 11.0 / 1.8 + 0.19 / 9.0	377	6228	300	94.5%	72.5%	87.5%	598	60	2.9%	0	2.9%
29%	0.30 / 10.0 / 1.8 + 0.19 / 8.0	377	6228	300	94.5%	72.5%	87.5%	598	60	2.9%	0	2.9%
29%	0.40 / 9.0 / 1.5 + 0.25 / 7.0	376	6477	321	94.4%	75.4%	93.8%	598	60	2.9%	42	4.9%
29%	0.40 / 8.0 / 1.5 + 0.25 / 6.0	376	6477	321	94.4%	75.4%	93.8%	598	60	2.9%	42	4.9%
29%	0.50 / 8.0 / 1.5 + 0.31 / 6.0	376	6477	321	94.4%	75.4%	93.8%	598	60	2.9%	42	4.9%
29%	0.60 / 8.0 / 1.5 + 0.38 / 6.0	376	6477	321	94.4%	75.4%	93.8%	598	60	2.9%	42	4.9%
31%	0.30 / 9.0 / 2.1 + 0.19 / 7.0	382	6543	322	95.8%	76.2%	94.0%	639	60	2.9%	0	2.9%
31%	0.30 / 8.0 / 2.1 + 0.19 / 6.0	382	6543	322	95.8%	76.2%	94.0%	639	60	2.9%	0	2.9%
31%	0.30 / 9.0 / 2.0 + 0.19 / 7.0	382	6543	322	95.8%	76.2%	94.0%	639	60	2.9%	0	2.9%
31%	0.30 / 8.0 / 2.0 + 0.19 / 6.0	382	6543	322	95.8%	76.2%	94.0%	639	60	2.9%	0	2.9%
31%	0.30 / 9.0 / 1.9 + 0.19 / 7.0	382	6543	322	95.8%	76.2%	94.0%	639	60	2.9%	0	2.9%
31%	0.30 / 8.0 / 1.9 + 0.19 / 6.0	382	6543	322	95.8%	76.2%	94.0%	639	60	2.9%	0	2.9%
31%	0.30 / 9.0 / 1.8 + 0.19 / 7.0	382	6543	322	95.8%	76.2%	94.0%	639	60	2.9%	0	2.9%
31%	0.30 / 8.0 / 1.8 + 0.19 / 6.0	382	6543	322	95.8%	76.2%	94.0%	639	60	2.9%	0	2.9%
31%	0.30 / 12.0 / 1.7 + 0.19 / 10.0	377	6405	310	94.6%	74.6%	90.6%	639	60	2.9%	0	2.9%
31%	0.30 / 11.0 / 1.7 + 0.19 / 9.0	377	6405	310	94.6%	74.6%	90.6%	639	60	2.9%	0	2.9%
31%	0.30 / 10.0 / 1.7 + 0.19 / 8.0	377	6405	310	94.6%	74.6%	90.6%	639	60	2.9%	0	2.9%
31%	0.30 / 12.0 / 1.6 + 0.19 / 10.0	377	6405	310	94.6%	74.6%	90.6%	639	60	2.9%	0	2.9%
31%	0.30 / 11.0 / 1.6 + 0.19 / 9.0	377	6405	310	94.6%	74.6%	90.6%	639	60	2.9%	0	2.9%
31%	0.30 / 10.0 / 1.6 + 0.19 / 8.0	377	6405	310	94.6%	74.6%	90.6%	639	60	2.9%	0	2.9%
33%	0.30 / 9.0 / 1.7 + 0.19 / 7.0	382	6719	332	95.9%	78.2%	97.1%	681	60	2.9%	0	2.9%
33%	0.30 / 8.0 / 1.7 + 0.19 / 6.0	382	6719	332	95.9%	78.2%	97.1%	681	60	2.9%	0	2.9%
33%	0.30 / 9.0 / 1.6 + 0.19 / 7.0	382	6719	332	95.9%	78.2%	97.1%	681	60	2.9%	0	2.9%
33%	0.30 / 8.0 / 1.6 + 0.19 / 6.0	382	6719	332	95.9%	78.2%	97.1%	681	60	2.9%	0	2.9%
33%	0.30 / 12.0 / 1.5 + 0.19 / 10.0	377	6417	310	94.6%	74.7%	90.6%	681	60	2.9%	48	5.2%
33%	0.30 / 11.0 / 1.5 + 0.19 / 9.0	377	6417	310	94.6%	74.7%	90.6%	681	60	2.9%	48	5.2%
33%	0.30 / 10.0 / 1.5 + 0.19 / 8.0	377	6417	310	94.6%	74.7%	90.6%	681	60	2.9%	42	4.9%
35%	0.30 / 9.0 / 1.5 + 0.19 / 7.0	382	6731	332	95.9%	78.4%	97.1%	723	60	2.9%	42	4.9%
35%	0.30 / 8.0 / 1.5 + 0.19 / 6.0	382	6731	332	95.9%	78.4%	97.1%	723	60	2.9%	42	4.9%

* see text in Section 5 for explanation

Appendix D: IM240 Cutpoint Tables

IM240	Cutpoints	Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Composite + Mode 2	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
47%	0.20 / 12.0 / 2.1 + 0.13 / 10.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 11.0 / 2.1 + 0.13 / 9.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 10.0 / 2.1 + 0.13 / 8.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 9.0 / 2.1 + 0.13 / 7.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 8.0 / 2.1 + 0.13 / 6.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 12.0 / 2.0 + 0.13 / 10.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 11.0 / 2.0 + 0.13 / 9.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 10.0 / 2.0 + 0.13 / 8.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 9.0 / 2.0 + 0.13 / 7.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 8.0 / 2.0 + 0.13 / 6.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 12.0 / 1.9 + 0.13 / 10.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 11.0 / 1.9 + 0.13 / 9.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 10.0 / 1.9 + 0.13 / 8.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 9.0 / 1.9 + 0.13 / 7.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 8.0 / 1.9 + 0.13 / 6.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 12.0 / 1.8 + 0.13 / 10.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 11.0 / 1.8 + 0.13 / 9.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 10.0 / 1.8 + 0.13 / 8.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 9.0 / 1.8 + 0.13 / 7.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 8.0 / 1.8 + 0.13 / 6.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 12.0 / 1.7 + 0.13 / 10.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 11.0 / 1.7 + 0.13 / 9.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 10.0 / 1.7 + 0.13 / 8.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 9.0 / 1.7 + 0.13 / 7.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 8.0 / 1.7 + 0.13 / 6.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 12.0 / 1.6 + 0.13 / 10.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 11.0 / 1.6 + 0.13 / 9.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 10.0 / 1.6 + 0.13 / 8.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 9.0 / 1.6 + 0.13 / 7.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
47%	0.20 / 8.0 / 1.6 + 0.13 / 6.0	390	7126	332	98.0%	83.0%	97.1%	975	227	11.0%	0	11.0%
49%	0.20 / 12.0 / 1.5 + 0.13 / 10.0	390	7138	332	98.0%	83.1%	97.1%	1017	227	11.0%	48	13.3%
49%	0.20 / 11.0 / 1.5 + 0.13 / 9.0	390	7138	332	98.0%	83.1%	97.1%	1017	227	11.0%	48	13.3%
49%	0.20 / 10.0 / 1.5 + 0.13 / 8.0	390	7138	332	98.0%	83.1%	97.1%	1017	227	11.0%	42	13.0%
49%	0.20 / 9.0 / 1.5 + 0.13 / 7.0	390	7138	332	98.0%	83.1%	97.1%	1017	227	11.0%	42	13.0%
49%	0.20 / 8.0 / 1.5 + 0.13 / 6.0	390	7138	332	98.0%	83.1%	97.1%	1017	227	11.0%	42	13.0%

* see text in Section 5 for explanation

Appendix E

ASM Cutpoint Tables

Appendix E: ASM Cutpoint Tables

ASM		Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Cutpoints	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
10%	0.80 / 15.0 / 2.5	279	4631	222	70.0%	53.9%	65.0%	215	0	0.0%	6	0.3%
10%	0.80 / 15.0 / 2.4	279	4631	222	70.0%	53.9%	65.0%	215	0	0.0%	6	0.3%
10%	1.00 / 15.0 / 2.4	279	4631	222	70.0%	53.9%	65.0%	215	0	0.0%	6	0.3%
10%	1.20 / 15.0 / 2.4	279	4631	222	70.0%	53.9%	65.0%	215	0	0.0%	6	0.3%
10%	0.80 / 20.0 / 2.5	275	4562	222	69.1%	53.1%	65.0%	209	0	0.0%	6	0.3%
10%	0.80 / 18.0 / 2.5	275	4562	222	69.1%	53.1%	65.0%	209	0	0.0%	6	0.3%
10%	0.80 / 20.0 / 2.4	275	4562	222	69.1%	53.1%	65.0%	209	0	0.0%	6	0.3%
10%	1.00 / 20.0 / 2.4	275	4562	222	69.1%	53.1%	65.0%	209	0	0.0%	6	0.3%
10%	1.20 / 20.0 / 2.4	275	4562	222	69.1%	53.1%	65.0%	209	0	0.0%	6	0.3%
10%	0.80 / 18.0 / 2.4	275	4562	222	69.1%	53.1%	65.0%	209	0	0.0%	6	0.3%
10%	1.00 / 18.0 / 2.4	275	4562	222	69.1%	53.1%	65.0%	209	0	0.0%	6	0.3%
10%	1.20 / 18.0 / 2.4	275	4562	222	69.1%	53.1%	65.0%	209	0	0.0%	6	0.3%
10%	0.80 / 20.0 / 2.2	275	4562	222	69.1%	53.1%	65.0%	215	0	0.0%	6	0.3%
10%	1.00 / 20.0 / 2.2	275	4562	222	69.1%	53.1%	65.0%	215	0	0.0%	6	0.3%
10%	1.20 / 20.0 / 2.2	275	4562	222	69.1%	53.1%	65.0%	215	0	0.0%	6	0.3%
10%	0.80 / 18.0 / 2.2	275	4562	222	69.1%	53.1%	65.0%	215	0	0.0%	6	0.3%
10%	1.00 / 18.0 / 2.2	275	4562	222	69.1%	53.1%	65.0%	215	0	0.0%	6	0.3%
10%	1.20 / 18.0 / 2.2	275	4562	222	69.1%	53.1%	65.0%	215	0	0.0%	6	0.3%
10%	0.80 / 20.0 / 2.1	275	4562	222	69.1%	53.1%	65.0%	215	0	0.0%	6	0.3%
10%	1.00 / 20.0 / 2.1	275	4562	222	69.1%	53.1%	65.0%	215	0	0.0%	6	0.3%
10%	1.20 / 20.0 / 2.1	275	4562	222	69.1%	53.1%	65.0%	215	0	0.0%	6	0.3%
10%	0.80 / 18.0 / 2.1	275	4562	222	69.1%	53.1%	65.0%	215	0	0.0%	6	0.3%
10%	1.00 / 18.0 / 2.1	275	4562	222	69.1%	53.1%	65.0%	215	0	0.0%	6	0.3%
10%	1.20 / 18.0 / 2.1	275	4562	222	69.1%	53.1%	65.0%	215	0	0.0%	6	0.3%
10%	1.00 / 15.0 / 2.5	271	4591	218	68.0%	53.4%	63.6%	209	0	0.0%	6	0.3%
10%	1.20 / 15.0 / 2.5	271	4591	218	68.0%	53.4%	63.6%	209	0	0.0%	6	0.3%
10%	1.00 / 20.0 / 2.5	267	4521	218	67.1%	52.6%	63.6%	203	0	0.0%	6	0.3%
10%	1.20 / 20.0 / 2.5	267	4521	218	67.1%	52.6%	63.6%	203	0	0.0%	6	0.3%
10%	1.00 / 18.0 / 2.5	267	4521	218	67.1%	52.6%	63.6%	203	0	0.0%	6	0.3%
10%	1.20 / 18.0 / 2.5	267	4521	218	67.1%	52.6%	63.6%	203	0	0.0%	6	0.3%
11%	0.60 / 15.0 / 2.5	295	4754	235	74.1%	55.4%	68.7%	233	0	0.0%	6	0.3%
11%	0.60 / 15.0 / 2.4	295	4754	235	74.1%	55.4%	68.7%	233	0	0.0%	6	0.3%
11%	0.60 / 20.0 / 2.5	291	4685	235	73.1%	54.5%	68.7%	227	0	0.0%	6	0.3%
11%	0.60 / 18.0 / 2.5	291	4685	235	73.1%	54.5%	68.7%	227	0	0.0%	6	0.3%
11%	0.60 / 20.0 / 2.4	291	4685	235	73.1%	54.5%	68.7%	227	0	0.0%	6	0.3%

* see Section 5 for explanation

Appendix E: ASM Cutpoint Tables

ASM Failure Rate	Cutpoints	Excess Emissions Identified			Identification Rates			Fails	Errors of Commission	Ec Rate*	Discrepant Failures	Probable Ec Rate
		HC	CO	NOx	HC	CO	NOx					
11%	0.60 / 18.0 / 2.4	291	4685	235	73.1%	54.5%	68.7%	227	0	0.0%	6	0.3%
11%	0.60 / 20.0 / 2.2	291	4685	235	73.1%	54.5%	68.7%	233	0	0.0%	6	0.3%
11%	0.60 / 18.0 / 2.2	291	4685	235	73.1%	54.5%	68.7%	233	0	0.0%	6	0.3%
11%	0.60 / 20.0 / 2.1	291	4685	235	73.1%	54.5%	68.7%	233	0	0.0%	6	0.3%
11%	0.60 / 18.0 / 2.1	291	4685	235	73.1%	54.5%	68.7%	233	0	0.0%	6	0.3%
11%	0.80 / 15.0 / 2.0	279	4631	225	70.0%	53.9%	65.9%	227	0	0.0%	6	0.3%
11%	1.00 / 15.0 / 2.0	279	4631	225	70.0%	53.9%	65.9%	227	0	0.0%	6	0.3%
11%	1.20 / 15.0 / 2.0	279	4631	225	70.0%	53.9%	65.9%	227	0	0.0%	6	0.3%
11%	0.80 / 15.0 / 2.2	279	4631	222	70.0%	53.9%	65.0%	221	0	0.0%	6	0.3%
11%	1.00 / 15.0 / 2.2	279	4631	222	70.0%	53.9%	65.0%	221	0	0.0%	6	0.3%
11%	1.20 / 15.0 / 2.2	279	4631	222	70.0%	53.9%	65.0%	221	0	0.0%	6	0.3%
11%	0.80 / 15.0 / 2.1	279	4631	222	70.0%	53.9%	65.0%	221	0	0.0%	6	0.3%
11%	1.00 / 15.0 / 2.1	279	4631	222	70.0%	53.9%	65.0%	221	0	0.0%	6	0.3%
11%	1.20 / 15.0 / 2.1	279	4631	222	70.0%	53.9%	65.0%	221	0	0.0%	6	0.3%
11%	0.80 / 20.0 / 2.0	275	4562	225	69.1%	53.1%	65.9%	221	0	0.0%	6	0.3%
11%	1.00 / 20.0 / 2.0	275	4562	225	69.1%	53.1%	65.9%	221	0	0.0%	6	0.3%
11%	1.20 / 20.0 / 2.0	275	4562	225	69.1%	53.1%	65.9%	221	0	0.0%	6	0.3%
11%	0.80 / 18.0 / 2.0	275	4562	225	69.1%	53.1%	65.9%	221	0	0.0%	6	0.3%
11%	1.00 / 18.0 / 2.0	275	4562	225	69.1%	53.1%	65.9%	221	0	0.0%	6	0.3%
11%	1.20 / 18.0 / 2.0	275	4562	225	69.1%	53.1%	65.9%	221	0	0.0%	6	0.3%
12%	0.60 / 15.0 / 1.9	296	4764	249	74.3%	55.5%	72.8%	257	0	0.0%	6	0.3%
12%	0.60 / 15.0 / 2.0	295	4754	238	74.1%	55.4%	69.6%	245	0	0.0%	6	0.3%
12%	0.60 / 15.0 / 2.2	295	4754	235	74.1%	55.4%	68.7%	239	0	0.0%	6	0.3%
12%	0.60 / 15.0 / 2.1	295	4754	235	74.1%	55.4%	68.7%	239	0	0.0%	6	0.3%
12%	0.60 / 20.0 / 1.9	292	4695	249	73.4%	54.7%	72.8%	251	0	0.0%	6	0.3%
12%	0.60 / 18.0 / 1.9	292	4695	249	73.4%	54.7%	72.8%	251	0	0.0%	6	0.3%
12%	0.60 / 20.0 / 2.0	291	4685	238	73.1%	54.5%	69.6%	239	0	0.0%	6	0.3%
12%	0.60 / 18.0 / 2.0	291	4685	238	73.1%	54.5%	69.6%	239	0	0.0%	6	0.3%
12%	0.80 / 15.0 / 1.9	284	4698	246	71.4%	54.7%	71.8%	245	0	0.0%	6	0.3%
12%	1.00 / 15.0 / 1.9	284	4698	246	71.4%	54.7%	71.8%	245	0	0.0%	6	0.3%
12%	1.20 / 15.0 / 1.9	284	4698	246	71.4%	54.7%	71.8%	245	0	0.0%	6	0.3%
12%	0.80 / 20.0 / 1.9	281	4629	246	70.4%	53.9%	71.8%	239	0	0.0%	6	0.3%
12%	1.00 / 20.0 / 1.9	281	4629	246	70.4%	53.9%	71.8%	239	0	0.0%	6	0.3%
12%	1.20 / 20.0 / 1.9	281	4629	246	70.4%	53.9%	71.8%	239	0	0.0%	6	0.3%
12%	0.80 / 18.0 / 1.9	281	4629	246	70.4%	53.9%	71.8%	239	0	0.0%	6	0.3%

* see Section 5 for explanation

Appendix E: ASM Cutpoint Tables

ASM		Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Cutpoints	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
12%	1.00 / 18.0 / 1.9	281	4629	246	70.4%	53.9%	71.8%	239	0	0.0%	6	0.3%
12%	1.20 / 18.0 / 1.9	281	4629	246	70.4%	53.9%	71.8%	239	0	0.0%	6	0.3%
12%	1.00 / 12.0 / 2.5	271	4648	218	68.0%	54.1%	63.6%	257	42	2.0%	6	2.3%
12%	1.20 / 12.0 / 2.5	271	4648	218	68.0%	54.1%	63.6%	257	42	2.0%	6	2.3%
13%	0.60 / 20.0 / 1.7	297	4851	267	74.4%	56.5%	77.9%	275	0	0.0%	6	0.3%
13%	0.60 / 18.0 / 1.7	297	4851	267	74.4%	56.5%	77.9%	275	0	0.0%	6	0.3%
13%	0.80 / 15.0 / 1.7	289	4853	263	72.5%	56.5%	76.8%	269	0	0.0%	6	0.3%
13%	1.00 / 15.0 / 1.7	289	4853	263	72.5%	56.5%	76.8%	269	0	0.0%	6	0.3%
13%	1.20 / 15.0 / 1.7	289	4853	263	72.5%	56.5%	76.8%	269	0	0.0%	6	0.3%
13%	0.80 / 20.0 / 1.7	285	4784	263	71.5%	55.7%	76.8%	263	0	0.0%	6	0.3%
13%	1.00 / 20.0 / 1.7	285	4784	263	71.5%	55.7%	76.8%	263	0	0.0%	6	0.3%
13%	1.20 / 20.0 / 1.7	285	4784	263	71.5%	55.7%	76.8%	263	0	0.0%	6	0.3%
13%	0.80 / 18.0 / 1.7	285	4784	263	71.5%	55.7%	76.8%	263	0	0.0%	6	0.3%
13%	1.00 / 18.0 / 1.7	285	4784	263	71.5%	55.7%	76.8%	263	0	0.0%	6	0.3%
13%	1.20 / 18.0 / 1.7	285	4784	263	71.5%	55.7%	76.8%	263	0	0.0%	6	0.3%
13%	0.80 / 10.0 / 2.5	281	4743	222	70.5%	55.2%	65.0%	269	42	2.0%	6	2.3%
13%	0.80 / 10.0 / 2.4	281	4743	222	70.5%	55.2%	65.0%	269	42	2.0%	6	2.3%
13%	1.00 / 10.0 / 2.4	281	4743	222	70.5%	55.2%	65.0%	269	42	2.0%	6	2.3%
13%	1.20 / 10.0 / 2.4	281	4743	222	70.5%	55.2%	65.0%	269	42	2.0%	6	2.3%
13%	0.80 / 10.0 / 2.2	281	4743	222	70.5%	55.2%	65.0%	275	42	2.0%	6	2.3%
13%	1.00 / 10.0 / 2.2	281	4743	222	70.5%	55.2%	65.0%	275	42	2.0%	6	2.3%
13%	1.20 / 10.0 / 2.2	281	4743	222	70.5%	55.2%	65.0%	275	42	2.0%	6	2.3%
13%	0.80 / 10.0 / 2.1	281	4743	222	70.5%	55.2%	65.0%	275	42	2.0%	6	2.3%
13%	1.00 / 10.0 / 2.1	281	4743	222	70.5%	55.2%	65.0%	275	42	2.0%	6	2.3%
13%	1.20 / 10.0 / 2.1	281	4743	222	70.5%	55.2%	65.0%	275	42	2.0%	6	2.3%
13%	0.80 / 12.0 / 2.0	279	4689	225	70.0%	54.6%	65.9%	275	42	2.0%	6	2.3%
13%	1.00 / 12.0 / 2.0	279	4689	225	70.0%	54.6%	65.9%	275	42	2.0%	6	2.3%
13%	0.80 / 12.0 / 2.0	279	4689	225	70.0%	54.6%	65.9%	275	42	2.0%	6	2.3%
13%	1.00 / 12.0 / 2.0	279	4689	225	70.0%	54.6%	65.9%	275	42	2.0%	6	2.3%
13%	1.20 / 12.0 / 2.0	279	4689	225	70.0%	54.6%	65.9%	275	42	2.0%	6	2.3%
13%	0.80 / 12.0 / 2.5	279	4689	222	70.0%	54.6%	65.0%	263	42	2.0%	6	2.3%
13%	0.80 / 12.0 / 2.4	279	4689	222	70.0%	54.6%	65.0%	263	42	2.0%	6	2.3%
13%	1.00 / 12.0 / 2.4	279	4689	222	70.0%	54.6%	65.0%	263	42	2.0%	6	2.3%
13%	1.20 / 12.0 / 2.4	279	4689	222	70.0%	54.6%	65.0%	263	42	2.0%	6	2.3%
13%	0.80 / 12.0 / 2.2	279	4689	222	70.0%	54.6%	65.0%	269	42	2.0%	6	2.3%

* see Section 5 for explanation

Appendix E: ASM Cutpoint Tables

ASM		Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Cutpoints	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
13%	1.00 / 12.0 / 2.2	279	4689	222	70.0%	54.6%	65.0%	269	42	2.0%	6	2.3%
13%	1.20 / 12.0 / 2.2	279	4689	222	70.0%	54.6%	65.0%	269	42	2.0%	6	2.3%
13%	0.80 / 12.0 / 2.1	279	4689	222	70.0%	54.6%	65.0%	269	42	2.0%	6	2.3%
13%	1.00 / 12.0 / 2.1	279	4689	222	70.0%	54.6%	65.0%	269	42	2.0%	6	2.3%
13%	1.20 / 12.0 / 2.1	279	4689	222	70.0%	54.6%	65.0%	269	42	2.0%	6	2.3%
13%	1.00 / 10.0 / 2.5	273	4702	218	68.5%	54.7%	63.6%	263	42	2.0%	6	2.3%
13%	1.20 / 10.0 / 2.5	273	4702	218	68.5%	54.7%	63.6%	263	42	2.0%	6	2.3%
14%	0.60 / 15.0 / 1.7	300	4920	267	75.4%	57.3%	77.9%	281	0	0.0%	6	0.3%
14%	0.60 / 11.0 / 2.0	297	4866	238	74.5%	56.7%	69.6%	299	42	2.0%	6	2.3%
14%	0.60 / 10.0 / 2.0	297	4866	238	74.5%	56.7%	69.6%	299	42	2.0%	6	2.3%
14%	0.60 / 9.0 / 2.0	297	4866	238	74.5%	56.7%	69.6%	299	42	2.0%	6	2.3%
14%	0.60 / 10.0 / 2.0	297	4866	238	74.5%	56.7%	69.6%	299	42	2.0%	6	2.3%
14%	0.60 / 10.0 / 2.5	297	4866	235	74.5%	56.7%	68.7%	287	42	2.0%	6	2.3%
14%	0.60 / 10.0 / 2.4	297	4866	235	74.5%	56.7%	68.7%	287	42	2.0%	6	2.3%
14%	0.60 / 10.0 / 2.2	297	4866	235	74.5%	56.7%	68.7%	293	42	2.0%	6	2.3%
14%	0.60 / 10.0 / 2.1	297	4866	235	74.5%	56.7%	68.7%	293	42	2.0%	6	2.3%
14%	0.60 / 12.0 / 2.0	295	4812	238	74.1%	56.0%	69.6%	293	42	2.0%	6	2.3%
14%	0.60 / 12.0 / 2.0	295	4812	238	74.1%	56.0%	69.6%	293	42	2.0%	6	2.3%
14%	0.60 / 12.0 / 2.5	295	4812	235	74.1%	56.0%	68.7%	281	42	2.0%	6	2.3%
14%	0.60 / 12.0 / 2.4	295	4812	235	74.1%	56.0%	68.7%	281	42	2.0%	6	2.3%
14%	0.60 / 12.0 / 2.2	295	4812	235	74.1%	56.0%	68.7%	287	42	2.0%	6	2.3%
14%	0.60 / 12.0 / 2.1	295	4812	235	74.1%	56.0%	68.7%	287	42	2.0%	6	2.3%
14%	0.80 / 11.0 / 1.8	286	4810	246	71.8%	56.0%	71.8%	299	42	2.0%	6	2.3%
14%	1.00 / 11.0 / 1.8	286	4810	246	71.8%	56.0%	71.8%	299	42	2.0%	6	2.3%
14%	0.80 / 10.0 / 1.8	286	4810	246	71.8%	56.0%	71.8%	299	42	2.0%	6	2.3%
14%	1.00 / 10.0 / 1.8	286	4810	246	71.8%	56.0%	71.8%	299	42	2.0%	6	2.3%
14%	0.80 / 9.0 / 1.8	286	4810	246	71.8%	56.0%	71.8%	299	42	2.0%	6	2.3%
14%	1.00 / 9.0 / 1.8	286	4810	246	71.8%	56.0%	71.8%	299	42	2.0%	6	2.3%
14%	0.80 / 10.0 / 1.9	286	4810	246	71.8%	56.0%	71.8%	299	42	2.0%	6	2.3%
14%	1.00 / 10.0 / 1.9	286	4810	246	71.8%	56.0%	71.8%	299	42	2.0%	6	2.3%
14%	1.20 / 10.0 / 1.9	286	4810	246	71.8%	56.0%	71.8%	299	42	2.0%	6	2.3%
14%	0.80 / 12.0 / 1.8	284	4756	246	71.4%	55.4%	71.8%	293	42	2.0%	6	2.3%
14%	1.00 / 12.0 / 1.8	284	4756	246	71.4%	55.4%	71.8%	293	42	2.0%	6	2.3%
14%	0.80 / 12.0 / 1.9	284	4756	246	71.4%	55.4%	71.8%	293	42	2.0%	6	2.3%
14%	1.00 / 12.0 / 1.9	284	4756	246	71.4%	55.4%	71.8%	293	42	2.0%	6	2.3%

* see Section 5 for explanation

Appendix E: ASM Cutpoint Tables

ASM		Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Cutpoints	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
14%	1.20 / 12.0 / 1.9	284	4756	246	71.4%	55.4%	71.8%	293	42	2.0%	6	2.3%
14%	0.80 / 11.0 / 2.0	281	4743	225	70.5%	55.2%	65.9%	281	42	2.0%	6	2.3%
14%	1.00 / 11.0 / 2.0	281	4743	225	70.5%	55.2%	65.9%	281	42	2.0%	6	2.3%
14%	0.80 / 10.0 / 2.0	281	4743	225	70.5%	55.2%	65.9%	281	42	2.0%	6	2.3%
14%	1.00 / 10.0 / 2.0	281	4743	225	70.5%	55.2%	65.9%	281	42	2.0%	6	2.3%
14%	0.80 / 9.0 / 2.0	281	4743	225	70.5%	55.2%	65.9%	281	42	2.0%	6	2.3%
14%	1.00 / 9.0 / 2.0	281	4743	225	70.5%	55.2%	65.9%	281	42	2.0%	6	2.3%
14%	0.80 / 10.0 / 2.0	281	4743	225	70.5%	55.2%	65.9%	281	42	2.0%	6	2.3%
14%	1.00 / 10.0 / 2.0	281	4743	225	70.5%	55.2%	65.9%	281	42	2.0%	6	2.3%
14%	1.20 / 10.0 / 2.0	281	4743	225	70.5%	55.2%	65.9%	281	42	2.0%	6	2.3%
15%	0.60 / 11.0 / 1.8	298	4876	249	74.8%	56.8%	72.8%	311	42	2.0%	6	2.3%
15%	0.60 / 10.0 / 1.8	298	4876	249	74.8%	56.8%	72.8%	311	42	2.0%	6	2.3%
15%	0.60 / 9.0 / 1.8	298	4876	249	74.8%	56.8%	72.8%	311	42	2.0%	6	2.3%
15%	0.60 / 10.0 / 1.9	298	4876	249	74.8%	56.8%	72.8%	311	42	2.0%	6	2.3%
15%	0.60 / 12.0 / 1.8	296	4822	249	74.3%	56.1%	72.8%	305	42	2.0%	6	2.3%
15%	0.60 / 12.0 / 1.9	296	4822	249	74.3%	56.1%	72.8%	305	42	2.0%	6	2.3%
15%	0.80 / 12.0 / 1.7	289	4911	263	72.5%	57.2%	76.8%	317	42	2.0%	6	2.3%
15%	1.00 / 12.0 / 1.7	289	4911	263	72.5%	57.2%	76.8%	317	42	2.0%	6	2.3%
15%	1.20 / 12.0 / 1.7	289	4911	263	72.5%	57.2%	76.8%	317	42	2.0%	6	2.3%
16%	0.60 / 10.0 / 1.7	302	5032	267	75.8%	58.6%	77.9%	335	42	2.0%	6	2.3%
16%	0.60 / 12.0 / 1.7	300	4978	267	75.4%	58.0%	77.9%	329	42	2.0%	6	2.3%
16%	0.80 / 10.0 / 1.7	291	4965	263	72.9%	57.8%	76.8%	323	42	2.0%	6	2.3%
16%	1.00 / 10.0 / 1.7	291	4965	263	72.9%	57.8%	76.8%	323	42	2.0%	6	2.3%
16%	1.20 / 10.0 / 1.7	291	4965	263	72.9%	57.8%	76.8%	323	42	2.0%	6	2.3%
18%	0.80 / 8.0 / 2.0	298	5251	233	74.7%	61.1%	68.0%	377	42	2.0%	6	2.3%
18%	1.00 / 8.0 / 2.0	298	5251	233	74.7%	61.1%	68.0%	377	42	2.0%	6	2.3%
19%	0.40 / 20.0 / 2.0	316	5100	241	79.4%	59.4%	70.3%	400	6	0.3%	6	0.6%
19%	0.40 / 18.0 / 2.0	316	5100	241	79.4%	59.4%	70.3%	400	6	0.3%	6	0.6%
19%	0.40 / 15.0 / 2.0	316	5100	241	79.4%	59.4%	70.3%	400	6	0.3%	6	0.6%
19%	0.40 / 20.0 / 2.5	316	5100	237	79.4%	59.4%	69.4%	388	6	0.3%	6	0.6%
19%	0.40 / 18.0 / 2.5	316	5100	237	79.4%	59.4%	69.4%	388	6	0.3%	6	0.6%
19%	0.40 / 15.0 / 2.5	316	5100	237	79.4%	59.4%	69.4%	388	6	0.3%	6	0.6%
19%	0.40 / 20.0 / 2.4	316	5100	237	79.4%	59.4%	69.4%	388	6	0.3%	6	0.6%
19%	0.40 / 18.0 / 2.4	316	5100	237	79.4%	59.4%	69.4%	388	6	0.3%	6	0.6%
19%	0.40 / 15.0 / 2.4	316	5100	237	79.4%	59.4%	69.4%	388	6	0.3%	6	0.6%

* see Section 5 for explanation

Appendix E: ASM Cutpoint Tables

ASM Failure Rate	Cutpoints	Excess Emissions Identified			Identification Rates			Fails	Errors of Commission	Ec Rate*	Discrepant Failures	Probable Ec Rate
		HC	CO	NOx	HC	CO	NOx					
19%	0.40 / 20.0 / 2.2	316	5100	237	79.4%	59.4%	69.4%	394	6	0.3%	6	0.6%
19%	0.40 / 18.0 / 2.2	316	5100	237	79.4%	59.4%	69.4%	394	6	0.3%	6	0.6%
19%	0.40 / 15.0 / 2.2	316	5100	237	79.4%	59.4%	69.4%	394	6	0.3%	6	0.6%
19%	0.40 / 20.0 / 2.1	316	5100	237	79.4%	59.4%	69.4%	394	6	0.3%	6	0.6%
19%	0.40 / 18.0 / 2.1	316	5100	237	79.4%	59.4%	69.4%	394	6	0.3%	6	0.6%
19%	0.40 / 15.0 / 2.1	316	5100	237	79.4%	59.4%	69.4%	394	6	0.3%	6	0.6%
19%	0.60 / 8.0 / 2.0	314	5375	245	78.7%	62.6%	71.7%	394	42	2.0%	6	2.3%
19%	0.60 / 11.0 / 1.5	313	5282	274	78.5%	61.5%	80.1%	400	42	2.0%	48	4.3%
19%	0.60 / 10.0 / 1.5	313	5282	274	78.5%	61.5%	80.1%	400	42	2.0%	48	4.3%
19%	0.60 / 9.0 / 1.5	313	5282	274	78.5%	61.5%	80.1%	400	42	2.0%	48	4.3%
19%	0.60 / 12.0 / 1.5	311	5228	274	78.0%	60.9%	80.1%	394	42	2.0%	48	4.3%
19%	0.80 / 11.0 / 1.5	306	5272	274	76.8%	61.4%	80.0%	394	42	2.0%	48	4.3%
19%	1.00 / 11.0 / 1.5	306	5272	274	76.8%	61.4%	80.0%	394	42	2.0%	48	4.3%
19%	0.80 / 10.0 / 1.5	306	5272	274	76.8%	61.4%	80.0%	394	42	2.0%	48	4.3%
19%	1.00 / 10.0 / 1.5	306	5272	274	76.8%	61.4%	80.0%	394	42	2.0%	48	4.3%
19%	0.80 / 9.0 / 1.5	306	5272	274	76.8%	61.4%	80.0%	394	42	2.0%	48	4.3%
19%	1.00 / 9.0 / 1.5	306	5272	274	76.8%	61.4%	80.0%	394	42	2.0%	48	4.3%
19%	0.80 / 12.0 / 1.5	304	5218	274	76.3%	60.8%	80.0%	388	42	2.0%	48	4.3%
19%	1.00 / 12.0 / 1.5	304	5218	274	76.3%	60.8%	80.0%	388	42	2.0%	48	4.3%
19%	0.80 / 8.0 / 1.8	303	5318	253	76.0%	61.9%	73.9%	394	42	2.0%	6	2.3%
19%	1.00 / 8.0 / 1.8	303	5318	253	76.0%	61.9%	73.9%	394	42	2.0%	6	2.3%
20%	0.40 / 20.0 / 1.9	317	5110	252	79.6%	59.5%	73.5%	412	6	0.3%	6	0.6%
20%	0.40 / 18.0 / 1.9	317	5110	252	79.6%	59.5%	73.5%	412	6	0.3%	6	0.6%
20%	0.40 / 15.0 / 1.9	317	5110	252	79.6%	59.5%	73.5%	412	6	0.3%	6	0.6%
20%	0.60 / 8.0 / 1.8	315	5385	257	78.9%	62.7%	75.0%	406	42	2.0%	6	2.3%
21%	0.40 / 20.0 / 1.7	321	5266	269	80.7%	61.3%	78.6%	436	6	0.3%	6	0.6%
21%	0.40 / 18.0 / 1.7	321	5266	269	80.7%	61.3%	78.6%	436	6	0.3%	6	0.6%
21%	0.40 / 15.0 / 1.7	321	5266	269	80.7%	61.3%	78.6%	436	6	0.3%	6	0.6%
21%	0.40 / 10.0 / 2.5	318	5212	237	79.8%	60.7%	69.4%	442	48	2.3%	6	2.6%
21%	0.40 / 10.0 / 2.4	318	5212	237	79.8%	60.7%	69.4%	442	48	2.3%	6	2.6%
21%	0.40 / 12.0 / 2.5	316	5158	237	79.4%	60.1%	69.4%	436	48	2.3%	6	2.6%
21%	0.40 / 12.0 / 2.4	316	5158	237	79.4%	60.1%	69.4%	436	48	2.3%	6	2.6%
21%	0.40 / 12.0 / 2.2	316	5158	237	79.4%	60.1%	69.4%	442	48	2.3%	6	2.6%
21%	0.40 / 12.0 / 2.1	316	5158	237	79.4%	60.1%	69.4%	442	48	2.3%	6	2.6%
22%	0.40 / 11.0 / 2.0	318	5212	241	79.8%	60.7%	70.3%	454	48	2.3%	6	2.6%

* see Section 5 for explanation

Appendix E: ASM Cutpoint Tables

ASM Failure Rate	Cutpoints	Excess Emissions Identified			Identification Rates			Fails	Errors of Commission	Ec Rate*	Discrepant Failures	Probable Ec Rate
		HC	CO	NOx	HC	CO	NOx					
22%	0.40 / 10.0 / 2.0	318	5212	241	79.8%	60.7%	70.3%	454	48	2.3%	6	2.6%
22%	0.40 / 9.0 / 2.0	318	5212	241	79.8%	60.7%	70.3%	454	48	2.3%	6	2.6%
22%	0.40 / 10.0 / 2.0	318	5212	241	79.8%	60.7%	70.3%	454	48	2.3%	6	2.6%
22%	0.40 / 10.0 / 2.2	318	5212	237	79.8%	60.7%	69.4%	448	48	2.3%	6	2.6%
22%	0.40 / 10.0 / 2.1	318	5212	237	79.8%	60.7%	69.4%	448	48	2.3%	6	2.6%
22%	0.40 / 12.0 / 1.8	317	5168	252	79.6%	60.2%	73.5%	460	48	2.3%	6	2.6%
22%	0.40 / 12.0 / 1.9	317	5168	252	79.6%	60.2%	73.5%	460	48	2.3%	6	2.6%
22%	0.40 / 12.0 / 2.0	316	5158	241	79.4%	60.1%	70.3%	448	48	2.3%	6	2.6%
22%	0.40 / 12.0 / 2.0	316	5158	241	79.4%	60.1%	70.3%	448	48	2.3%	6	2.6%
23%	0.60 / 8.0 / 1.5	324	5659	274	81.2%	65.9%	80.1%	484	42	2.0%	48	4.3%
23%	0.40 / 12.0 / 1.7	321	5323	269	80.7%	62.0%	78.6%	484	48	2.3%	6	2.6%
23%	0.40 / 11.0 / 1.8	319	5222	252	80.1%	60.8%	73.5%	466	48	2.3%	6	2.6%
23%	0.40 / 10.0 / 1.8	319	5222	252	80.1%	60.8%	73.5%	466	48	2.3%	6	2.6%
23%	0.40 / 9.0 / 1.8	319	5222	252	80.1%	60.8%	73.5%	466	48	2.3%	6	2.6%
23%	0.40 / 10.0 / 1.9	319	5222	252	80.1%	60.8%	73.5%	466	48	2.3%	6	2.6%
23%	0.80 / 8.0 / 1.5	317	5649	274	79.5%	65.8%	80.0%	478	42	2.0%	48	4.3%
23%	1.00 / 8.0 / 1.5	317	5649	274	79.5%	65.8%	80.0%	478	42	2.0%	48	4.3%
24%	0.60 / 11.0 / 1.4	327	5694	306	82.1%	66.3%	89.5%	502	84	4.0%	48	6.4%
24%	0.60 / 10.0 / 1.4	327	5694	306	82.1%	66.3%	89.5%	502	84	4.0%	48	6.4%
24%	0.60 / 9.0 / 1.4	327	5694	306	82.1%	66.3%	89.5%	502	84	4.0%	48	6.4%
24%	0.60 / 12.0 / 1.4	325	5640	306	81.6%	65.7%	89.5%	496	84	4.0%	48	6.4%
24%	0.40 / 8.0 / 2.0	324	5572	246	81.4%	64.9%	71.8%	502	48	2.3%	6	2.6%
24%	0.40 / 10.0 / 1.7	323	5377	269	81.1%	62.6%	78.6%	490	48	2.3%	6	2.6%
24%	0.80 / 11.0 / 1.4	320	5684	306	80.4%	66.2%	89.4%	496	84	4.0%	48	6.4%
24%	1.00 / 11.0 / 1.4	320	5684	306	80.4%	66.2%	89.4%	496	84	4.0%	48	6.4%
24%	0.80 / 10.0 / 1.4	320	5684	306	80.4%	66.2%	89.4%	496	84	4.0%	48	6.4%
24%	1.00 / 10.0 / 1.4	320	5684	306	80.4%	66.2%	89.4%	496	84	4.0%	48	6.4%
24%	0.80 / 9.0 / 1.4	320	5684	306	80.4%	66.2%	89.4%	496	84	4.0%	48	6.4%
24%	1.00 / 9.0 / 1.4	320	5684	306	80.4%	66.2%	89.4%	496	84	4.0%	48	6.4%
24%	0.80 / 12.0 / 1.4	318	5630	306	79.9%	65.5%	89.4%	490	84	4.0%	48	6.4%
24%	1.00 / 12.0 / 1.4	318	5630	306	79.9%	65.5%	89.4%	490	84	4.0%	48	6.4%
25%	0.40 / 8.0 / 1.8	325	5582	257	81.6%	65.0%	75.1%	514	48	2.3%	6	2.6%
26%	0.60 / 11.0 / 1.3	327	5706	306	82.1%	66.4%	89.5%	544	84	4.0%	90	8.4%
26%	0.60 / 10.0 / 1.3	327	5706	306	82.1%	66.4%	89.5%	544	84	4.0%	90	8.4%
26%	0.60 / 9.0 / 1.3	327	5706	306	82.1%	66.4%	89.5%	544	84	4.0%	90	8.4%

* see Section 5 for explanation

Appendix E: ASM Cutpoint Tables

ASM		Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Cutpoints	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
26%	0.60 / 12.0 / 1.3	325	5652	306	81.6%	65.8%	89.5%	538	84	4.0%	90	8.4%
26%	0.40 / 11.0 / 1.5	324	5472	274	81.4%	63.7%	80.1%	544	48	2.3%	48	4.6%
26%	0.40 / 10.0 / 1.5	324	5472	274	81.4%	63.7%	80.1%	544	48	2.3%	48	4.6%
26%	0.40 / 9.0 / 1.5	324	5472	274	81.4%	63.7%	80.1%	544	48	2.3%	48	4.6%
26%	0.40 / 12.0 / 1.5	323	5418	274	80.9%	63.1%	80.1%	538	48	2.3%	48	4.6%
26%	0.80 / 11.0 / 1.3	320	5696	306	80.4%	66.3%	89.4%	538	84	4.0%	90	8.4%
26%	1.00 / 11.0 / 1.3	320	5696	306	80.4%	66.3%	89.4%	538	84	4.0%	90	8.4%
26%	0.80 / 10.0 / 1.3	320	5696	306	80.4%	66.3%	89.4%	538	84	4.0%	90	8.4%
26%	1.00 / 10.0 / 1.3	320	5696	306	80.4%	66.3%	89.4%	538	84	4.0%	90	8.4%
26%	0.80 / 9.0 / 1.3	320	5696	306	80.4%	66.3%	89.4%	538	84	4.0%	90	8.4%
26%	1.00 / 9.0 / 1.3	320	5696	306	80.4%	66.3%	89.4%	538	84	4.0%	90	8.4%
26%	0.80 / 12.0 / 1.3	318	5642	306	79.9%	65.7%	89.4%	532	84	4.0%	90	8.4%
26%	1.00 / 12.0 / 1.3	318	5642	306	79.9%	65.7%	89.4%	532	84	4.0%	90	8.4%
27%	0.30 / 12.0 / 1.8	345	5594	262	86.6%	65.1%	76.7%	568	90	4.3%	0	4.3%
27%	0.30 / 11.0 / 1.8	345	5594	262	86.6%	65.1%	76.7%	568	90	4.3%	0	4.3%
27%	0.30 / 10.0 / 1.8	345	5594	262	86.6%	65.1%	76.7%	568	90	4.3%	0	4.3%
27%	0.30 / 9.0 / 1.8	345	5594	262	86.6%	65.1%	76.7%	568	90	4.3%	0	4.3%
27%	0.30 / 12.0 / 2.0	344	5584	251	86.4%	65.0%	73.4%	556	90	4.3%	0	4.3%
27%	0.30 / 11.0 / 2.0	344	5584	251	86.4%	65.0%	73.4%	556	90	4.3%	0	4.3%
27%	0.30 / 10.0 / 2.0	344	5584	251	86.4%	65.0%	73.4%	556	90	4.3%	0	4.3%
27%	0.30 / 9.0 / 2.0	344	5584	251	86.4%	65.0%	73.4%	556	90	4.3%	0	4.3%
28%	0.60 / 8.0 / 1.4	338	6071	306	84.8%	70.7%	89.5%	586	84	4.0%	48	6.4%
28%	0.80 / 8.0 / 1.4	331	6061	306	83.1%	70.6%	89.4%	580	84	4.0%	48	6.4%
28%	1.00 / 8.0 / 1.4	331	6061	306	83.1%	70.6%	89.4%	580	84	4.0%	48	6.4%
28%	0.60 / 12.0 / 1.2	329	5753	308	82.7%	67.0%	89.9%	586	84	4.0%	132	10.4%
28%	0.40 / 8.0 / 1.5	329	5755	274	82.5%	67.0%	80.1%	586	48	2.3%	48	4.6%
28%	0.80 / 11.0 / 1.2	324	5797	308	81.4%	67.5%	89.8%	586	84	4.0%	132	10.4%
28%	1.00 / 11.0 / 1.2	324	5797	308	81.4%	67.5%	89.8%	586	84	4.0%	132	10.4%
28%	0.80 / 10.0 / 1.2	324	5797	308	81.4%	67.5%	89.8%	586	84	4.0%	132	10.4%
28%	1.00 / 10.0 / 1.2	324	5797	308	81.4%	67.5%	89.8%	586	84	4.0%	132	10.4%
28%	0.80 / 9.0 / 1.2	324	5797	308	81.4%	67.5%	89.8%	586	84	4.0%	132	10.4%
28%	1.00 / 9.0 / 1.2	324	5797	308	81.4%	67.5%	89.8%	586	84	4.0%	132	10.4%
28%	0.80 / 12.0 / 1.2	323	5743	308	80.9%	66.9%	89.8%	580	84	4.0%	132	10.4%
28%	1.00 / 12.0 / 1.2	323	5743	308	80.9%	66.9%	89.8%	580	84	4.0%	132	10.4%
29%	0.30 / 8.0 / 2.0	351	5943	256	88.0%	69.2%	74.9%	604	90	4.3%	0	4.3%

* see Section 5 for explanation

Appendix E: ASM Cutpoint Tables

ASM		Excess Emissions Identified			Identification Rates				Errors of		Discrepant	Probable
Failure Rate	Cutpoints	HC	CO	NOx	HC	CO	NOx	Fails	Commission	Ec Rate*	Failures	Ec Rate
29%	0.60 / 11.0 / 1.2	331	5807	308	83.1%	67.6%	89.9%	592	84	4.0%	132	10.4%
29%	0.60 / 10.0 / 1.2	331	5807	308	83.1%	67.6%	89.9%	592	84	4.0%	132	10.4%
29%	0.60 / 9.0 / 1.2	331	5807	308	83.1%	67.6%	89.9%	592	84	4.0%	132	10.4%
30%	0.30 / 8.0 / 1.8	351	5953	268	88.2%	69.3%	78.2%	616	90	4.3%	0	4.3%
30%	0.60 / 8.0 / 1.3	338	6083	306	84.8%	70.8%	89.5%	628	84	4.0%	90	8.4%
30%	0.80 / 8.0 / 1.3	331	6073	306	83.1%	70.7%	89.4%	622	84	4.0%	90	8.4%
30%	1.00 / 8.0 / 1.3	331	6073	306	83.1%	70.7%	89.4%	622	84	4.0%	90	8.4%
31%	0.30 / 12.0 / 1.5	351	5813	283	88.0%	67.7%	82.7%	640	90	4.3%	42	6.4%
31%	0.30 / 11.0 / 1.5	351	5813	283	88.0%	67.7%	82.7%	640	90	4.3%	42	6.4%
31%	0.30 / 10.0 / 1.5	351	5813	283	88.0%	67.7%	82.7%	640	90	4.3%	42	6.4%
31%	0.30 / 9.0 / 1.5	351	5813	283	88.0%	67.7%	82.7%	640	90	4.3%	42	6.4%
31%	0.40 / 11.0 / 1.4	339	5885	306	85.0%	68.5%	89.5%	646	90	4.3%	48	6.6%
31%	0.40 / 10.0 / 1.4	339	5885	306	85.0%	68.5%	89.5%	646	90	4.3%	48	6.6%
31%	0.40 / 9.0 / 1.4	339	5885	306	85.0%	68.5%	89.5%	646	90	4.3%	48	6.6%
31%	0.40 / 12.0 / 1.4	337	5830	306	84.5%	67.9%	89.5%	640	90	4.3%	48	6.6%
32%	0.80 / 8.0 / 1.2	335	6174	308	84.1%	71.9%	89.8%	670	84	4.0%	132	10.4%
32%	1.00 / 8.0 / 1.2	335	6174	308	84.1%	71.9%	89.8%	670	84	4.0%	132	10.4%
33%	0.30 / 8.0 / 1.5	355	6096	283	89.0%	71.0%	82.7%	682	90	4.3%	42	6.4%
33%	0.40 / 8.0 / 1.4	343	6167	306	86.1%	71.8%	89.5%	688	90	4.3%	48	6.6%
33%	0.60 / 8.0 / 1.2	342	6184	308	85.8%	72.0%	89.9%	676	84	4.0%	132	10.4%
33%	0.40 / 11.0 / 1.3	339	5897	306	85.0%	68.7%	89.5%	688	90	4.3%	90	8.7%
33%	0.40 / 10.0 / 1.3	339	5897	306	85.0%	68.7%	89.5%	688	90	4.3%	90	8.7%
33%	0.40 / 9.0 / 1.3	339	5897	306	85.0%	68.7%	89.5%	688	90	4.3%	90	8.7%
33%	0.40 / 12.0 / 1.3	337	5843	306	84.5%	68.0%	89.5%	682	90	4.3%	90	8.7%
35%	0.40 / 8.0 / 1.3	343	6180	306	86.1%	71.9%	89.5%	729	90	4.3%	90	8.7%
35%	0.40 / 12.0 / 1.2	341	5943	308	85.6%	69.2%	89.9%	729	90	4.3%	132	10.7%
36%	0.30 / 12.0 / 1.4	356	6167	306	89.3%	71.8%	89.5%	735	132	6.4%	42	8.4%
36%	0.30 / 11.0 / 1.4	356	6167	306	89.3%	71.8%	89.5%	735	132	6.4%	42	8.4%
36%	0.30 / 10.0 / 1.4	356	6167	306	89.3%	71.8%	89.5%	735	132	6.4%	42	8.4%
36%	0.30 / 9.0 / 1.4	356	6167	306	89.3%	71.8%	89.5%	735	132	6.4%	42	8.4%
36%	0.40 / 11.0 / 1.2	343	5997	308	86.1%	69.8%	89.9%	735	90	4.3%	132	10.7%
36%	0.40 / 10.0 / 1.2	343	5997	308	86.1%	69.8%	89.9%	735	90	4.3%	132	10.7%
36%	0.40 / 9.0 / 1.2	343	5997	308	86.1%	69.8%	89.9%	735	90	4.3%	132	10.7%
38%	0.30 / 8.0 / 1.4	360	6450	306	90.3%	75.1%	89.5%	777	132	6.4%	42	8.4%
38%	0.30 / 12.0 / 1.3	356	6179	306	89.3%	71.9%	89.5%	777	132	6.4%	84	10.4%

* see Section 5 for explanation

Appendix E: ASM Cutpoint Tables

ASM Failure Rate	Cutpoints	Excess Emissions Identified			Identification Rates			Fails	Errors of Commission	Ec Rate*	Discrepant Failures	Probable Ec Rate
		HC	CO	NOx	HC	CO	NOx					
38%	0.30 / 11.0 / 1.3	356	6179	306	89.3%	71.9%	89.5%	777	132	6.4%	84	10.4%
38%	0.30 / 10.0 / 1.3	356	6179	306	89.3%	71.9%	89.5%	777	132	6.4%	84	10.4%
38%	0.30 / 9.0 / 1.3	356	6179	306	89.3%	71.9%	89.5%	777	132	6.4%	84	10.4%
38%	0.40 / 8.0 / 1.2	347	6280	308	87.1%	73.1%	89.9%	777	90	4.3%	132	10.7%
40%	0.60 / 11.0 / 1.0	364	6429	325	91.3%	74.9%	95.0%	837	174	8.4%	221	19.1%
40%	0.80 / 11.0 / 1.0	364	6429	325	91.3%	74.9%	95.0%	837	174	8.4%	221	19.1%
40%	1.00 / 11.0 / 1.0	364	6429	325	91.3%	74.9%	95.0%	837	174	8.4%	221	19.1%
40%	0.60 / 10.0 / 1.0	364	6429	325	91.3%	74.9%	95.0%	837	174	8.4%	221	19.1%
40%	0.80 / 10.0 / 1.0	364	6429	325	91.3%	74.9%	95.0%	837	174	8.4%	221	19.1%
40%	1.00 / 10.0 / 1.0	364	6429	325	91.3%	74.9%	95.0%	837	174	8.4%	221	19.1%
40%	0.60 / 9.0 / 1.0	364	6429	325	91.3%	74.9%	95.0%	837	174	8.4%	221	19.1%
40%	0.80 / 9.0 / 1.0	364	6429	325	91.3%	74.9%	95.0%	837	174	8.4%	221	19.1%
40%	1.00 / 9.0 / 1.0	364	6429	325	91.3%	74.9%	95.0%	837	174	8.4%	221	19.1%
40%	0.60 / 12.0 / 1.0	362	6375	325	90.9%	74.2%	95.0%	831	174	8.4%	221	19.1%
40%	0.80 / 12.0 / 1.0	362	6375	325	90.9%	74.2%	95.0%	831	174	8.4%	221	19.1%
40%	1.00 / 12.0 / 1.0	362	6375	325	90.9%	74.2%	95.0%	831	174	8.4%	221	19.1%
40%	0.30 / 12.0 / 1.2	360	6280	308	90.3%	73.1%	89.9%	825	132	6.4%	126	12.4%
40%	0.30 / 11.0 / 1.2	360	6280	308	90.3%	73.1%	89.9%	825	132	6.4%	126	12.4%
40%	0.30 / 10.0 / 1.2	360	6280	308	90.3%	73.1%	89.9%	825	132	6.4%	126	12.4%
40%	0.30 / 9.0 / 1.2	360	6280	308	90.3%	73.1%	89.9%	825	132	6.4%	126	12.4%
40%	0.30 / 8.0 / 1.3	360	6462	306	90.3%	75.2%	89.5%	819	132	6.4%	84	10.4%
42%	0.60 / 8.0 / 1.0	368	6712	325	92.4%	78.1%	95.0%	879	174	8.4%	180	17.1%
42%	0.80 / 8.0 / 1.0	368	6712	325	92.4%	78.1%	95.0%	879	174	8.4%	180	17.1%
42%	1.00 / 8.0 / 1.0	368	6712	325	92.4%	78.1%	95.0%	879	174	8.4%	180	17.1%
42%	0.30 / 8.0 / 1.2	364	6562	308	91.4%	76.4%	89.9%	867	132	6.4%	126	12.4%
43%	0.40 / 11.0 / 1.0	364	6485	325	91.3%	75.5%	95.0%	897	180	8.7%	138	15.3%
43%	0.40 / 10.0 / 1.0	364	6485	325	91.3%	75.5%	95.0%	897	180	8.7%	138	15.3%
43%	0.40 / 9.0 / 1.0	364	6485	325	91.3%	75.5%	95.0%	897	180	8.7%	138	15.3%
43%	0.40 / 12.0 / 1.0	362	6431	325	90.9%	74.9%	95.0%	891	180	8.7%	138	15.3%
45%	0.40 / 8.0 / 1.0	368	6768	325	92.4%	78.8%	95.0%	939	180	8.7%	138	15.3%
46%	0.30 / 12.0 / 1.0	381	6767	325	95.6%	78.8%	95.0%	945	180	8.7%	132	15.0%
46%	0.30 / 11.0 / 1.0	381	6767	325	95.6%	78.8%	95.0%	945	180	8.7%	132	15.0%
46%	0.30 / 10.0 / 1.0	381	6767	325	95.6%	78.8%	95.0%	945	180	8.7%	132	15.0%
46%	0.30 / 9.0 / 1.0	381	6767	325	95.6%	78.8%	95.0%	945	180	8.7%	132	15.0%
48%	0.30 / 8.0 / 1.0	385	7050	325	96.6%	82.1%	95.0%	987	180	8.7%	132	15.0%

* see Section 5 for explanation

Appendix F

Scatter Plots and Regression Tables

Table F-1
Regression Tables
All Vehicles

```
Dependent Variable is:  HC FTP
    R^2 = 81.9%
s = 0.6266  with  106 - 2 = 104  DOF

Standard Error:  0.62 g/mi

Source       Sum of Squares
Regression      184.815
Residual         40.839


Variable      Coefficient          s.e. of Coeff
Constant         -0.118               0.078
HC IM240          1.318               0.061
```

```
Dependent Variable is:  HC FTP
    R^2 = 73.4%
s = 0.7602  with  106 - 2 = 104  DOF

Standard Error:  0.76 g/mi

Source       Sum of Squares
Regression      165.550
Residual         60.103


Variable      Coefficient          s.e. of Coeff
Constant         -0.056               0.094
HC ASM            2.264               0.134
```

```
Dependent Variable is:  CO FTP
    R^2 = 54.2%
s = 13.47  with  106 - 2 = 104  DOF

Standard Error:  13.4 g/mi

Source       Sum of Squares
Regression     22318.900
Residual       18857.200


Variable      Coefficient          s.e. of Coeff
Constant          2.625               1.609
CO IM240          0.929               0.084
```

```
Dependent Variable is:  CO FTP
    R^2 = 67.9%
s = 11.27  with  106 - 2 = 104  DOF

Standard Error:  11.2 g/mi

Source       Sum of Squares
Regression     27959.200
Residual       13216.900


Variable      Coefficient          s.e. of Coeff
Constant          3.358               1.274
CO ASM            0.970               0.065
```

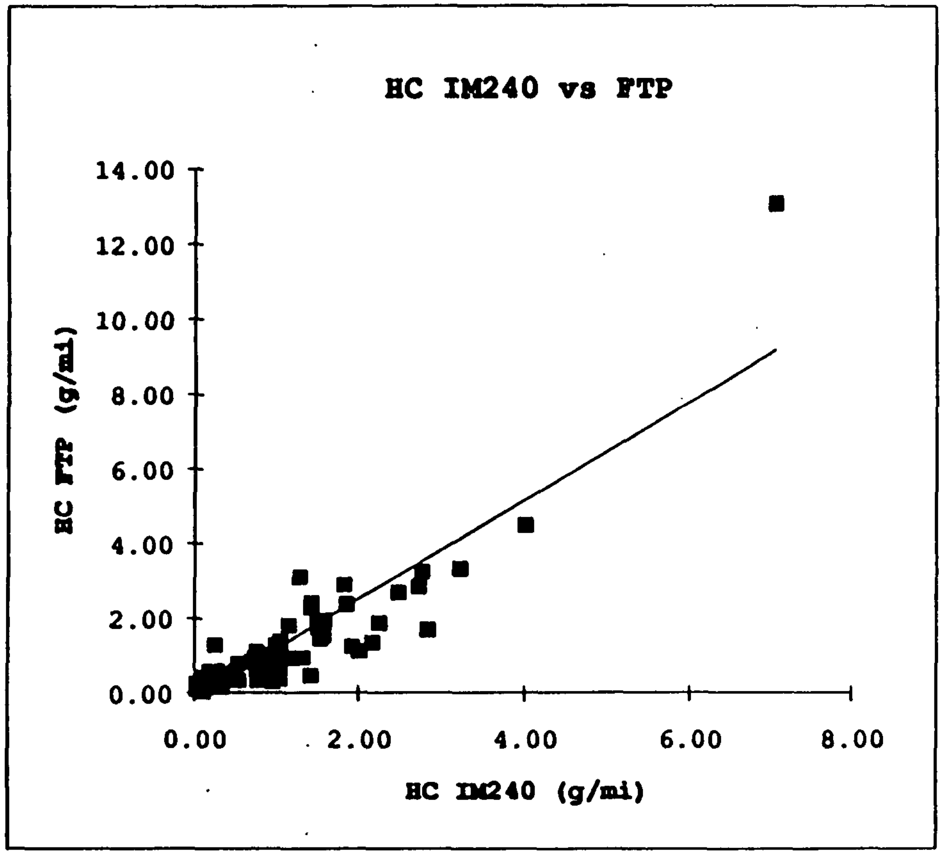
```
Dependent Variable is:  NOx FTP
    R^2 = 69.7%
s = 0.6570  with  106 - 2 = 104  DOF

Standard Error:  0.65 g/mi

Source       Sum of Squares
Regression      103.202
Residual         44.889


Variable      Coefficient          s.e. of Coeff
Constant         -0.046               0.104
NOx IM240         0.724               0.047
```

```
Dependent Variable is:  NOx FTP
    R^2 = 71.4%
s = 0.6386  with  106 - 2 = 104  DOF

Standard Error:  0.64 g/mi

Source       Sum of Squares
Regression      105.685
Residual         42.406


Variable      Coefficient          s.e. of Coeff
Constant         -0.002               0.098
NOx ASM           0.831               0.052
```

Figure F-1

HC Scatterplots

All Vehicles



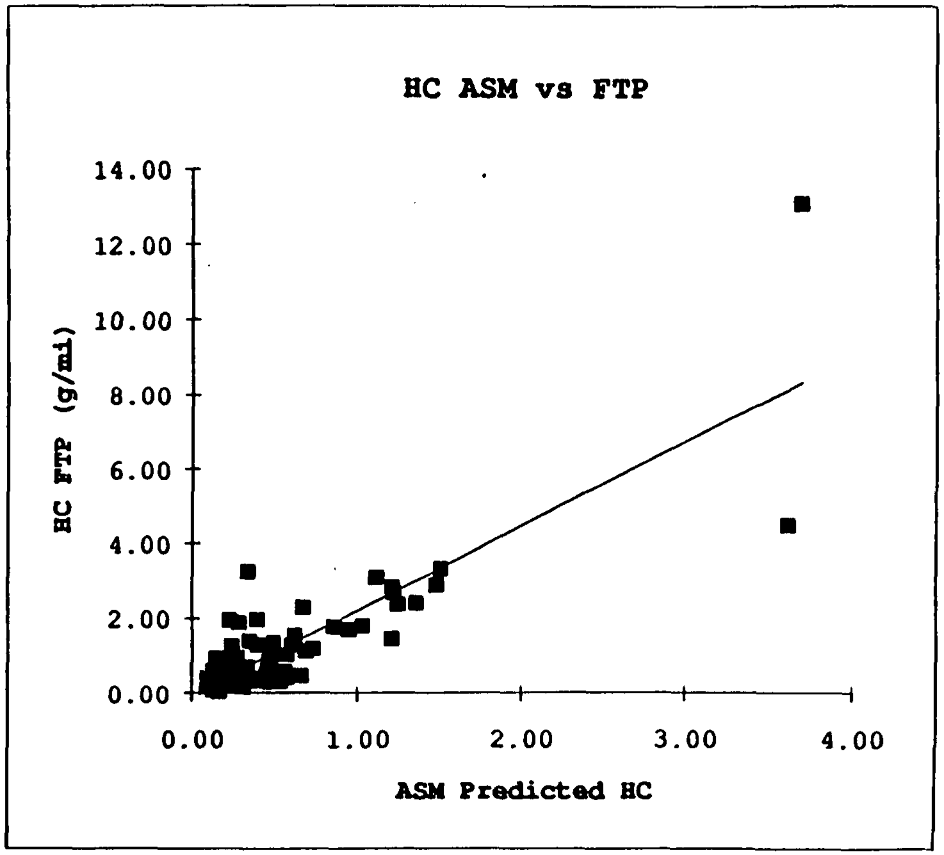


Figure F-2
CO Scatterplots
All Vehicles

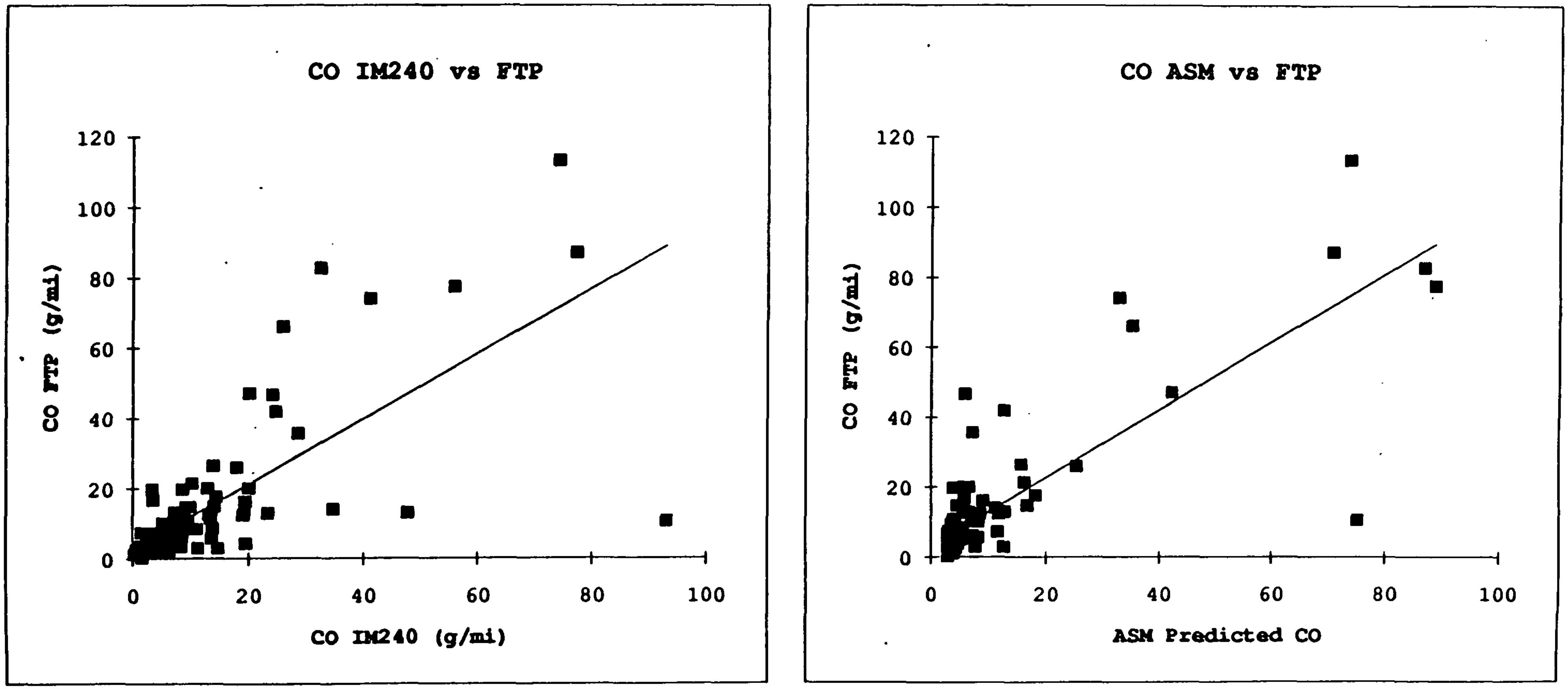
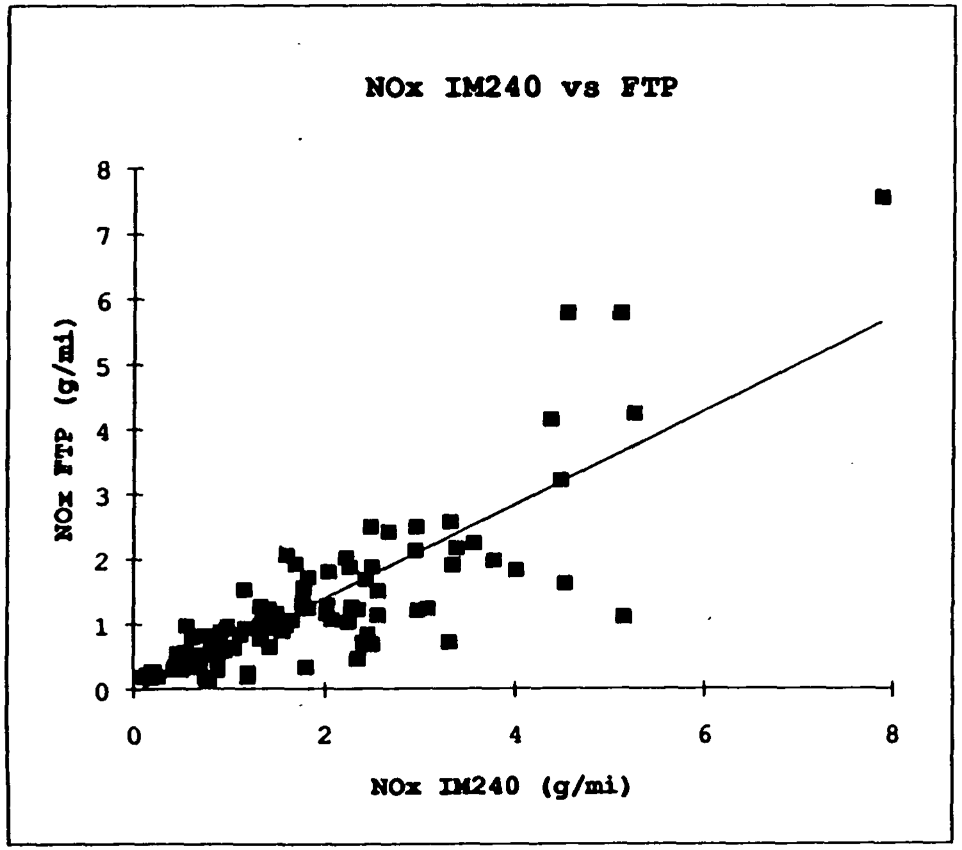


Figure F-3
NOx Scatterplots
All Vehicles



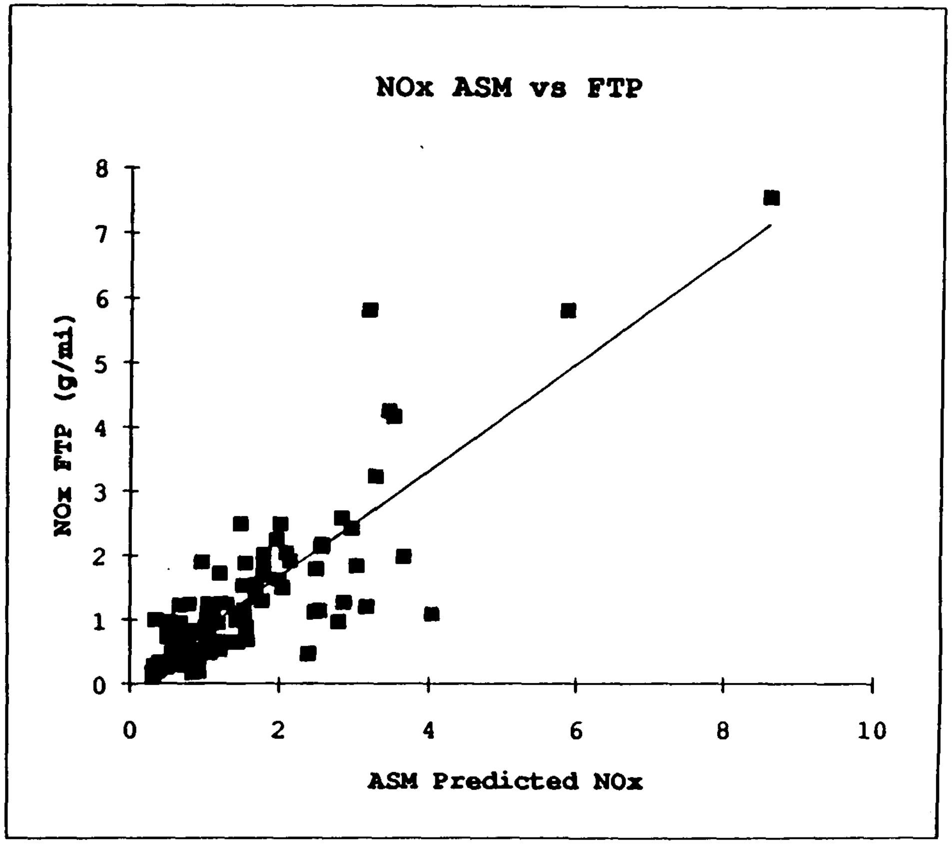


Table F-2
Regression Tables
Vehicle 3211 Removed

```
Dependent Variable is:  HC FTP
    R^2 = 82.6%
s = 0.6169  with  105 - 2 = 103  DOF

Standard Error:  0.61 g/mi

Source      Sum of Squares
Regression     186.255
Residual        39.194


Variable     Coefficient          s.e. of Coeff
Constant       -0.112                 0.077
HC IM240        1.326                 0.060
```

```
Dependent Variable is:  HC FTP
    R^2 = 73.8%
s = 0.7578  with  105 - 2 = 105  DOF

Standard Error:  0.75 g/mi

Source      Sum of Squares
Regression     166.299
Residual        59.149


Variable     Coefficient          s.e. of Coeff
Constant       -0.050                 0.094
HC ASM          2.271                 0.133
```

```
Dependent Variable is:  CO FTP
    R^2 = 74.6%
s = 10.08  with  105 - 2 = 103  DOF

Standard Error:  10.0 g/mi

Source      Sum of Squares
Regression    30708.400
Residual      10462.600


Variable     Coefficient          s.e. of Coeff
Constant       -0.164                 1.243
CO IM240        1.269                 0.073
```

```
Dependent Variable is:  CO FTP
    R^2 = 80.2%
s = 8.892  with  105 - 2 = 103  DOF

Standard Error:  8.9 g/mi

Source      Sum of Squares
Regression    33027.000
Residual       8144.000


Variable     Coefficient          s.e. of Coeff
Constant        2.394                 1.012
CO ASM          1.140                 0.056
```

```
Dependent Variable is:  NOx FTP
    R^2 = 69.6%
s = 0.6598  with  105 - 2 = 103  DOF

Standard Error:  0.66 g/mi

Source      Sum of Squares
Regression     102.819
Residual        44.834


Variable     Coefficient          s.e. of Coeff
Constant       -0.051                 0.106
NOx IM240       0.725                 0.047
```

```
Dependent Variable is:  NOx FTP
    R^2 = 71.4%
s = 0.6386  with  105 - 2 = 103  DOF

Standard Error:  0.64 g/mi

Source      Sum of Squares
Regression     105.685
Residual        42.406


Variable     Coefficient          s.e. of Coeff
Constant       -0.002                 0.098
NOx ASM         0.831                 0.052
```

Figure F-4

HC Scatterplots

Vehicle 3211 Removed

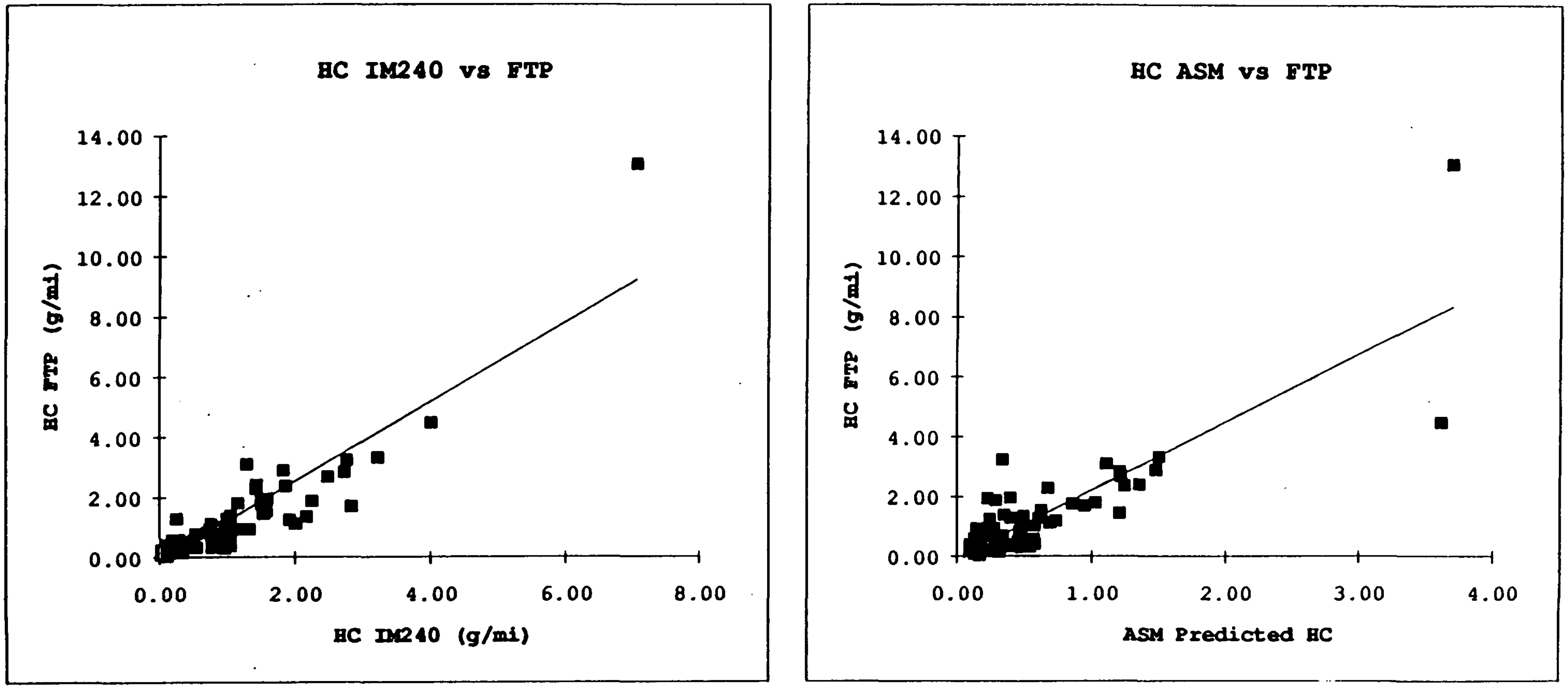
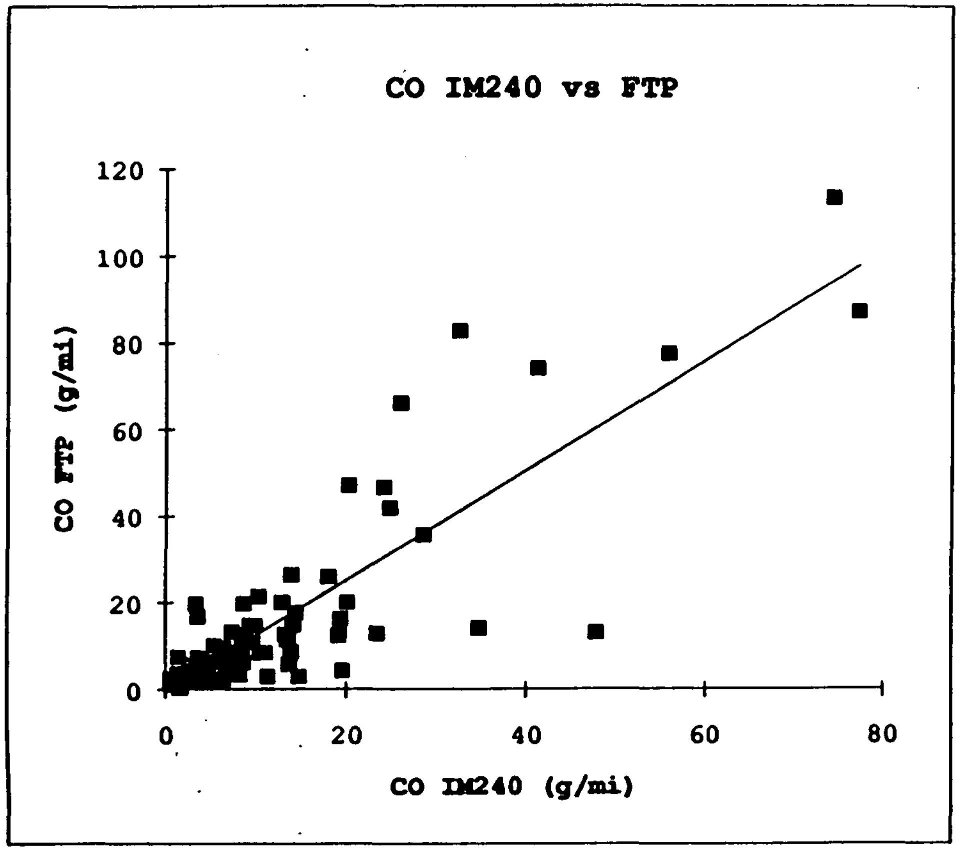


Figure F-5
CO Scatterplots
Vehicle 3211 Removed



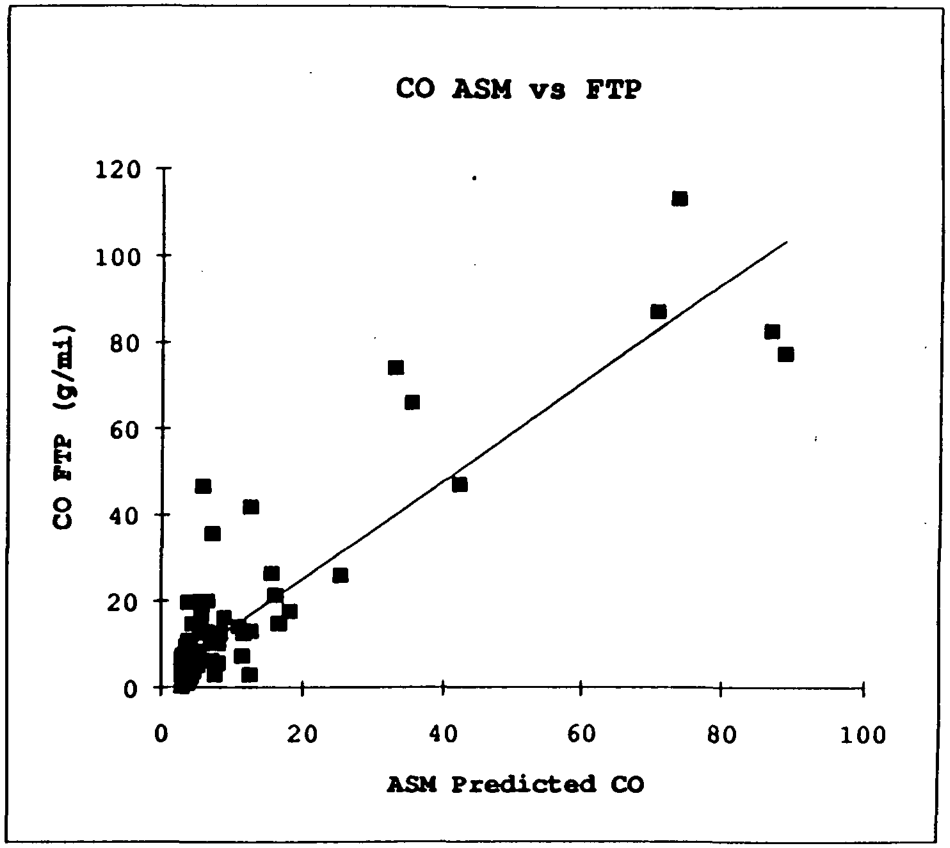
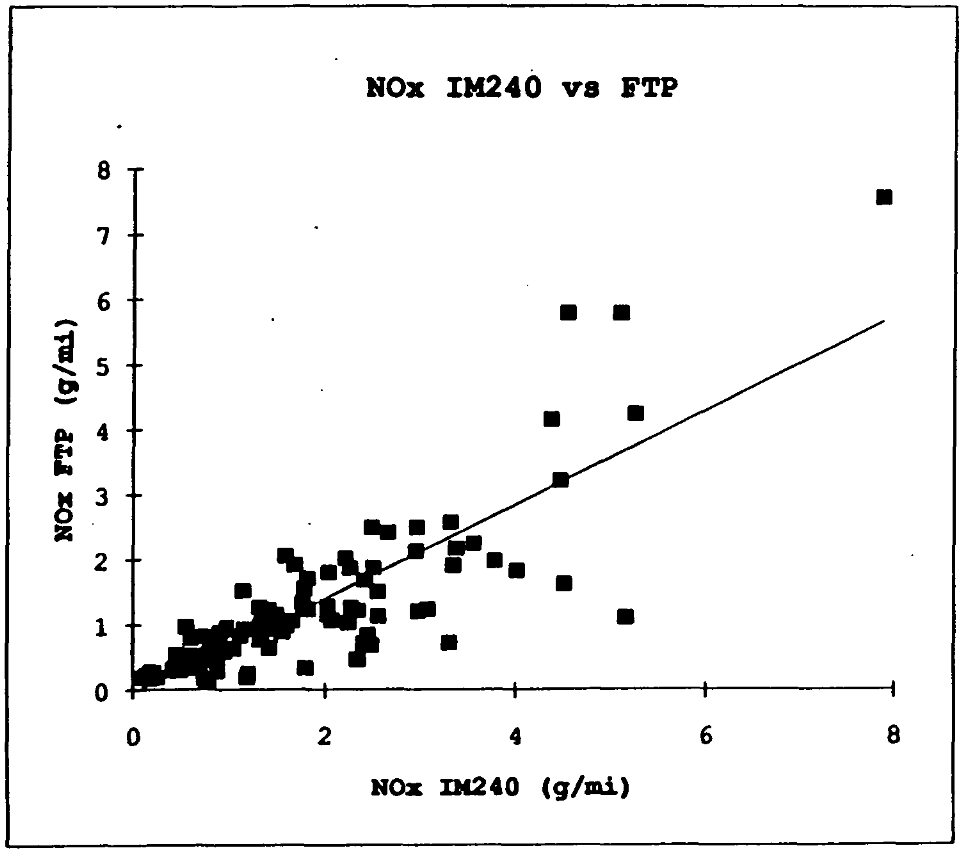


Figure F-6

NOx Scatterplots

Vehicle 3211 Removed



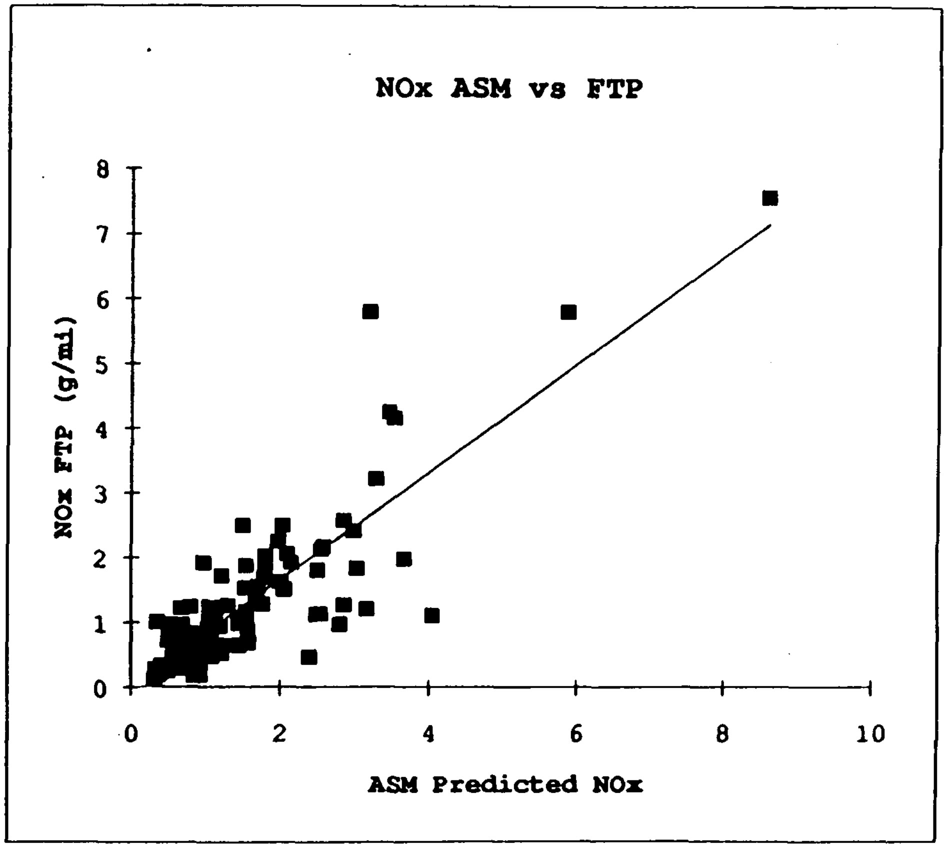


Table F-3
Regression Tables
Vehicles Near Standards

```
Dependent Variable is:  HC FTP
    R^2 = 63.0%
s = 0.1953  with  43 - 2 = 41  DOF

Standard Error:  0.19 g/mi

Source      Sum of Squares
Regression       2.662
Residual         1.563


Variable      Coefficient          s.e. of Coeff
Constant         0.271                0.048
HC IM240         0.531                0.064
```

```
Dependent Variable is:  HC FTP
    R^2 = 17.6%
s = 0.2915  with  43 - 2 = 41  DOF

Standard Error:  0.28 g/mi

Source      Sum of Squares
Regression       0.742
Residual         3.483


Variable      Coefficient          s.e. of Coeff
Constant         0.342                 0.092
HC ASM           0.818                 0.277
```

```
Dependent Variable is:  CO FTP
    R^2 = 24.8%
s = 4.360  with  43 - 2 = 41  DOF

Standard Error:  4.3 g/mi

Source      Sum of Squares
Regression     257.268
Residual       779.566


Variable      Coefficient          s.e. of Coeff
Constant         4.308                1.243
CO IM240         0.490                0.133
```

```
Dependent Variable is:  CO FTP
    R^2 = 13.3%
s = 4.683  with  43 - 2 = 41  DOF

Standard Error:  4.6 g/mi

Source      Sum of Squares
Regression     137.732
Residual       899.102


Variable      Coefficient          s.e. of Coeff
Constant         4.622                 1.586
CO ASM           0.684                 0.273
```

```
Dependent Variable is:  NOx FTP
    R^2 = 45.6%
s = 0.3349  with  43 - 2 = 41  DOF

Standard Error:  0.34 g/mi

Source      Sum of Squares
Regression       3.848
Residual         4.599


Variable      Coefficient          s.e. of Coeff
Constant         0.670                0.103
NOx IM240        0.276                0.047
```

```
Dependent Variable is:  NOx FTP
    R^2 = 26.0%
s = 0.3904  with  43 - 2 = 41 DOF

Standard Error:  0.39 g/mi

Source      Sum of Squares
Regression       2.200
Residual         6.248


Variable      Coefficient          s.e. of Coeff
Constant         0.792                 0.121
NOx ASM          0.266                 0.070
```

Figure F-7
HC Scatterplots
Vehicles Near Standards

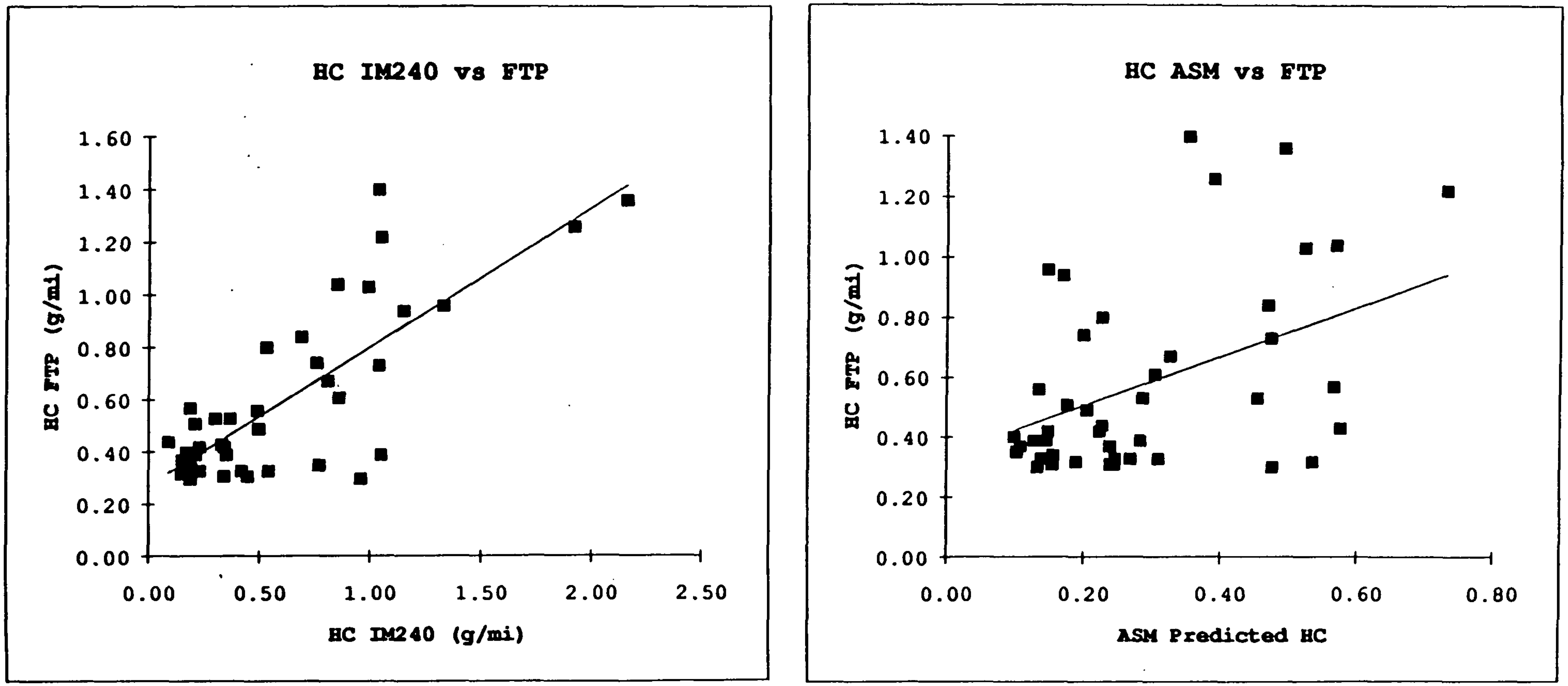


Figure F-8

CO Scatterplots

Vehicles Near Standards

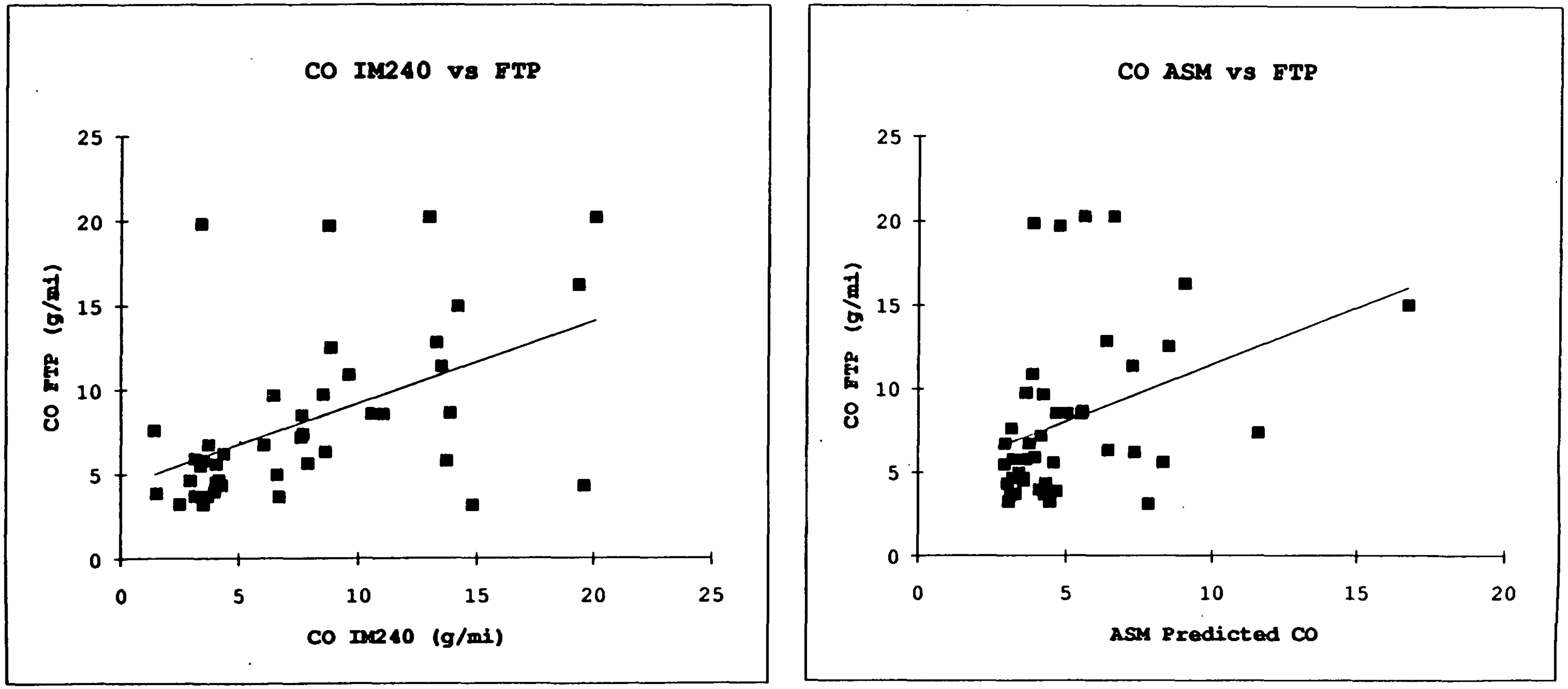
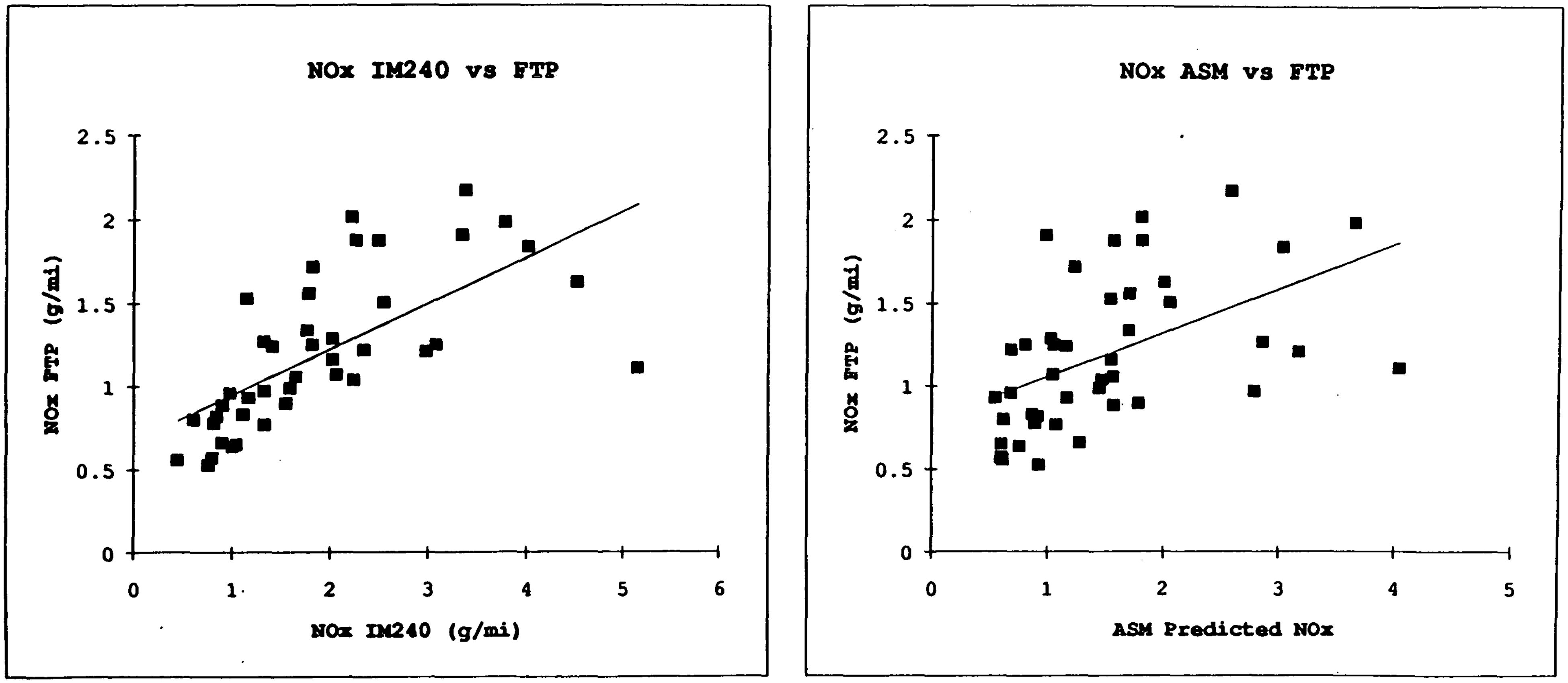


Figure F-9
NOx Scatterplots
Vehicles Near Standards



Appendix G:

ARCO, Sierra, Environment Canada Data Analysis

1.0 Introduction

The objective of this report is to respond to the pilot ASM test programs performed by Sierra Research, Inc., ARCO Products Company, and Environment Canada. Sierra and ARCO both previously published papers praising the capabilities of the ASM, and both concluded that some form of the ASM could replace the IM240 as an enhanced I/M test.

EPA has concluded that the ARCO and Sierra reports are incorrect in claiming the ASM as equal to the IM240. Based on a comparison with a similar database of IM240 vehicles, the ASM is inferior to the IM240 at identifying excess emissions without committing false failures. Moreover, a series of regressions were run for both the ASM and the IM240 versus the FTP. The scatterplots for these regressions, contained in the Appendix to this report, show significant variability for the ASM at predicting FTP values, compared to the IM240.

A contractor for EPA is currently testing a number of vehicles at a state I/M lane in Mesa, Arizona on both the IM240, and a 4 mode steady state test, which includes two ASMs, the ASM2525 and the ASM5015. A sample of vehicles is being recruited to the contractor's lab for further FTP testing. The data from that program will give EPA a chance to determine, with greater confidence, if some form of the ASM is as effective as the IM240.

This report focuses on a small dataset of vehicles, therefore the conclusions made in this report are subject to change when more data is available to EPA. However, from the data that has been presented to EPA to date on the ASMs, the IM240 remains the only enhanced I/M test.

2.0 Database Description

There are 31 vehicles in the ASM database EPA used for this analysis. The data were gathered from programs performed by three different organizations: Environment Canada[1], Sierra Research[2], and ARCO Products[3].

---

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

[2] 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.

EPA started performing ASM tests in Mesa Arizona on September 10, 1992. These data will be the topic of a separate analysis.

A number of vehicles in the ASM database were tested with and without implanted defects, so 51 test configurations were used for this analysis. All the vehicles tested by the three different organizations received the ASM5015 and the FTP, but ARCO did not perform the ASM2525. This left 39 test configurations receiving multiple-mode ASM tests and FTPs.

2.1 ASM Vehicles Removed from Database

There were originally 55 vehicles tested in the three programs, resulting in 117 test configurations, broken down as follows: Environment Canada (32 vehicles or 36 configurations); Sierra Research (18 vehicles or 51 configurations), and ARCO Products (5 vehicles or 30 configurations). Vehicles were removed from the database for reasons which are discussed below.

First, all pre-1983 vehicles were removed to focus on newer technology vehicles. So 3 Canadian vehicles and 5 Sierra vehicles were removed, leaving 29 Canadian vehicles with 33 configurations and 13 Sierra vehicles also with 33 configurations.

Next all pre-1988 Canadian vehicles were removed. Canadian vehicle standards were not lowered to 0.41/3.4/1.0 until the 1988 model year, so the prior model years could not be used. So 13 Canadian vehicles were removed, leaving 16 Canadian vehicles with 20 configurations.

Next, all ARCO vehicles that were not certified to the 50-state standards of 0.41/3.4/1.0 were removed. Three ARCO vehicles were certified to California-only standards, so they were removed, leaving 2 ARCO vehicles with 12 configurations.

Finally, all Sierra configurations that received hot-start FTPs instead of cold-start FTPs were removed. Because the normal cold-start FTP is more variable than hot-start FTPs, short test comparisons should be made using cold-start FTPs. Also, vehicles are certified using cold-start FTPs, so the results are more relevant. So 14 Sierra configurations were removed, leaving 13 Sierra vehicles with 19 configurations.

---

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

2.2 Selection of IM240 Vehicles Used in Database

In order to compare the ASM to the IM240, the analysis should be performed on a set of vehicles that have received both tests. However, none of the ASM vehicles received the IM240, therefore 39 vehicles were randomly selected from the Indiana laboratory IM240 database. These vehicles were chosen from those used in the IM240 cutpoint table analysis in EPA's I/M Costs, Benefits, and Impacts Analysis, which included 274 vehicles with both IM240 and FTP results. In order to make the IM240 database similar to the ASM database, the following process was used.

First, the ASM vehicles were categorized by emission levels according to the following table:

Table 1. Number of Vehicles in Database per Emittant Category.

HC/CO Category	NOx Category	HC Range*	CO Range*	NOx Range	# in Dataset
Normal	Normal	0≤HC<0.82	0≤CO<10.2	0≤NOx<2	29
Normal	High	0≤HC<0.82	0≤CO<10.2	2≤NOx<4	1
High	Normal	0.82≤HC<1.64	10.2≤CO<13.6	0≤NOx<2	2
Very High	Normal	1.64≤HC<10.0	13.6≤CO<150	0≤NOx<2	4
Very High	High	1.64≤HC<10.0	13.6≤CO<150	2≤NOx<4	3

* These are the same categories as those used in the I/M Technical Support Document

Second, the Lab IM240 database was broken down into these same categories. All vehicles were 1983+ model years, and only vehicles that received the lab IM240 *after* the FTP were kept in the database. This kept the IM240 database as similar as possible to the ASM database. From the remaining vehicles, a random sample was chosen from each category so that both databases had the same number of vehicles in each category.

By selecting the same number of vehicles from each emittant range, it prevents one test from getting an unfair advantage in achieving identification rates. For example, if the IM240 database included considerably higher FTP scores, it would have identified much more excess emissions, thus making its Identification Rates (IDRs) higher.

3.0 Calculating ASM Mass Emissions

Sierra indicated (SAE Paper No. 891120) that calculated ASM mass emissions correlate better to the FTP than concentration measurements, so their method of converting ASM NOx concentration measurements to "mass" emissions was applied to this ASM database for HC and CO, as well as NOx. This was done by multiplying the emission concentrations (ppm for HC and NOx, and % for CO) by the vehicles' Inertia Weights (IW), yielding the following units: kiloton-ppm for HC (IW * ppm/10^3), ton-% for CO (IW * %), and megaton-ppm for NOx (IW * ppm/10^6). These are the values EPA used for the regressions in this report.

3.1 EPA Equations Versus Sierra Equations

In their test program, Sierra measured the ASM emissions on both a concentration basis and mass basis. This allowed them to regress Concentration * Inertia Weight (IW) versus mass emissions for the same test, and develop equations that convert [Concentration * IW] to Mass. As expected, these mass calculations correlated very well with the measured mass emissions.

Sierra's next step was to regress the *measured* steady state mass emissions against the FTP emissions and report r^2s for these regressions. They did not actually use the calculated mass emissions to predict FTP scores. This is where EPA's analysis of the ASMs was slightly different. EPA regressed the [Concentration * IW] values against the FTP emissions for each vehicle. This was done because EPA did not have measured mass emissions from all three test programs compiled in this report. However, the major benefit of the ASMs, according to Sierra and ARCO, is the ability to use the less expensive BAR90 type analyzers when measuring the exhaust concentrations. Since this is a claimed benefit of the ASMs, the readings from these less expensive analyzers should be used when comparing the ASM to the IM240.

4.0 Multiple Linear Regressions for the ASM

Using data from all three previously mentioned programs, EPA calculated the IW * Concentration for each emittant. Then a multiple linear regression was performed, using the calculated (IW*Concentration) ASM2525 and ASM5015 scores as two separate variables vs measured FTP emissions. Equations were developed from these regressions that predict an FTP score from a combination of the ASM2525 and ASM5015 concentrations * IW scores:

Table 2. Equations Developed to Predict FTP from ASM Modes.

Predicted FTP = [IW (A*ASM2525 + B*ASM5015) + C]

Emittant	**A**	**B**	**C**	**r2**
HC (ppm)	-3.96×10^{-7}	4.60×10^{-7}	0.523520	49.2%
CO (%)	2.64×10^{-3}	5.10×10^{-5}	4.222840	43.5%
NOx (ppm)	1.13×10^{-7}	1.30×10^{-7}	0.515531	71.4%

4.1 Simple Linear Regressions

Aside from those already mentioned, regressions were also run for each individual ASM mode vs the FTP, and for the IM240 vs the FTP. Since the IM240 is a transient test, like the FTP, it correlates much better to the FTP than the ASM modes.

4.1.1 Coefficient of Determination (r^2)

The r^2 may be interpreted as the proportion of the total FTP variability that was predicted by the short test. For example, if the r^2 equalled 100%, the short test would have perfectly predicted the FTP scores for these cars. If the r^2 for these vehicles was zero, the short test would not have any linear relationship to the FTP.

The r^2 data, listed in table below, show that the IM240 is considerably better than the ASM tests in predicting FTP HC, CO, and NOx scores. For HC and CO, less than half of the FTP variation is explained by the ASM scores.

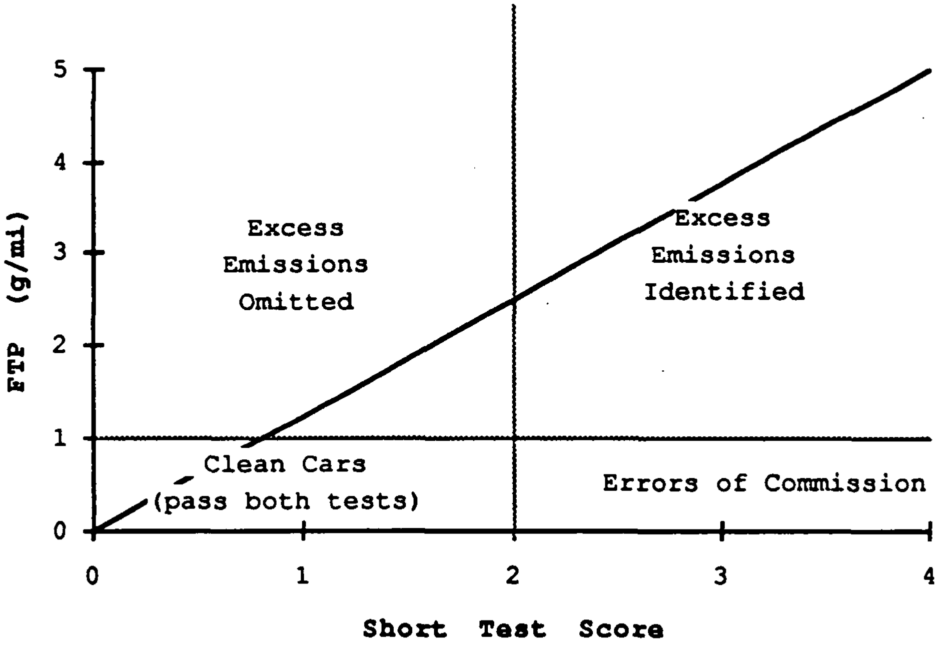
Table 3. Statistical Comparison of the FTP Versus I/M Tests

	HC			**CO**			**NOx**		
	IM240	**5015**	**2525**	**IM240**	**5015**	**2525**	**IM240**	**5015**	**2525**
r^2	95%	36%	20%	92%	45%	44%	84%	62%	70%

4.2 Scatterplots

For an I/M test, more important than the r^2 is the ability to identify high proportions of dirty cars without falsely failing vehicles. The IM240 also has a significant advantage at identifying more of the dirty cars while failing less of the clean cars. The scatterplots in the appendix show this clearly. When viewing the plots, consider the following chart for a reference.

Figure 1. Sample Scatterplot Used to Define Terms



The short test cutpoint under consideration is the vertical line, and the FTP standard is the horizontal line. The intersection of these lines splits the chart into quadrants. The goal of the short test is to maximize the number of FTP failing vehicles into the upper right quadrant, while minimizing the false failures in the lower right quadrant.

The more vehicles that appear in the upper left quadrant, the less effective the test becomes, because these are all dirty cars that are not identified by the short test. From this perspective, the advantages of the IM240 is clear. Every IM240 chart shows that an x-axis value (cutpoint) can be selected that clearly places the vast majority of dirty cars in the upper-right quadrant, without errors of commission. The ASM tests do not display this trait nearly as well. Only the 2-mode ASM tests and the IM240 scatterplots have the horizontal and vertical lines on them, so the reader can examine different cutpoint scenarios.

4.2.1 Scatterplot Statistics

Each of the regression scatterplots contains the following information:

- The best-fit regression line showing predicted FTP for a continuum of short test scores, developed from a regression of the actual data.
- 'Boundary Lines' at + 2 and - 2 standard error from the predicted value.
- A horizontal dotted line at the FTP standard.
- A box containing descriptive statistics.

On each Regression plot, a box in the upper-left corner provides the following statistics: 1) The equation of the line used to predict FTP values from the short test's score. 2) r^2, discussed above. 3) The standard error* , a statistic that describes the variability of the FTP score predicted from the selected short test. The next section discusses standard error in more detail.

4.3 Standard Error as a Measure of Variability

The weakness of the ASM tests regarding r^2 and the low proportion of cars that can be identified as dirty while simultaneously avoiding false failures, is related to test variability. The standard error is an objective measurement of test variability. The following shows that the ASM tests are significantly more variable than the IM240, using the standard error as an objective measure of variability.

4.3.1 Assumptions Made for Using Standard Error

The following assumptions were made in order to use standard error as it is used in this report:

- Linear relationship between the FTP and the short tests.
- Normally distributed data.
- Homoscedastic distribution (i.e., the standard deviation of FTP values is constant for all short test values).

---

* What is referred to in this report is formally termed standard error of estimate, but for convenience purposes, will simply be called standard error.

The standard error is similar to standard deviation because a bandwidth of ±1 std. error includes ≈68% of the data and ±2 std. error includes ≈95% of the data.

4.3.2 Example Using Standard Error

Consider a 3000 lb. vehicle that emits 1500 ppm NOx on both the ASM5015 and ASM2525. Plugging these numbers into the equation for predicting FTP values (Table 2) yields 1.61 g/mi. However, because the standard error for ASM NOx (see Table 4) is 0.36 g/mile, roughly 5% of the FTP scores predicted by the ASM result will be greater than 2.33 g/mile (1.61 + 2*0.36) or less than 0.89 g/mile (1.61 - 2*0.36). Since half of these will err on the low side, it is probable that ≈2.5% of the vehicles identified as failures by an ASM cutpoint of 1.61 g/mi would be false failures.

4.3.3 Effect of Standard Error on "Safe FTP Predictions"

In order to be confident the false failure rate would be less than 2.5% the selected cutpoint should predict an FTP value of 2 standard errors greater than the FTP standard. This ensures that the low values (FTP prediction - 2 std. error) are still failing the FTP.

For example,

FTP NOx standard is 1.0 g/mi
The ASM NOx std. error is 0.36 g/mi
$FTP_{standard}$ + 2 std. errors = 1.72 g/mi

So, the selected ASM cutpoint should predict an FTP of no less than 1.72 g/mi. Applying the same logic to the IM240, whose standard error is 0.28 g/mi, a predicted FTP score of 1.56 g/mi (1.0 + 2*0.28) will also yield an error of commission rate less than 2.5%. But because the "safe" predicted FTP score is more stringent, the excess emissions identified will be higher. The standard errors and predicted FTP levels that are expected to limit false failures to approximately 2.5% are compared in Table 4 below.

Table 4. Comparison of ASM and IM240 Standard errors And Their Effect on Predicted FTP Stringency at a 2.5% False Failure Rate

	HC		CO		NOx	
	IM240	ASM	IM240	ASM	IM240	ASM
1 std. error (g/mi)	0.24	0.60	3.8	4.8	0.28	0.36
Predicted FTP Level @ ≈2.5% Ec (g/ mi)	0.89	1.61	11.0	13.0	1.56	1.72

5.0 Cutpoint Tables

Another way to assess the effectiveness of I/M tests is to evaluate the following factors, which were discussed in detail in Section 4.2.1 of EPA's I/M Costs, Benefits, and Impacts Analysis: excess emission identification rates, failure rates, 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 (normal emitters are defined as vehicles whose FTP HC < 0.82 g/mi and FTP CO < 10.2 g/mi), but are clean enough to make the cost effectiveness of repairs an issue. These factors are highly interactive, for example, high IDRs can be achieved with stringent cutpoints, but this will adversely affect failure rates.

Cutpoint tables for the ASM tests and the IM240 in the appendix allow these factors to be compared. The cutpoints for the tables were chosen using an iterative process. The goal was to select cutpoints that would give reasonable identification rates while limiting errors of commission. The goal was to keep the Ec rate at 0% for both procedures.

For both cutpoint tables, four different cutpoints were selected for each of the three emittants, resulting in 64 different cutpoint combinations. For the IM240, the "Two Ways to Pass Criteria" was used, as described in Section 4.2.3.2 of EPA's I/M Costs, Benefits, and Impacts Analysis. This is a method of combining the composite HC and CO scores with the bag 2 HC and CO scores in order to minimize Errors of Commission on vehicles with cold start problems, while maintaining high Identification Rates.

5.1 Selecting ASM Cutpoints

Scatterplots were done plotting Measured FTP vs. Calculated FTP from the ASM scores. From these scatterplots, EPA determined a range of cutpoints to use for the cutpoint tables. For example, looking at Chart x, FTP CO vs ASM

Prediction CO, it can be determined that an ASM Prediction between 6 and 10 grams/mile would identify most dirty vehicles (those above the standard of 3.4 g/mi) without failing the clean vehicles. It is also obvious that a cutpoint of 5 would falsely fail at least one vehicle while achieving no added benefit. Consequently, the chosen CO cutpoints for the ASM range from 6 to 20. The range of cutpoints for HC and NOx were chosen the same way.

5.1.1 Using Standard error to Predict Reasonable Cutpoints

Although the cutpoint tables do include a wide range of cutpoints, there is still a concern that the errors of commission are not representative of what they might be in a real world scenario. For this reason, the cutpoints shaded at the end of each table were selected using the standard error.

The ASM cutpoints used are identical to the "safe FTP predictions" in Table 4. This is because the values are obtained from calculations using both ASM scores. Each mode has a "sliding scale" of cutpoints, dependent on the other mode results. In other words, no single ASM5015 or ASM2525 value can be used for a cutpoint since a vehicle might be clean on one mode and very dirty on the other. The cutpoints for the IM240, on the other hand, are direct IM240 scores, in grams per mile. The "safe cutpoints" for the IM240 were determined by calculating the IM240 score that would predict the "safe FTP Level ≈ 2.5% Ec" (see Table 4), using the equations on each respective IM240 scatterplot.

For example, the IM240 HC FTP Level ≈ 2.5% Ec is 0.89 g/mi. The regression equation on the IM240 vs FTP scatterplot is:

$$FTP_{pred.} = 1.429 * IM240 + 0.04;$$

Since we want to predict an FTP of no less than 0.89 g/mi, setting $FTP_{pred.}$ equal to 0.89 yields an IM240 score of 0.60 g/mi. This was done to calculate each "safe cutpoint" for the IM240.

5.2 Limitations of Cutpoint Tables

It is important to recognize several limitations in these tables. Most important is that the database is very small and does not represent the in use fleet. Additionally, the vehicles were preconditioned by the FTP before the ASM test and before the IM240 tests, so the correlation between these short tests will be much better than can be expected for vehicles tested in an I/M lane, because of all the uncontrolled variables associated with I/M lane tests like temperature, fuel RVP, distance driven prior to the test, catalyst temperature, etc. Because all of these variables were controlled for the vehicles in the ASM and IM240 databases, the cutpoints can be very stringent while still avoiding false failures. For example, the IM240 table shows that cutpoints of 0.4/6/1.0 yield IDRs of 97%, 93%, and 100%, for HC, CO and NOx, respectively, without errors of commission. If cutpoints this stringent were used for random vehicles tested in I/M lanes, the error of commission rate would be unacceptably high. Similarly, because of the introduced malfunctions, the failure rates are not representative of the in-use fleet failure rates for an acceptable I/M program. So, while it is valid to use these cutpoint tables to compare the ASM to the IM240, it is not valid to assume that the rates are representative of those that will be realized in a real I/M program. The ASM and IM240 testing that EPA is currently sponsoring in Mesa will provide the actual in-use fleet rates.

5.3 IM240 Identifies Much More Excess Emissions

Using the cutpoint tables to compare the two procedures, the IM240 did considerably better than the Two-Mode ASM at each tests' optimal cutpoints* . The IM240 identified 97% of excess HC, 93% of excess CO, and 100% of excess NOx at cutpoints of 0.4/6/1.0 (HC/CO/NOx). The Two-Mode ASM identified 87%, 80%, and 75% of HC, CO, and NOx, respectively at cutpoints of 0.6/6/1.50.

As discussed in the Variability section, using the standard error of estimate to choose cutpoints that should prevent exceeding an error of commission rate of 2.5% can help in assessing the performance of I/M tests. The shaded cutpoints at the end of each test's cutpoint table suggest that the IM240's performance is significantly better than the two-mode ASMs. Using the "safe" cutpoints, the IM240 identifies 92%, 84%, and 71% excess of the excess HC, CO, and NOx, respectively - the Two-Mode ASM only identifies 75%, 63%, and 64%.

6.0 <u>Summary</u>

The ASM tests were considerably more variable than the IM240 under controlled laboratory conditions, as evidenced by subjective analyses of the scatter plots and objective measurements using the standard error statistic. Testing at real-world I/M lanes will add considerably more variability to both tests, because conditions known to affect emissions such as temperature, humidity, and vehicle operating conditions prior to the test. These uncontrolled variables are expected to add proportionally more variability to

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* 'Optimal Cutpoints', as used here, is the lowest cutpoints the test could go to and still have zero errors of commission.

a steady state test like the ASM, but data are not available to evaluate the validity of the hypothesis.

On the other hand, the increased variability associated with actual I/M testing will be somewhat offset for the ASM by adding two additional modes; a 50 mph steady mode at road-load horsepower, and an idle mode. This four-mode ASM procedure is now being performed by EPA in a Mesa Arizona I/M lane.

The result of these offsetting effects on variability will determine the viability of the ASM as a lower cost substitute for the IM240. A final conclusion should be postponed until enough Mesa data can gathered for a valid evaluation.

Appendix A

Cutpoint Tables

"Two Ways to Pass" Lab IM240s

39 1983+ Randomly Selected Vehicles

IM240 Cut-Points Comp + Bag 2	Identification Rate HC	Identification Rate CO	Identification Rate NOx	Number of Failures	Failure Rate	Number of Ec's	Ec Rate	Failure Rate for FTP Passing Vehicles	Failure Rate for Normal Emitting Vehicles
0.4/15/2.00 + 0.3/12	96%	86%	93%	22	48%	0	0%	0%	16%
0.8/15/2.00 + 0.5/12	91%	80%	71%	17	37%	0	0%	0%	3%
1.0/15/2.00 + 0.6/12	91%	80%	71%	16	35%	0	0%	0%	3%
1.2/15/2.00 + 0.8/12	91%	80%	71%	16	35%	0	0%	0%	3%
0.4/10/2.00 + 0.3/ 8	96%	86%	93%	22	48%	0	0%	0%	16%
0.8/10/2.00 + 0.5/ 8	91%	82%	71%	18	39%	0	0%	0%	6%
1.0/10/2.00 + 0.6/ 8	91%	82%	71%	17	37%	0	0%	0%	6%
1.2/10/2.00 + 0.8/ 8	91%	82%	71%	17	37%	0	0%	0%	6%
0.4/ 6/2.00 + 0.3/4.5	97%	91%	97%	26	57%	0	0%	0%	29%
0.8/ 6/2.00 + 0.5/4.5	94%	89%	75%	23	50%	0	0%	0%	23%
1.0/ 6/2.00 + 0.6/4.5	94%	89%	75%	22	48%	0	0%	0%	23%
1.2/ 6/2.00 + 0.8/4.5	94%	89%	75%	22	48%	0	0%	0%	23%
0.4/ 5/2.00 + 0.3/ 4	97%	**94%**	97%	30	65%	1	2%	10%	42%
0.8/ 5/2.00 + 0.5/ 4	94%	**92%**	75%	27	59%	1	2%	10%	35%
1.0/ 5/2.00 + 0.6/ 4	94%	**92%**	75%	26	57%	1	2%	10%	35%
1.2/ 5/2.00 + 0.8/ 4	94%	**92%**	75%	26	57%	1	2%	10%	35%
0.4/15/1.50 + 0.3/12	96%	86%	93%	22	48%	0	0%	0%	16%
0.8/15/1.50 + 0.5/12	91%	80%	71%	17	37%	0	0%	0%	3%
1.0/15/1.50 + 0.6/12	91%	80%	71%	16	35%	0	0%	0%	3%
1.2/15/1.50 + 0.8/12	91%	80%	71%	16	35%	0	0%	0%	3%
0.4/10/1.50 + 0.3/ 8	96%	86%	93%	22	48%	0	0%	0%	16%
0.8/10/1.50 + 0.5/ 8	91%	82%	71%	18	39%	0	0%	0%	6%
1.0/10/1.50 + 0.6/ 8	91%	82%	71%	17	37%	0	0%	0%	6%
1.2/10/1.50 + 0.8/ 8	91%	82%	71%	17	37%	0	0%	0%	6%
0.4/ 6/1.50 + 0.3/4.5	97%	91%	97%	26	57%	0	0%	0%	29%
0.8/ 6/1.50 + 0.5/4.5	94%	89%	75%	23	50%	0	0%	0%	23%
1.0/ 6/1.50 + 0.6/4.5	94%	89%	75%	22	48%	0	0%	0%	23%
1.2/ 6/1.50 + 0.8/4.5	94%	89%	75%	22	48%	0	0%	0%	23%
0.4/ 5/1.50 + 0.3/ 4	97%	**94%**	97%	30	65%	1	2%	10%	42%
0.8/ 5/1.50 + 0.5/ 4	94%	**92%**	75%	27	59%	1	2%	10%	35%
1.0/ 5/1.50 + 0.6/ 4	94%	**92%**	75%	26	57%	1	2%	10%	35%
1.2/ 5/1.50 + 0.8/ 4	94%	**92%**	75%	26	57%	1	2%	10%	35%
0.4/15/1.25 + 0.3/12	96%	87%	95%	23	50%	0	0%	0%	19%
0.8/15/1.25 + 0.5/12	91%	81%	73%	18	39%	0	0%	0%	6%
1.0/15/1.25 + 0.6/12	91%	81%	73%	17	37%	0	0%	0%	6%
1.2/15/1.25 + 0.8/12	91%	81%	73%	17	37%	0	0%	0%	6%

"Two Ways to Pass" Lab IM240s

39 1983+ Randomly Selected Vehicles

IM240 Cut-Points Comp + Bag 2	Identification Rate			Number of Failures	Failure Rate	Number of Ec's	Ec Rate	Failure Rate for FTP Passing Vehicles	Failure Rate for Normal Emitting Vehicles
	HC	CO	NOx						
0.4/10/1.25 + 0.3/ 8	96%	87%	95%	23	50%	0	0%	0%	19%
0.8/10/1.25 + 0.5/ 8	91%	83%	73%	19	41%	0	0%	0%	10%
1.0/10/1.25 + 0.6/ 8	91%	83%	73%	18	39%	0	0%	0%	10%
1.2/10/1.25 + 0.8/ 8	91%	83%	73%	18	39%	0	0%	0%	10%
0.4/ 6/1.25 + 0.3/4.5	97%	91%	97%	26	57%	0	0%	0%	29%
0.8/ 6/1.25 + 0.5/4.5	94%	89%	75%	23	50%	0	0%	0%	23%
1.0/ 6/1.25 + 0.6/4.5	94%	89%	75%	22	48%	0	0%	0%	23%
1.2/ 6/1.25 + 0.8/4.5	94%	89%	75%	22	48%	0	0%	0%	23%
0.4/ 5/1.25 + 0.3/ 4	97%	**94%**	97%	30	65%	1	2%	10%	42%
0.8/ 5/1.25 + 0.5/ 4	94%	**92%**	75%	27	59%	1	2%	10%	35%
1.0/ 5/1.25 + 0.6/ 4	94%	**92%**	75%	26	57%	1	2%	10%	35%
1.2/ 5/1.25 + 0.8/ 4	94%	**92%**	75%	26	57%	1	2%	10%	35%
0.4/15/1.00 + 0.3/12	97%	91%	100%	27	59%	0	0%	0%	32%
0.8/15/1.00 + 0.5/12	95%	90%	93%	25	54%	0	0%	0%	29%
1.0/15/1.00 + 0.6/12	95%	90%	93%	24	52%	0	0%	0%	29%
1.2/15/1.00 + 0.8/12	95%	90%	93%	24	52%	0	0%	0%	29%
0.4/10/1.00 + 0.3/ 8	97%	91%	100%	27	59%	0	0%	0%	32%
0.8/10/1.00 + 0.5/ 8	95%	90%	93%	25	54%	0	0%	0%	29%
1.0/10/1.00 + 0.6/ 8	95%	90%	93%	24	52%	0	0%	0%	29%
1.2/10/1.00 + 0.8/ 8	95%	90%	93%	24	52%	0	0%	0%	29%
0.4/ 6/1.00 + 0.3/4.5	97%	93%	100%	29	63%	0	0%	0%	39%
0.8/ 6/1.00 + 0.5/4.5	95%	92%	93%	27	59%	0	0%	0%	35%
1.0/ 6/1.00 + 0.6/4.5	95%	92%	93%	26	57%	0	0%	0%	35%
1.2/ 6/1.00 + 0.8/4.5	95%	92%	93%	26	57%	0	0%	0%	35%
0.4/ 5/1.00 + 0.3/ 4	97%	**96%**	100%	32	70%	1	2%	10%	48%
0.8/ 5/1.00 + 0.5/ 4	95%	**94%**	93%	30	65%	1	2%	10%	45%
1.0/ 5/1.00 + 0.6/ 4	95%	**94%**	93%	29	63%	1	2%	10%	45%
1.2/ 5/1.00 + 0.8/ 4	95%	**94%**	93%	29	63%	1	2%	10%	45%
0.6/10/1.60 + 0.5/ 8	92%	84%	71%	19	41%	0	0%	0%	10%

Identification Rates in bold indicate that the cutpoint for that emittant has caused the Error(s) of Commission

Two - Mode ASM Test -- ASM5015 and ASM2525

39 Vehicles Multi-ASM Mode Cut-Points HC/CO/NOx	Identification Rate HC	CO	NOx	Number of Failures	Failure Rate	Number of Ec's	Ec Rate	Failure Rate for FTP Passing Vehicles	Failure Rate for Normal Emitting Vehicles
0.6/20/2.00	88%	77%	68%	13	33%	1	3%	9%	17%
0.8/20/2.00	75%	62%	49%	7	18%	0	0%	0%	3%
1.0/20/2.00	74%	60%	43%	6	15%	0	0%	0%	0%
1.5/20/2.00	74%	60%	43%	6	15%	0	0%	0%	0%
0.6/15/2.00	88%	77%	68%	13	33%	1	3%	9%	17%
0.8/15/2.00	75%	62%	49%	7	18%	0	0%	0%	3%
1.0/15/2.00	75%	62%	49%	7	18%	0	0%	0%	3%
1.5/15/2.00	75%	62%	49%	7	18%	0	0%	0%	3%
0.6/ 8/2.00	88%	81%	68%	14	36%	1	3%	9%	20%
0.8/ 8/2.00	76%	67%	49%	8	21%	0	0%	0%	7%
1.0/ 8/2.00	76%	67%	49%	8	21%	0	0%	0%	7%
1.5/ 8/2.00	76%	67%	49%	8	21%	0	0%	0%	7%
0.6/ 6/2.00	88%	82%	68%	15	38%	1	3%	9%	23%
0.6/ 6/2.00	87%	80%	59%	11	28%	0	0%	0%	10%
1.0/ 6/2.00	87%	80%	59%	11	28%	0	0%	0%	10%
1.5/ 6/2.00	87%	80%	59%	11	28%	0	0%	0%	10%
0.6/20/1.50	88%	78%	83%	14	36%	1	3%	9%	20%
0.8/20/1.50	75%	63%	64%	8	21%	0	0%	0%	7%
1.0/20/1.50	74%	61%	58%	7	18%	0	0%	0%	3%
1.5/20/1.50	74%	61%	58%	7	18%	0	0%	0%	3%
0.6/15/1.50	88%	78%	83%	14	36%	1	3%	9%	20%
0.8/15/1.50	75%	63%	64%	8	21%	0	0%	0%	7%
1.0/15/1.50	75%	63%	64%	8	21%	0	0%	0%	7%
1.5/15/1.50	75%	63%	64%	8	21%	0	0%	0%	7%
0.6/ 8/1.50	88%	82%	83%	15	38%	1	3%	9%	23%
0.8/ 8/1.50	76%	67%	64%	9	23%	0	0%	0%	10%
1.0/ 8/1.50	76%	67%	64%	9	23%	0	0%	0%	10%
1.5/ 8/1.50	76%	67%	64%	9	23%	0	0%	0%	10%
0.6/ 6/1.50	88%	83%	83%	16	41%	1	3%	9%	27%
0.6/ 6/1.50	87%	80%	75%	12	31%	0	0%	0%	13%
1.0/ 6/1.50	87%	80%	75%	12	31%	0	0%	0%	13%
1.5/ 6/1.50	87%	80%	75%	12	31%	0	0%	0%	13%
0.6/20/1.25	88%	78%	83%	14	36%	1	3%	9%	20%
0.8/20/1.25	75%	63%	64%	9	23%	1	3%	9%	10%
1.0/20/1.25	74%	61%	58%	8	21%	1	3%	9%	7%
1.5/20/1.25	74%	61%	58%	8	21%	1	3%	9%	7%

Two - Mode ASM Test -- ASM5015 and ASM2525

39 Vehicles Multi-ASM Mode Cut-Points	Identification Rate			Number of	Failure	Number of	Ec	Failure Rate for FTP Passing	Failure Rate for Normal Emitting
HC/CO/NOx	HC	CO	NOx	Failures	Rate	Ec's	Rate	Vehicles	Vehicles
0.6/15/1.25	**88%**	78%	**83%**	14	36%	1	3%	9%	20%
0.8/15/1.25	75%	63%	**64%**	9	23%	1	3%	9%	10%
1.0/15/1.25	75%	63%	**64%**	9	23%	1	3%	9%	10%
1.5/15/1.25	75%	63%	**64%**	9	23%	1	3%	9%	10%
0.6/ 8/1.25	**88%**	82%	**83%**	15	38%	1	3%	9%	23%
0.8/ 8/1.25	76%	67%	**64%**	10	26%	1	3%	9%	13%
1.0/ 8/1.25	76%	67%	**64%**	10	26%	1	3%	9%	13%
1.5/ 8/1.25	76%	67%	**64%**	10	26%	1	3%	9%	13%
0.6/ 6/1.25	**88%**	83%	**83%**	16	41%	1	3%	9%	27%
0.6/ 6/1.25	87%	80%	**75%**	13	33%	1	3%	9%	17%
1.0/ 6/1.25	87%	80%	**75%**	13	33%	1	3%	9%	17%
1.5/ 6/1.25	87%	80%	**75%**	13	33%	1	3%	9%	17%
0.6/20/1.00	**94%**	85%	**96%**	18	46%	2	5%	18%	30%
0.8/20/1.00	82%	72%	**86%**	14	36%	2	5%	18%	23%
1.0/20/1.00	80%	70%	**80%**	13	33%	2	5%	18%	20%
1.5/20/1.00	80%	70%	**80%**	13	33%	2	5%	18%	20%
0.6/15/1.00	**94%**	85%	**96%**	18	46%	2	5%	18%	30%
0.8/15/1.00	82%	72%	**86%**	14	36%	2	5%	18%	23%
1.0/15/1.00	82%	72%	**86%**	14	36%	2	5%	18%	23%
1.5/15/1.00	82%	72%	**86%**	14	36%	0	0%	0%	23%
0.6/ 8/1.00	**95%**	90%	**96%**	19	49%	2	5%	18%	33%
0.8/ 8/1.00	82%	76%	**86%**	15	38%	2	5%	18%	27%
1.0/ 8/1.00	82%	76%	**86%**	15	38%	2	5%	18%	27%
1.5/ 8/1.00	82%	76%	**86%**	15	38%	2	5%	18%	27%
0.6/ 6/1.00	**95%**	91%	**96%**	20	51%	2	5%	18%	37%
0.6/ 6/1.00	94%	90%	**96%**	18	46%	2	5%	18%	30%
1.0/ 6/1.00	94%	90%	**96%**	18	46%	2	5%	18%	30%
1.5/ 6/1.00	94%	90%	**96%**	18	46%	2	5%	18%	30%
1.6/13/1.72	75%	63%	64%	8	21%	0	0%	0%	7%

Identification Rates in bold indicate that the cutpoint for that emittant(s) has caused the Error(s) of Commission.

Appendix B

Scatterplots

Figure B-1

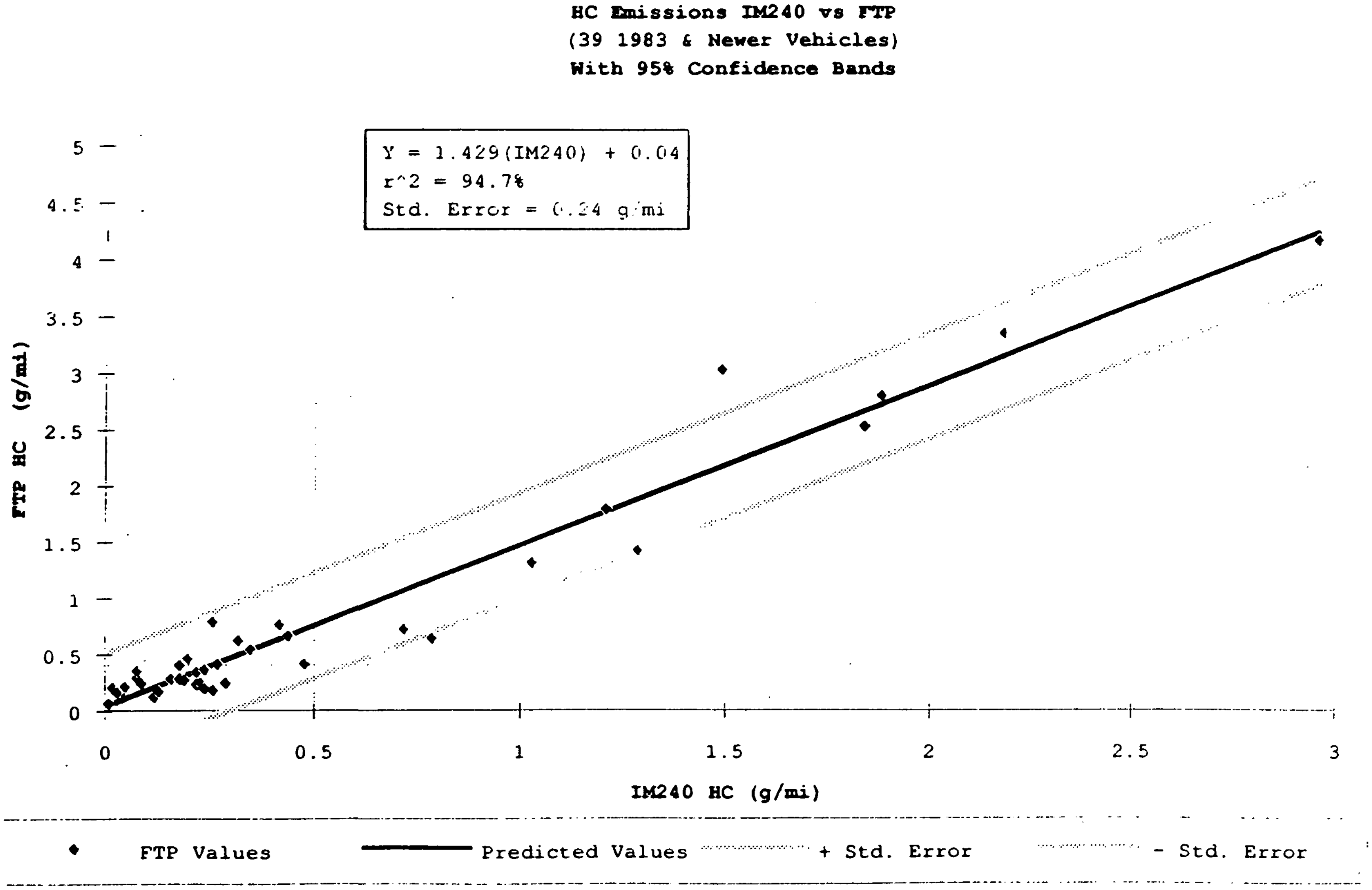

HC Emissions IM240 vs FTP
(39 1983 & Newer Vehicles)
With 95% Confidence Bands
Y = 1.429(IM240) + 0.04
r^2 = 94.7%
Std. Error = 0.24 g/mi
FTP HC (g/mi)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
IM240 HC (g/mi)
0
0.5
1
1.5
2
2.5
3
FTP Values
Predicted Values
+ Std. Error
- Std. Error

Figure B-2

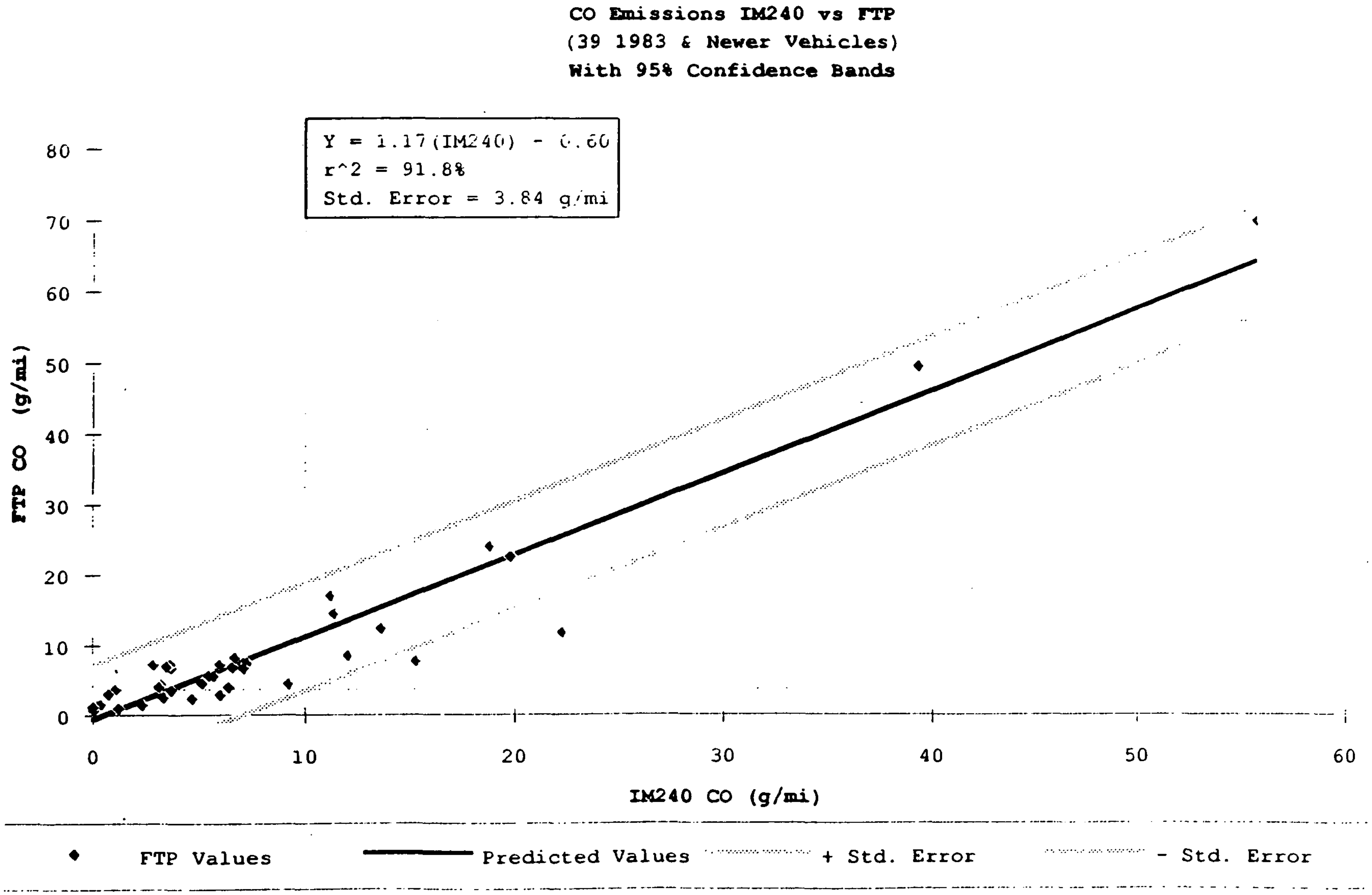

CO Emissions IM240 vs FTP
(39 1983 & Newer Vehicles)
With 95% Confidence Bands
Y = 1.17(IM240) - 0.60
r^2 = 91.8%
Std. Error = 3.84 g/mi
80
70
60
50
40
30
20
10
0
FTP CO (g/mi)
0
10
20
30
40
50
60
IM240 CO (g/mi)
FTP Values
Predicted Values
+ Std. Error
- Std. Error

Figure B-3

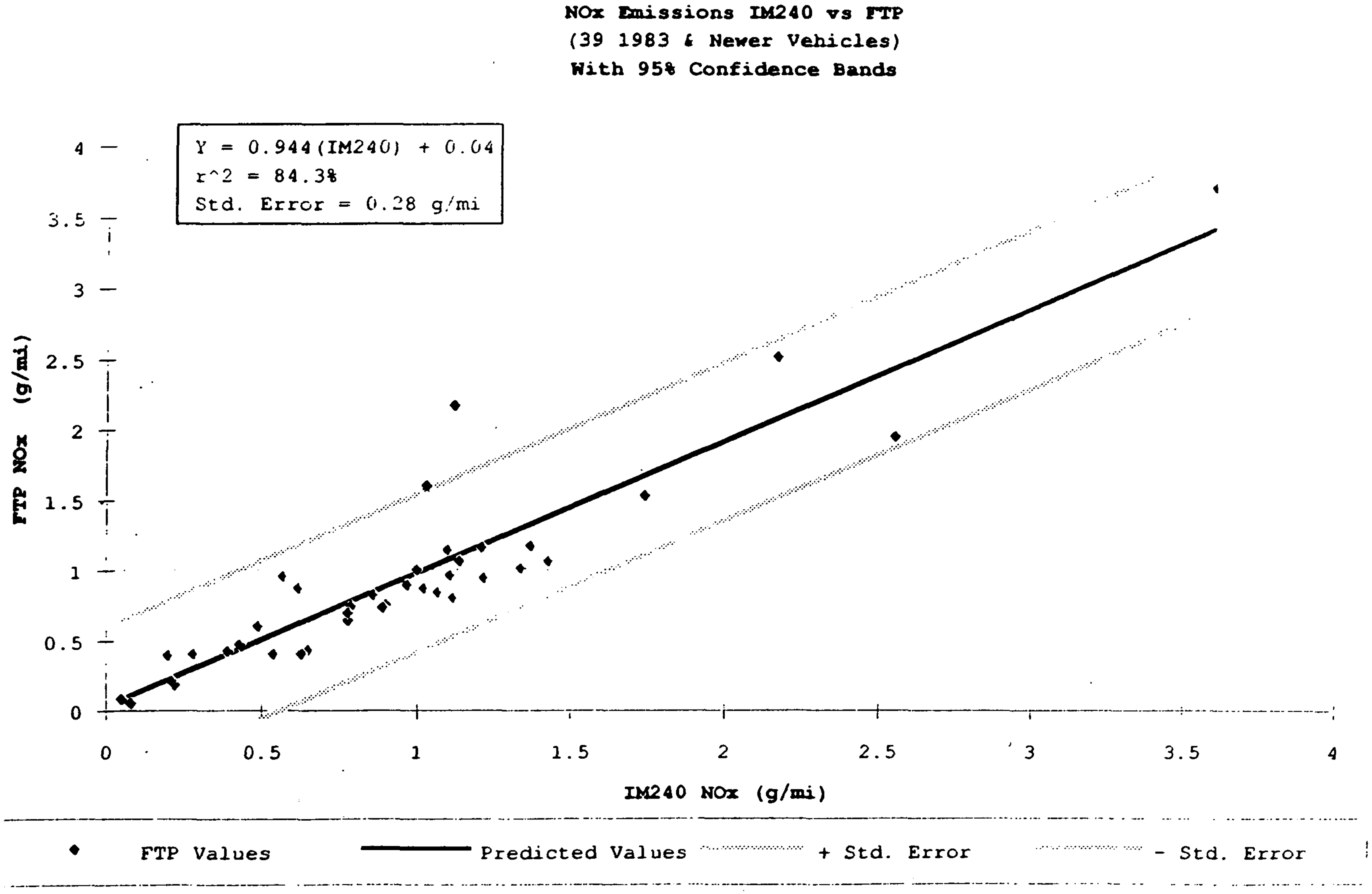

NOx Emissions IM240 vs FTP
(39 1983 & Newer Vehicles)
With 95% Confidence Bands
Y = 0.944(IM240) + 0.04
r^2 = 84.3%
Std. Error = 0.28 g/mi
FTP NOx (g/mi)
0
0.5
1
1.5
2
2.5
3
3.5
4
IM240 NOx (g/mi)
◆ FTP Values
Predicted Values
+ Std. Error
- Std. Error

Figure B-4

HC Emissions ASM 2-Mode vs FTP
(39 1983 & Newer Vehicles)

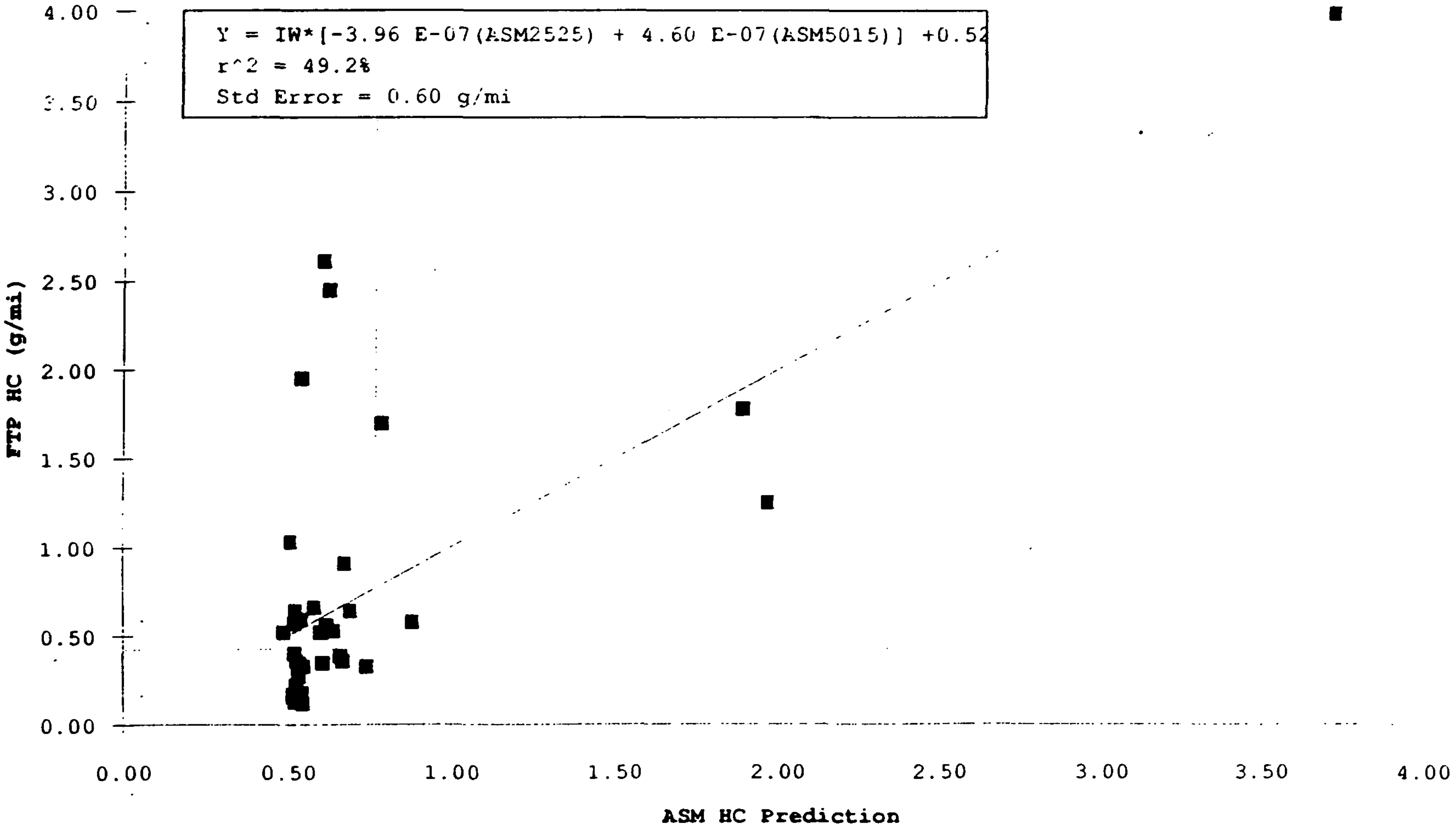


Figure B-5

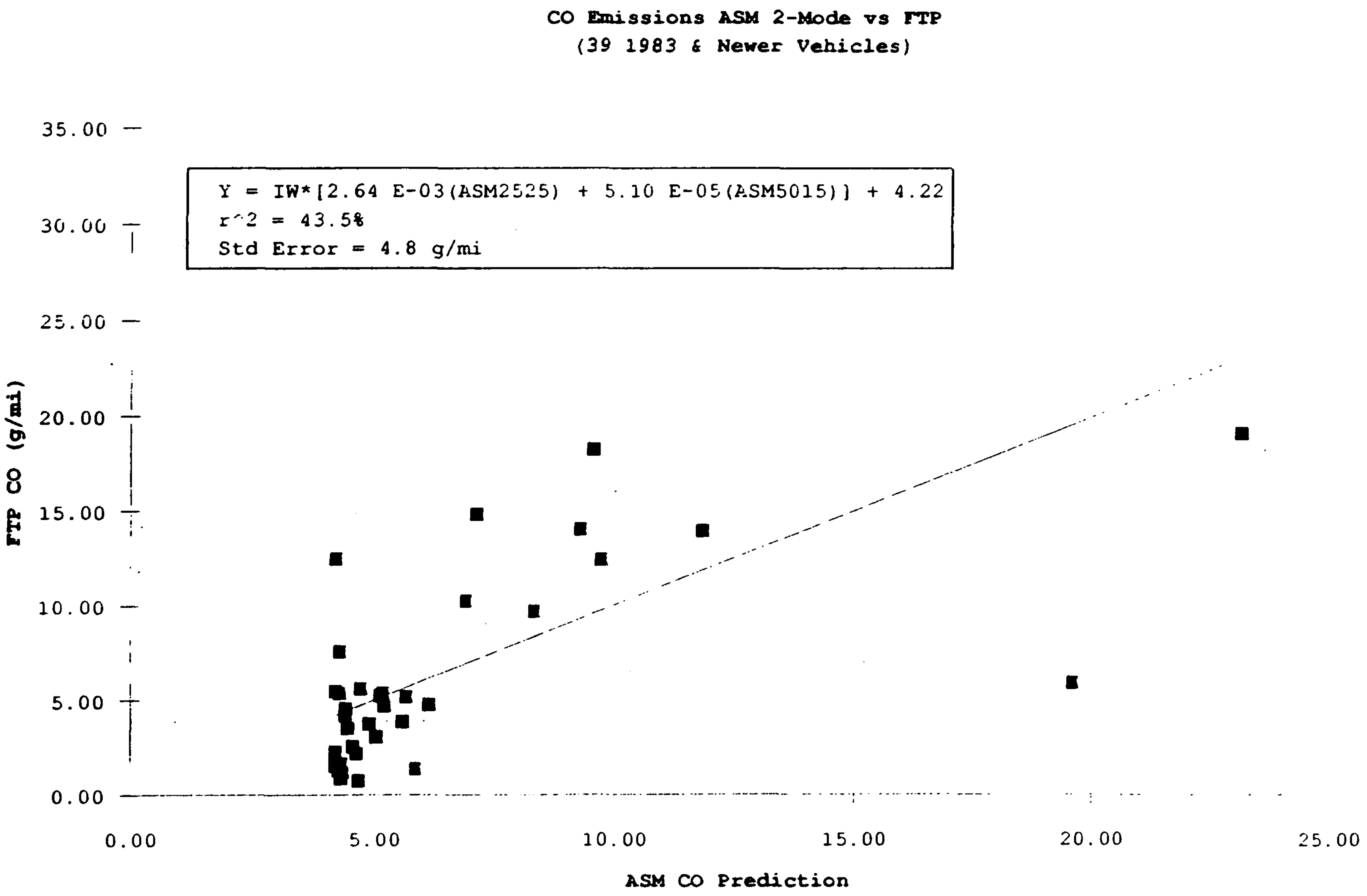

CO Emissions ASM 2-Mode vs FTP
(39 1983 & Newer Vehicles)
Y = IW*[2.64 E-03(ASM2525) + 5.10 E-05(ASM5015)] + 4.22
r^2 = 43.5%
Std Error = 4.8 g/mi
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
FTP CO (g/mi)
0.00
5.00
10.00
15.00
20.00
25.00
ASM CO Prediction

Figure B-6

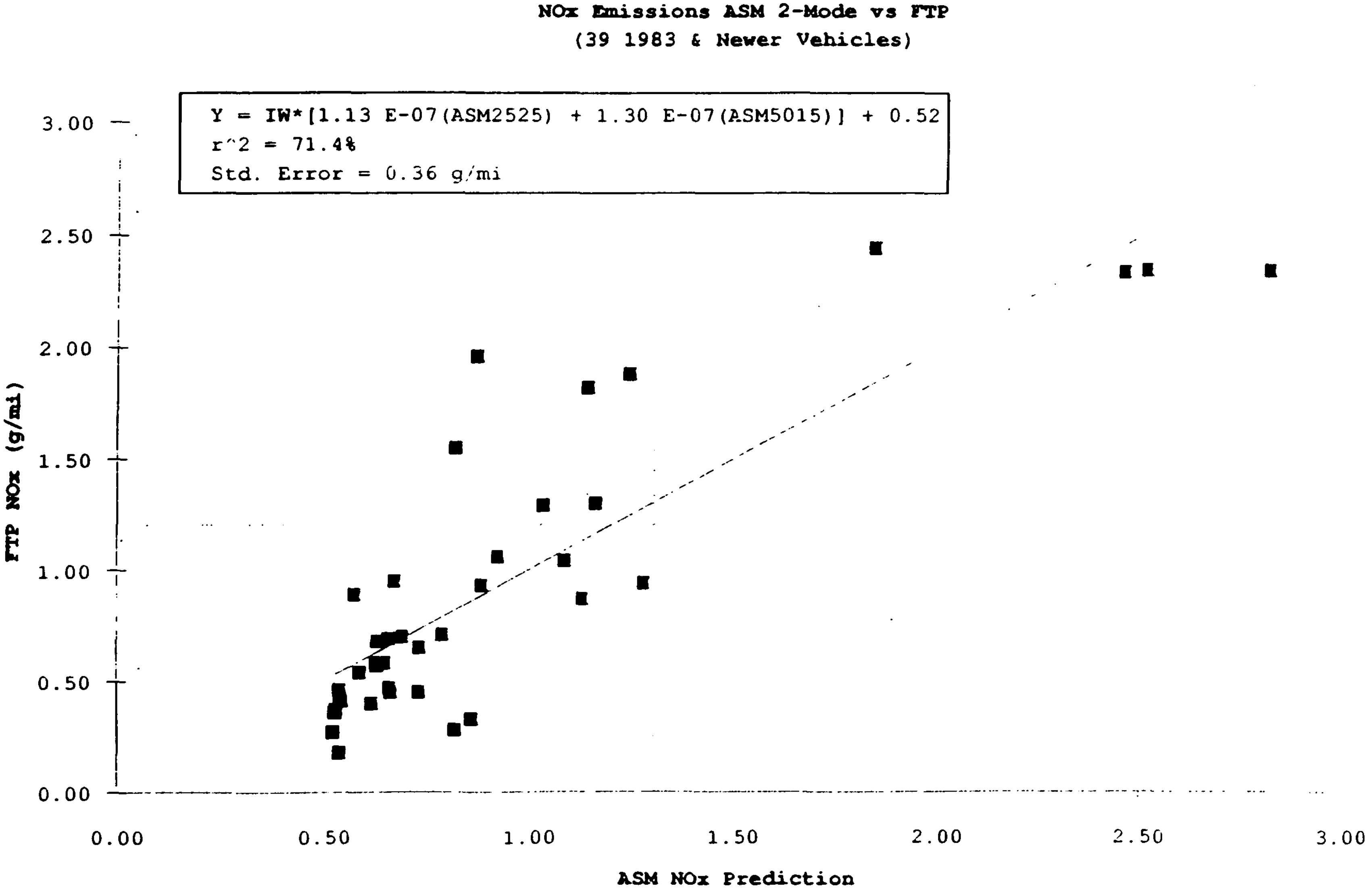

NOx Emissions ASM 2-Mode vs FTP
(39 1983 & Newer Vehicles)
Y = IW*[1.13 E-07(ASM2525) + 1.30 E-07(ASM5015)] + 0.52
r^2 = 71.4%
Std. Error = 0.36 g/mi
FTP NOx (g/mi)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
ASM NOx Prediction

Figure B-7

HC Emissions ASM5015 vs FTP
(69 1983 & Newer Vehicles - Including CA Certified Vehicles)
With 95% Confidence Interval

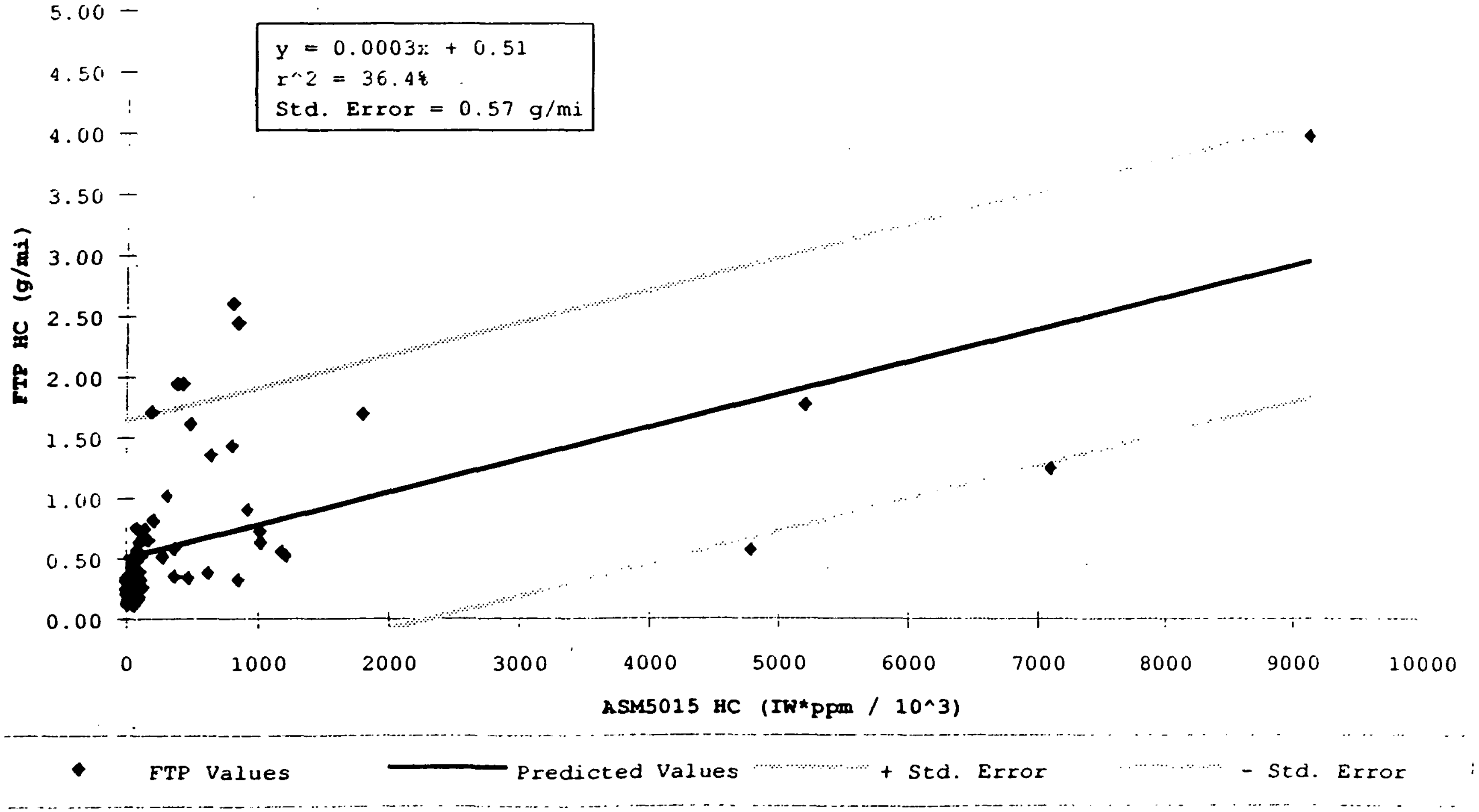


Figure B-8

CO Emissions ASM5015 vs FTP
(69 1983 & Newer Vehicles - Including CA Certified Vehicles)
With 95% Confidence Interval

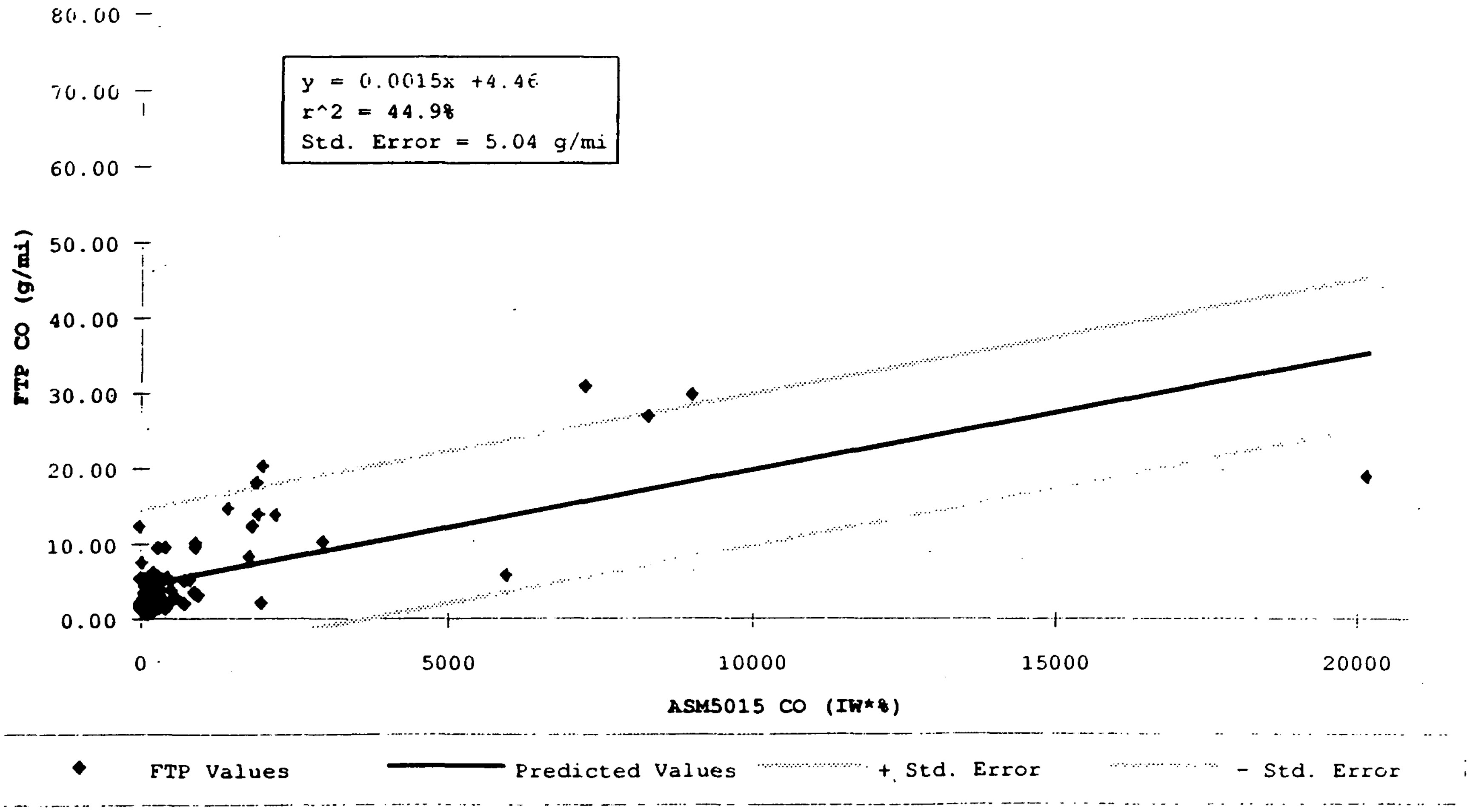


Figure B-9

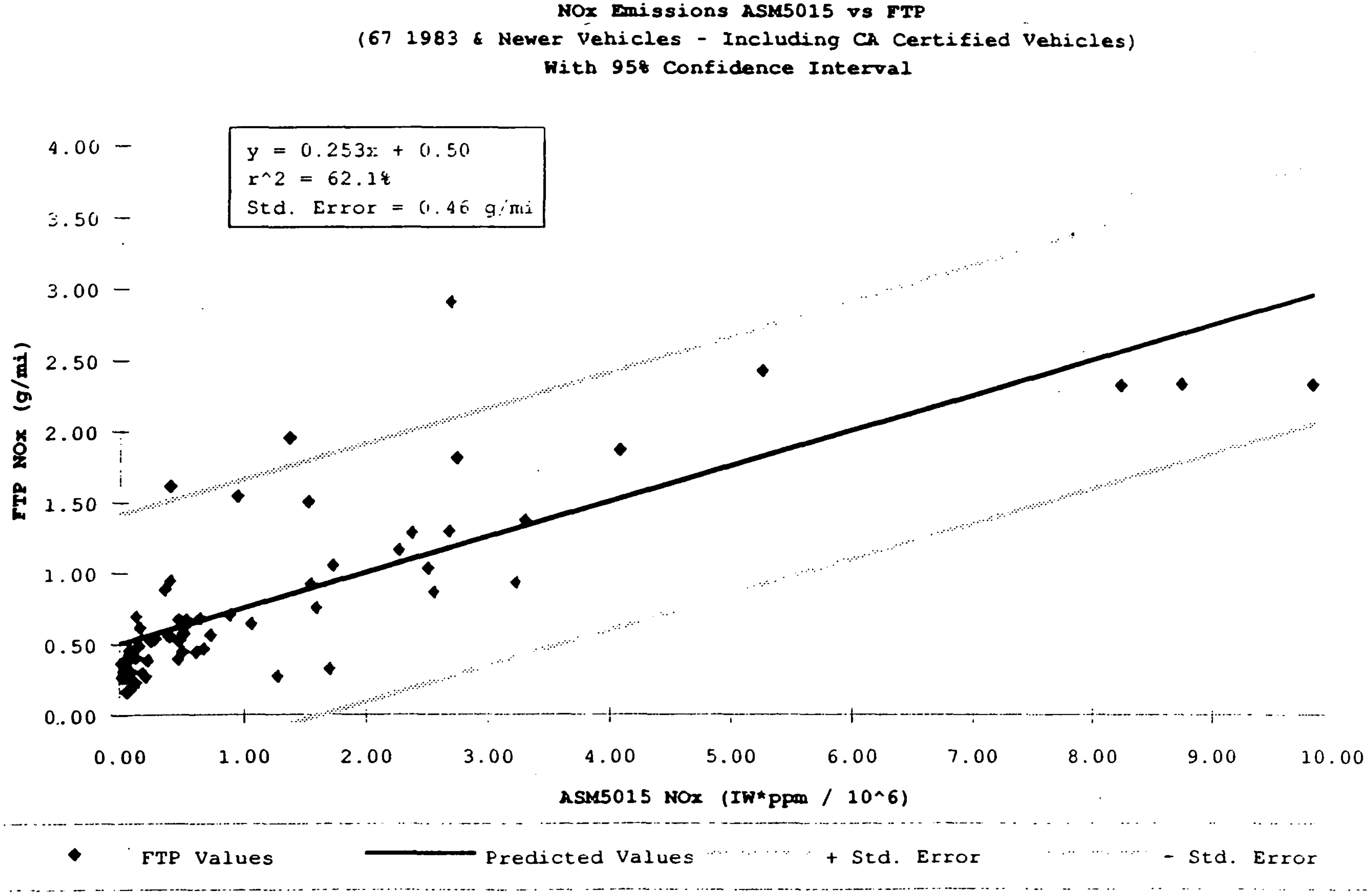
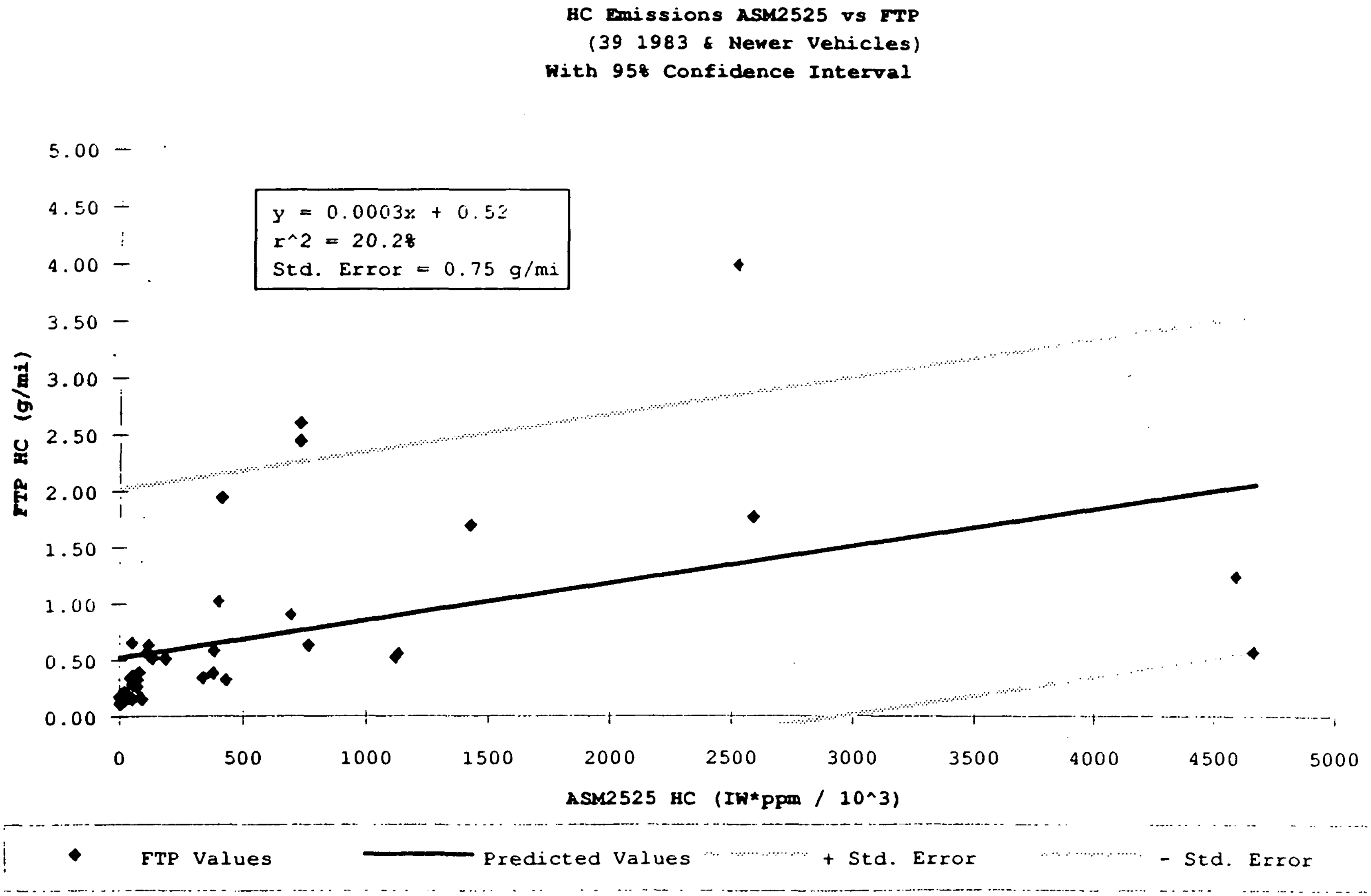

NOx Emissions ASM5015 vs FTP
(67 1983 & Newer Vehicles - Including CA Certified Vehicles)
With 95% Confidence Interval
y = 0.253x + 0.50
r^2 = 62.1%
Std. Error = 0.46 g/mi
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
FTP NOx (g/mi)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
ASM5015 NOx (IW*ppm / 10^6)
FTP Values
Predicted Values
+ Std. Error
- Std. Error

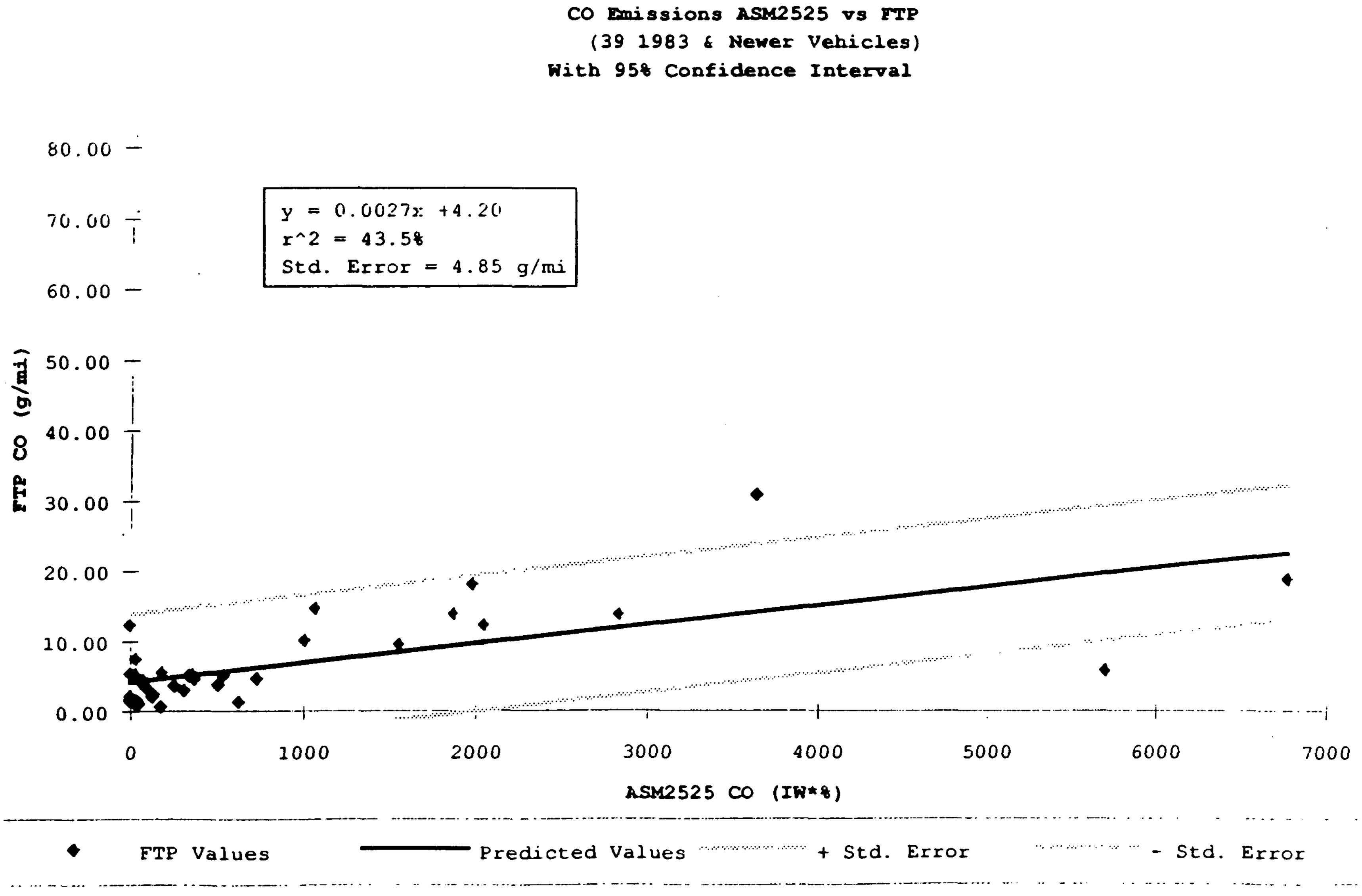
Figure B-10



HC Emissions ASM2525 vs FTP
(39 1983 & Newer Vehicles)
With 95% Confidence Interval

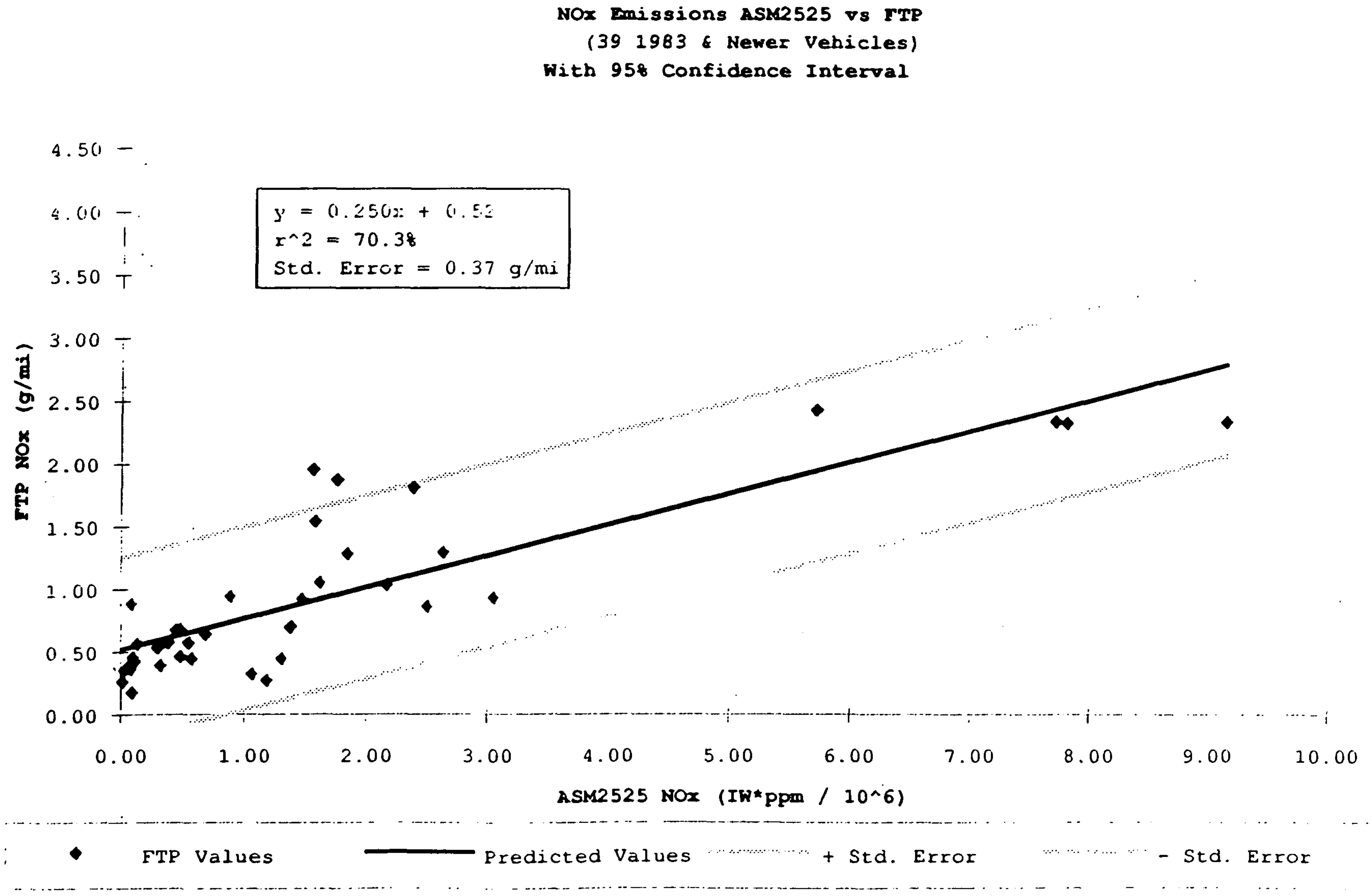
y = 0.0003x + 0.52
r^2 = 20.2%
Std. Error = 0.75 g/mi

Figure B-11



CO Emissions ASM2525 vs FTP
(39 1983 & Newer Vehicles)
With 95% Confidence Interval

Figure B-12


NOx Emissions ASM2525 vs FTP
(39 1983 & Newer Vehicles)
With 95% Confidence Interval
y = 0.250x + 0.52
r^2 = 70.3%
Std. Error = 0.37 g/mi
FTP NOx (g/mi)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
ASM2525 NOx (IW*ppm / 10^6)
FTP Values
Predicted Values
+ Std. Error
- Std. Error

Appendix H:

Estimated Cost of High-Tech I/M Testing

5.2.1 General Methodology

EPA's estimates of the costs of high-tech test procedures are driven by a number of assumptions. 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 used for the transient test are laboratory grade equipment. They are designed to higher accuracy and repeatability specifications than the NDIR analyzers used to perform the current I/M tests. Table 5-4 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	N_2 Gas	$30	250 tests	250 tests
Transient	H_2 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 an actual network of stations and lanes in a given city. One could attempt to assess land costs, building costs, staff and equipment costs, costs for all necessary support systems, and other cost factors. However, this approach would be very time consuming and would rely on information which is proprietary to the private contractors that operate the programs and is, therefore, unavailable. Instead, the cost of the increased number of lanes and stations is derived by analyzing current costs and subtracting out equipment, direct personnel, 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 a load equivalent to ETW / 250), a 40 second 2525 mode (25 mph at load equivalent to ETW / 300), 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 anemometer, 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
Anemometer	$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

Appendix I:

ASM and IM240 Credits for State Implementation Plans With MOBILE5 Runs

```
1 Maximum ASM, Purge, Pressure (annual) 0.4/8.0/1.8
 MOBILE5a (26-Mar-93)
0
-M114 Warning:
+              Purge Check emission benefits assume the use of a dynomometer and
               the IM240 transient test procedure driving cycle.
0I/M program selected:

0    Start year (January 1):               1983
     Pre-1981 MYR stringency rate:          40%
     First model year covered:             1968
     Last model year covered:              2020
     Waiver rate (pre-1981):                3.%
     Waiver rate (1981 and newer):          3.%
     Compliance Rate:                      96.%
     Inspection type:                      Test Only
     Inspection frequency                  Annual
     Vehicle types covered:                LDGV - Yes
                                          LDGT1 - Yes
                                          LDGT2 - Yes
                                           HDGV - Yes
     1981 & later MYR test type:           Loaded / Idle
     Cutpoints, HC:    0.400   CO:    8.000   NOx:    1.800
0Functional Check Program Description:
0Check Start   Model Yrs  Vehicle Classes Covered       Inspection       Comp
       (Janl)  Covered    LDGV   LDGT1  LDGT2  HDGV   Type      Freq      Rate

 Press 1983    1971-2020  Yes    Yes    Yes    Yes Test Only     Annual    96.0%
 Purge 1983    1971-2020  Yes    Yes    Yes    Yes Test Only     Annual    96.0%
 ATP   1983    1971-2020  Yes    Yes    Yes    Yes Test Only     Annual    96.0%
0Air pump system disablements:      Yes  Catalyst removals:                 Yes
 Fuel inlet restrictor disablements: Yes  Tailpipe lead deposit test:        Yes
 EGR disablement:                   Yes  Evaporative system disablements:   Yes
 PCV system disablements:           Yes  Missing gas caps:                  Yes
0...............                                Minimum Temp:  72. (F)       Maximum Temp:  92. (F)
                      Period 1 RVP: 10.5      Period 2 RVP:  8.7       Period 2 Start Yr: 1992
0VOC HC emission factors include evaporative HC emission factors.
0
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2000        I/M Program: Yes      Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                   Anti-tam. Program: Yes    Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                    Reformulated Gas: No
0  Veh. Type:       LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV      MC    All Veh
+                  ______    ______    ______    ______    ______    ______    ______    ______    ______    ______
 Veh. Speeds:       19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
      VMT Mix:      0.616     0.191     0.086               0.031     0.002     0.001     0.068     0.006
0Composite Emission Factors (Gm/Mile)
 VOC       HC:       1.73      1.83      2.45      2.02      6.02      0.65      0.87      2.23      5.53     2.000
 Exhaust   HC:       1.04      1.17      1.66      1.32      2.81      0.65      0.87      2.23      1.89     1.260
 Evaporat HC:        0.15      0.19      0.25      0.21      1.95                                    3.21     0.233
 Refuel L HC:        0.19      0.25      0.25      0.25      0.41                                             0.196
 Runing L HC:        0.29      0.16      0.24      0.18      0.74                                             0.249
 Rsting L HC:        0.06      0.06      0.06      0.06      0.10                                    0.43     0.062
 Exhaust   CO:      13.31     15.05     19.43     16.41     56.19      1.60      1.76     11.58     24.78    15.424
 Exhaust NOX:        1.09      1.25      1.68      1.38      4.67      1.37      1.51     10.69      0.77     1.932
```

```
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2001         I/M Program: Yes      Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                    Anti-tam. Program: Yes    Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                     Reformulated Gas: No
0  Veh. Type:         LDGV      LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV       MC     All Veh
+                    ______    ______    ______    ______    ______    ______    ______    ______    ______    ______
 Veh. Speeds:        19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:        0.613     0.192     0.086               0.031     0.001     0.001     0.069     0.006
0Composite Emission Factors (Gm/Mile)
 VOC      HC:         1.68      1.78      2.38      1.96      5.45      0.61      0.80      2.20      5.53      1.932
 Exhaust  HC:         1.03      1.15      1.64      1.30      2.54      0.61      0.80      2.20      1.89      1.238
 Evaporat HC:         0.14      0.17      0.22      0.19      1.74                                    3.21      0.214
 Refuel L HC:         0.19      0.25      0.25      0.25      0.41                                              0.195
 Runing L HC:         0.26      0.15      0.22      0.17      0.66                                              0.228
 Rsting L HC:         0.06      0.06      0.06      0.06      0.10                                    0.43      0.057
 Exhaust  CO:        13.25     14.82     19.27     16.20     48.47      1.55      1.69     11.49     24.78     15.084
 Exhaust NOX:         1.07      1.21      1.64      1.34      4.52      1.30      1.41      9.94      0.77      1.865
 ----------------------------------------------------------------------------------------------------------------------
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2003         I/M Program: Yes      Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                    Anti-tam. Program: Yes    Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                     Reformulated Gas: No
0  Veh. Type:         LDGV      LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV       MC     All Veh
+                    ______    ______    ______    ______    ______    ______    ______    ______    ______    ______
 Veh. Speeds:        19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:        0.606     0.194     0.087               0.031     0.002     0.002     0.072     0.006
0Composite Emission Factors (Gm/Mile)
 VOC      HC:         1.58      1.69      2.19      1.85      4.55      0.56      0.74      2.14      5.53      1.811
 Exhaust  HC:         1.01      1.13      1.59      1.27      2.13      0.56      0.74      2.14      1.89      1.203
 Evaporat HC:         0.12      0.14      0.14      0.14      1.41                                    3.21      0.176
 Refuel L HC:         0.19      0.25      0.25      0.25      0.41                                              0.195
 Runing L HC:         0.22      0.13      0.16      0.14      0.52                                              0.189
 Rsting L HC:         0.05      0.05      0.05      0.05      0.08                                    0.43      0.048
 Exhaust  CO:        13.17     14.52     19.01     15.90     36.06      1.48      1.63     11.36     24.78     14.553
 Exhaust NOX:         1.03      1.16      1.57      1.29      4.36      1.18      1.31      8.67      0.77      1.757
 ----------------------------------------------------------------------------------------------------------------------
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2006         I/M Program: Yes      Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                    Anti-tam. Program: Yes    Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                     Reformulated Gas: No
0  Veh. Type:         LDGV      LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV       MC     All Veh
+                    ______    ______    ______    ______    ______    ______    ______    ______    ______    ______
 Veh. Speeds:        19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:        0.599     0.197     0.087               0.031     0.002     0.002     0.076     0.006
0Composite Emission Factors (Gm/Mile)
 VOC      HC:         1.49      1.61      2.08      1.75      3.91      0.51      0.71      2.11      5.53      1.705
 Exhaust  HC:         0.98      1.09      1.53      1.22      1.90      0.51      0.71      2.11      1.89      1.169
 Evaporat HC:         0.10      0.11      0.11      0.11      1.13                                    3.21      0.148
 Refuel L HC:         0.19      0.25      0.25      0.25      0.40                                              0.194
 Runing L HC:         0.18      0.12      0.15      0.13      0.41                                              0.156
 Rsting L HC:         0.04      0.04      0.04      0.04      0.07                                    0.43      0.038
 Exhaust  CO:        13.08     14.28     18.62     15.61     28.81      1.42      1.59     11.24     24.78     14.173
 Exhaust NOX:         0.99      1.13      1.53      1.25      4.11      1.10      1.25      7.74      0.77      1.673
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0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2008        I/M Program: Yes      Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                   Anti-tam. Program: Yes    Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                    Reformulated Gas: No
0 Veh. Type:          LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV        MC  All Veh
+                   ______    ______    ______    ______    ______    ______    ______    ______    ______   ______
 Veh. Speeds:        19.6      19.6      19.6               19.6      19.6      19.6      19.6      19.6
     VMT Mix:       0.594     0.199     0.088              0.032     0.002     0.003     0.078     0.005
0Composite Emission Factors (Gm/Mile)
 VOC      HC:        1.44      1.58      2.05      1.73      3.67      0.50      0.69      2.11      5.53    1.663
 Exhaust  HC:        0.97      1.08      1.52      1.22      1.86      0.50      0.69      2.11      1.89    1.161
 Evaporat HC:        0.10      0.11      0.11      0.11      0.99                                    3.21    0.136
 Refuel L HC:        0.19      0.25      0.25      0.25      0.40                                            0.194
 Runing L HC:        0.16      0.11      0.14      0.12      0.35                                            0.139
 Rsting L HC:        0.03      0.04      0.04      0.04      0.06                                    0.43    0.033
 Exhaust  CO:       13.08     14.28     18.73     15.64     26.62      1.41      1.57     11.21     24.78   14.108
 Exhaust NOX:        0.97      1.09      1.49      1.22      3.95      1.08      1.22      7.29      0.77    1.629
 ____________________________________________________________________________________________________________________
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2011        I/M Program: Yes      Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                   Anti-tam. Program: Yes    Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                    Reformulated Gas: No
0 Veh. Type:          LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV        MC  All Veh
+                   ______    ______    ______    ______    ______    ______    ______    ______    ______   ______
 Veh. Speeds:        19.6      19.6      19.6               19.6      19.6      19.6      19.6      19.6
     VMT Mix:       0.588     0.201     0.088              0.032     0.002     0.003     0.080     0.005
0Composite Emission Factors (Gm/Mile)
 VOC      HC:        1.39      1.54      2.00      1.68      2.86      0.51      0.69      2.10      5.53    1.597
 Exhaust  HC:        0.96      1.07      1.52      1.21      1.58      0.51      0.69      2.10      1.89    1.147
 Evaporat HC:        0.09      0.09      0.09      0.09      0.64                                    3.21    0.114
 Refuel L HC:        0.19      0.25      0.25      0.25      0.40                                            0.194
 Runing L HC:        0.14      0.10      0.12      0.11      0.20                                            0.117
 Rsting L HC:        0.02      0.03      0.03      0.03      0.04                                    0.43    0.025
 Exhaust  CO:       13.07     14.31     18.88     15.70     18.32      1.42      1.58     11.18     24.78   13.850
 Exhaust NOX:        0.96      1.08      1.48      1.20      3.83      1.07      1.22      6.86      0.77    1.598
 ____________________________________________________________________________________________________________________
```

```
1 Maximum ASM, Purge, Pressure (biennial) 0.4/8.0/1.8
 MOBILE5a (26-Mar-93)
0
-M114 Warning:
+              Purge Check emission benefits assume the use of a dynomometer and
               the IM240 transient test procedure driving cycle.
0I/M program selected:

0    Start year (January 1):             1983
     Pre-1981 MYR stringency rate:        40%
     First model year covered:           1968
     Last model year covered:            2020
     Waiver rate (pre-1981):              3.%
     Waiver rate (1981 and newer):        3.%
     Compliance Rate:                    96.%
     Inspection type:                    Test Only
     Inspection frequency                Biennial
     Vehicle types covered:              LDGV - Yes
                                        LDGT1 - Yes
                                        LDGT2 - Yes
                                         HDGV - Yes
     1981 & later MYR test type:         Loaded / Idle
     Cutpoints, HC:    0.400   CO:    8.000   NOx:    1.800
0Functional Check Program Description:
0Check Start   Model Yrs  Vehicle Classes Covered        Inspection       Comp
       (Jan1)  Covered    LDGV   LDGT1  LDGT2  HDGV    Type     Freq      Rate

 Press 1983    1971-2020  Yes    Yes    Yes    Yes Test Only    Biennial  96.0%
 Purge 1983    1971-2020  Yes    Yes    Yes    Yes Test Only    Biennial  96.0%
 ATP   1983    1971-2020  Yes    Yes    Yes    Yes Test Only    Biennial  96.0%
0Air pump system disablements:       Yes  Catalyst removals:                 Yes
 Fuel inlet restrictor disablements: Yes  Tailpipe lead deposit test:        Yes
 EGR disablement:                    Yes  Evaporative system disablements:   Yes
 PCV system disablements:            Yes  Missing gas caps:                  Yes
0...............                              Minimum Temp:  72. (F)        Maximum Temp:  92. (F)
                       Period 1 RVP: 10.5     Period 2 RVP:  8.7        Period 2 Start Yr: 1992
0VOC HC emission factors include evaporative HC emission factors.
0
________________________________________________________________________________________________________________
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2000        I/M Program: Yes      Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                  Anti-tam. Program: Yes    Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                   Reformulated Gas: No
0  Veh. Type:     LDGV      LDGT1    LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV     MC     All Veh
+                ______    ______    ______    ______    ______    ______    ______    ______    ______  ______
 Veh. Speeds:    19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:     0.616     0.191     0.086               0.031     0.002     0.001    0.068     0.006
0Composite Emission Factors (Gm/Mile)
 VOC      HC:     1.80      1.91      2.58      2.12      6.23      0.65      0.87      2.23     5.53     2.073
 Exhaust  HC:     1.08      1.23      1.75      1.39      2.99      0.65      0.87      2.23     1.89     1.308
 Evaporat HC:     0.16      0.20      0.25      0.21      1.97                                   3.21     0.241
 Refuel L HC:     0.19      0.25      0.25      0.25      0.41                                            0.196
 Runing L HC:     0.30      0.18      0.26      0.20      0.76                                            0.266
 Rsting L HC:     0.06      0.06      0.06      0.06      0.10                                   0.43     0.062
 Exhaust  CO:    13.94     15.90     20.63     17.37     59.30      1.60      1.76     11.58    24.78    16.172
 Exhaust NOX:     1.12      1.27      1.72      1.41      4.71      1.37      1.51     10.69     0.77     1.958
 _______________________________________________________________________________________________________________
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May 6, 1993

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0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2001        I/M Program: Yes       Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                     Anti-tam. Program: Yes    Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                      Reformulated Gas: No
0  Veh. Type:         LDGV       LDGT1      LDGT2       LDGT       HDGV       LDDV       LDDT       HDDV        MC      All Veh
+                   ______     ______     ______     ______     ______     ______     ______     ______     ______     ______
 Veh. Speeds:        19.6       19.6       19.6                  19.6       19.6       19.6       19.6       19.6
    VMT Mix:         0.613      0.192      0.086                 0.031      0.001      0.001      0.069      0.006
0Composite Emission Factors (Gm/Mile)
 VOC      HC:        1.74       1.86       2.49       2.05       5.65       0.61       0.80       2.20       5.53      2.001
 Exhaust  HC:        1.07       1.20       1.72       1.36       2.70       0.61       0.80       2.20       1.89      1.283
 Evaporat HC:        0.15       0.18       0.23       0.19       1.76                                        3.21      0.221
 Refuel L HC:        0.19       0.25       0.25       0.25       0.41                                                  0.195
 Runing L HC:        0.28       0.17       0.24       0.19       0.68                                                  0.245
 Rsting L HC:        0.06       0.06       0.06       0.06       0.10                                        0.43      0.057
 Exhaust  CO:       13.85      15.62      20.38      17.09      51.17       1.55       1.69      11.49      24.78     15.786
 Exhaust NOX:        1.09       1.24       1.68       1.37       4.56       1.30       1.41       9.94       0.77      1.891
 ----------------------------------------------------------------------------------------------------------------------------
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2003        I/M Program: Yes       Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                     Anti-tam. Program: Yes    Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                      Reformulated Gas: No
0  Veh. Type:         LDGV       LDGT1      LDGT2       LDGT       HDGV       LDDV       LDDT       HDDV        MC      All Veh
+                   ______     ______     ______     ______     ______     ______     ______     ______     ______     ______
 Veh. Speeds:        19.6       19.6       19.6                  19.6       19.6       19.6       19.6       19.6
    VMT Mix:         0.606      0.194      0.087                 0.031      0.002      0.002      0.072      0.006
0Composite Emission Factors (Gm/Mile)
 VOC      HC:        1.64       1.76       2.28       1.92       4.73       0.56       0.74       2.14       5.53      1.874
 Exhaust  HC:        1.04       1.17       1.65       1.32       2.26       0.56       0.74       2.14       1.89      1.243
 Evaporat HC:        0.13       0.15       0.15       0.15       1.43                                        3.21      0.183
 Refuel L HC:        0.19       0.25       0.25       0.25       0.41                                                  0.195
 Runing L HC:        0.24       0.15       0.19       0.16       0.54                                                  0.206
 Rsting L HC:        0.05       0.05       0.05       0.05       0.08                                        0.43      0.048
 Exhaust  CO:       13.75      15.22      19.94      16.68      38.08       1.48       1.63      11.36      24.78     15.189
 Exhaust NOX:        1.06       1.19       1.60       1.32       4.40       1.18       1.31       8.67       0.77      1.783
 ----------------------------------------------------------------------------------------------------------------------------
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2006        I/M Program: Yes       Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                     Anti-tam. Program: Yes    Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                      Reformulated Gas: No
0  Veh. Type:         LDGV       LDGT1      LDGT2       LDGT       HDGV       LDDV       LDDT       HDDV        MC      All Veh
+                   ______     ______     ______     ______     ______     ______     ______     ______     ______     ______
 Veh. Speeds:        19.6       19.6       19.6                  19.6       19.6       19.6       19.6       19.6
    VMT Mix:         0.599      0.197      0.087                 0.031      0.002      0.002      0.076      0.006
0Composite Emission Factors (Gm/Mile)
 VOC      HC:        1.54       1.67       2.16       1.82       4.08       0.51       0.71       2.11       5.53      1.761
 Exhaust  HC:        1.01       1.13       1.57       1.26       2.02       0.51       0.71       2.11       1.89      1.203
 Evaporat HC:        0.11       0.12       0.12       0.12       1.16                                        3.21      0.155
 Refuel L HC:        0.19       0.25       0.25       0.25       0.40                                                  0.194
 Runing L HC:        0.19       0.13       0.17       0.14       0.43                                                  0.171
 Rsting L HC:        0.04       0.04       0.04       0.04       0.07                                        0.43      0.038
 Exhaust  CO:       13.63      14.92      19.42      16.29      30.45       1.42       1.59      11.24      24.78     14.749
 Exhaust NOX:        1.02       1.15       1.57       1.28       4.15       1.10       1.25       7.74       0.77      1.698
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0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2008        I/M Program: Yes      Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                   Anti-tam. Program: Yes     Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                    Reformulated Gas: No
0  Veh. Type:        LDGV      LDGT1      LDGT2      LDGT       HDGV       LDDV       LDDT       HDDV       MC      All Veh
+                  ______    ______     ______     ______     ______     ______     ______     ______     ______    ______
 Veh. Speeds:       19.6      19.6       19.6                  19.6       19.6       19.6       19.6       19.6
     VMT Mix:       0.594     0.199      0.088                 0.032      0.002      0.003      0.078      0.005
0Composite Emission Factors (Gm/Mile)
 VOC      HC:       1.49      1.64       2.12       1.79       3.84       0.50       0.69       2.11       5.53      1.717
 Exhaust  HC:       1.00      1.12       1.56       1.25       1.98       0.50       0.69       2.11       1.89      1.194
 Evaporat HC:       0.10      0.11       0.11       0.11       1.02                                         3.21      0.143
 Refuel L HC:       0.19      0.25       0.25       0.25       0.40                                                   0.194
 Runing L HC:       0.17      0.13       0.16       0.14       0.37                                                   0.153
 Rsting L HC:       0.03      0.04       0.04       0.04       0.06                                         0.43      0.033
 Exhaust  CO:      13.63     14.88      19.47      16.29      28.14       1.41       1.57      11.21      24.78     14.669
 Exhaust NOX:       1.00      1.12       1.53       1.25       3.99       1.08       1.22       7.29       0.77      1.655
 ______________________________________________________________________________________________________________________
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2011        I/M Program: Yes      Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                   Anti-tam. Program: Yes     Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                    Reformulated Gas: No
0  Veh. Type:        LDGV      LDGT1      LDGT2      LDGT       HDGV       LDDV       LDDT       HDDV       MC      All Veh
+                  ______    ______     ______     ______     ______     ______     ______     ______     ______    ______
 Veh. Speeds:       19.6      19.6       19.6                  19.6       19.6       19.6       19.6       19.6
     VMT Mix:       0.588     0.201      0.088                 0.032      0.002      0.003      0.080      0.005
0Composite Emission Factors (Gm/Mile)
 VOC      HC:       1.44      1.60       2.07       1.74       3.02       0.51       0.69       2.10       5.53      1.650
 Exhaust  HC:       0.99      1.11       1.56       1.24       1.68       0.51       0.69       2.10       1.89      1.179
 Evaporat HC:       0.09      0.10       0.10       0.10       0.66                                         3.21      0.122
 Refuel L HC:       0.19      0.25       0.25       0.25       0.40                                                   0.194
 Runing L HC:       0.15      0.12       0.14       0.12       0.23                                                   0.131
 Rsting L HC:       0.02      0.03       0.03       0.03       0.04                                         0.43      0.025
 Exhaust  CO:      13.62     14.92      19.62      16.35      19.39       1.42       1.58      11.18      24.78     14.395
 Exhaust NOX:       0.99      1.11       1.52       1.23       3.87       1.07       1.22       6.86       0.77      1.623
 ______________________________________________________________________________________________________________________
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1 Enhanced Performance Standard
 MOBILE5a (26-Mar-93)
0I/M program #1 selected:                         I/M program #2 selected:

0Start year (Jan 1):  1983                        Start year (Jan 1):  1983
 Pre-1981 stringency: 20%                         Pre-1981 stringency: 20%
 First MYR covered:   1968                        First MYR covered:   1986
 Last MYR covered:    2020                        Last MYR covered:    2020
 Waiver (pre-1981):    3.%                        Waiver (pre-1981):    3.%
 Waiver (1981+):       3.%                        Waiver (1981+):       3.%
 Compliance Rate:     96.%                        Compliance Rate:     96.%
 Inspection type:                                 Inspection type:
 Test Only                                        Test Only
 Inspection frequency: Annual                     Inspection frequency: Annual
 I/M program #1 vehicle types                     I/M program #2 vehicle types
      LDGV - Yes                                       LDGV - Yes
     LDGT1 - Yes                                      LDGT1 - Yes
     LDGT2 - Yes                                      LDGT2 - Yes
      HDGV - No                                        HDGV - Yes
 1981 & later MYR test type:                      1981 & later MYR test type:
      2500 rpm / Idle                                  IM240 test
 Cutpoints, HC:   220.000                         Cutpoints, HC:      0.800
 Cutpoints, CO:     1.200                         Cutpoints, CO:     20.000
 Cutpoints, NOx:  999.000                         Cutpoints, NOx:     2.000

0Functional Check Program Description:
0Check Start   Model Yrs  Vehicle Classes Covered       Inspection        Comp
       (Jan1)  Covered    LDGV   LDGT1  LDGT2  HDGV   Type       Freq      Rate

 Press 1983    1983-2020  Yes    Yes    Yes    No  Test Only     Annual    96.0%
 Purge 1983    1986-2020  Yes    Yes    Yes    No  Test Only     Annual    96.0%
 ATP   1983    1984-2020  Yes    Yes    Yes    No  Test Only     Annual    96.0%
0Air pump system disablements:       No   Catalyst removals:                  Yes
 Fuel inlet restrictor disablements: Yes  Tailpipe lead deposit test:         No
 EGR disablement:                    No   Evaporative system disablements:    No
 PCV system disablements:            No   Missing gas caps:                   No
0...............                   Minimum Temp:  72. (F)        Maximum Temp:  92. (F)
                     Period 1 RVP: 10.5    Period 2 RVP:  8.7      Period 2 Start Yr: 1992
0VOC HC emission factors include evaporative HC emission factors.
0
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2000       I/M Program: Yes      Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                 Anti-tam. Program: Yes    Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                  Reformulated Gas: No
0  Veh. Type:     LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV        MC   All Veh
+               ______    ______    ______    ______    ______    ______    ______    ______    ______    ______
 Veh. Speeds:     19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:    0.616     0.191     0.086               0.031     0.002     0.001     0.068     0.006
0Composite Emission Factors (Gm/Mile)
 VOC       HC:    1.63      1.82      2.37      1.99      6.94      0.65      0.87      2.23      5.53     1.955
 Exhaust   HC:    0.88      1.06      1.48      1.19      3.05      0.65      0.87      2.23      1.89     1.132
 Evaporat  HC:    0.18      0.22      0.27      0.24      2.32                                    3.21     0.267
 Refuel L  HC:    0.19      0.25      0.25      0.25      0.41                                             0.196
 Runing L  HC:    0.32      0.22      0.31      0.25      1.05                                             0.298
 Rsting L  HC:    0.06      0.06      0.06      0.06      0.10                                    0.43     0.062
 Exhaust   CO:   11.89     14.49     18.72     15.81     63.66      1.60      1.76     11.58     24.78    14.612
 Exhaust  NOX:    1.14      1.27      1.71      1.41      4.71      1.37      1.51     10.69      0.77     1.968
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0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2001        I/M Program: Yes       Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                    Anti-tam. Program: Yes      Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                     Reformulated Gas: No
0  Veh. Type:      LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV      MC     All Veh
+                 ------   ------    ------    ------    ------    ------    ------    ------    ------   ------
 Veh. Speeds:      19.6     19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:      0.613    0.192     0.086               0.031     0.001     0.001     0.069     0.006
0Composite Emission Factors (Gm/Mile)
 VOC       HC:     1.54     1.71      2.23      1.87      6.38      0.61      0.80      2.20      5.53     1.852
 Exhaust   HC:     0.85     1.01      1.41      1.13      2.74      0.61      0.80      2.20      1.89     1.086
 Evaporat  HC:     0.16     0.20      0.24      0.21      2.14                                    3.21     0.245
 Refuel L  HC:     0.19     0.25      0.25      0.25      0.41                                             0.195
 Runing L  HC:     0.29     0.20      0.28      0.22      1.00                                             0.270
 Rsting L  HC:     0.06     0.06      0.06      0.06      0.10                                    0.43     0.057
 Exhaust   CO:    11.59    13.90     18.06     15.19     54.65      1.55      1.69     11.49     24.78    13.978
 Exhaust  NOX:     1.10     1.22      1.65      1.35      4.56      1.30      1.41      9.94      0.77     1.890
 ----------------------------------------------------------------------------------------------------------------
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2003        I/M Program: Yes       Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                    Anti-tam. Program: Yes      Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                     Reformulated Gas: No
0  Veh. Type:      LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV      MC     All Veh
+                 ------   ------    ------    ------    ------    ------    ------    ------    ------   ------
 Veh. Speeds:      19.6     19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:      0.606    0.194     0.087               0.031     0.002     0.002     0.072     0.006
0Composite Emission Factors (Gm/Mile)
 VOC       HC:     1.40     1.55      1.96      1.68      5.52      0.56      0.74      2.14      5.53     1.682
 Exhaust   HC:     0.80     0.93      1.28      1.04      2.26      0.56      0.74      2.14      1.89     1.014
 Evaporat  HC:     0.13     0.16      0.16      0.16      1.86                                    3.21     0.203
 Refuel L  HC:     0.19     0.25      0.25      0.25      0.41                                             0.195
 Runing L  HC:     0.24     0.16      0.22      0.18      0.91                                             0.223
 Rsting L  HC:     0.05     0.05      0.05      0.05      0.08                                    0.43     0.048
 Exhaust   CO:    11.17    13.08     16.91     14.26     40.04      1.48      1.63     11.36     24.78    13.005
 Exhaust  NOX:     1.04     1.17      1.57      1.29      4.39      1.18      1.31      8.67      0.77     1.767
 ----------------------------------------------------------------------------------------------------------------
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2006        I/M Program: Yes       Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                    Anti-tam. Program: Yes      Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                     Reformulated Gas: No
0  Veh. Type:      LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV      MC     All Veh
+                 ------   ------    ------    ------    ------    ------    ------    ------    ------   ------
 Veh. Speeds:      19.6     19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:      0.599    0.197     0.087               0.031     0.002     0.002     0.076     0.006
0Composite Emission Factors (Gm/Mile)
 VOC       HC:     1.26     1.40      1.73      1.50      4.93      0.51      0.71      2.11      5.53     1.531
 Exhaust   HC:     0.74     0.85      1.14      0.94      1.99      0.51      0.71      2.11      1.89     0.949
 Evaporat  HC:     0.11     0.12      0.13      0.12      1.63                                    3.21     0.171
 Refuel L  HC:     0.19     0.25      0.25      0.25      0.40                                             0.194
 Runing L  HC:     0.19     0.13      0.18      0.15      0.84                                             0.179
 Rsting L  HC:     0.04     0.04      0.04      0.04      0.07                                    0.43     0.038
 Exhaust   CO:    10.83    12.40     15.76     13.43     31.53      1.42      1.59     11.24     24.78    12.293
 Exhaust  NOX:     0.99     1.11      1.51      1.23      4.14      1.10      1.25      7.74      0.77     1.668
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April 22, 1993

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0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2008        I/M Program: Yes       Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                   Anti-tam. Program: Yes     Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                    Reformulated Gas: No
0 Veh. Type:         LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV        MC    All Veh
+                   ______    ______    ______    ______    ______    ______    ______    ______    ______    ______
 Veh. Speeds:        19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:       0.594     0.199     0.088               0.032     0.002     0.003     0.078     0.005
0Composite Emission Factors (Gm/Mile)
 VOC       HC:       1.20      1.34      1.65      1.44      4.71      0.50      0.69      2.11      5.53      1.472
 Exhaust   HC:       0.73      0.83      1.11      0.91      1.94      0.50      0.69      2.11      1.89      0.931
 Evaporat  HC:       0.10      0.11      0.11      0.11      1.51                                    3.21      0.157
 Refuel L  HC:       0.19      0.25      0.25      0.25      0.40                                              0.194
 Runing L  HC:       0.16      0.12      0.15      0.13      0.79                                              0.157
 Rsting L  HC:       0.03      0.04      0.04      0.04      0.06                                    0.43      0.033
 Exhaust   CO:      10.72     12.30     15.68     13.33     28.91      1.41      1.57     11.21     24.78     12.122
 Exhaust  NOX:       0.97      1.08      1.48      1.20      3.98      1.08      1.22      7.29      0.77      1.621
 ---------------------------------------------------------------------------------------------------------------------
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2011        I/M Program: Yes       Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                   Anti-tam. Program: Yes     Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                    Reformulated Gas: No
0 Veh. Type:         LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV        MC    All Veh
+                   ______    ______    ______    ______    ______    ______    ______    ______    ______    ______
 Veh. Speeds:        19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:       0.588     0.201     0.088               0.032     0.002     0.003     0.080     0.005
0Composite Emission Factors (Gm/Mile)
 VOC       HC:       1.14      1.27      1.54      1.35      3.95      0.51      0.69      2.10      5.53      1.389
 Exhaust   HC:       0.71      0.80      1.05      0.88      1.61      0.51      0.69      2.10      1.89      0.902
 Evaporat  HC:       0.09      0.09      0.09      0.09      1.21                                    3.21      0.135
 Refuel L  HC:       0.19      0.25      0.25      0.25      0.40                                              0.194
 Runing L  HC:       0.14      0.10      0.12      0.11      0.69                                              0.132
 Rsting L  HC:       0.02      0.03      0.03      0.03      0.04                                    0.43      0.025
 Exhaust   CO:      10.62     12.15     15.43     13.15     19.07      1.42      1.58     11.18     24.78     11.694
 Exhaust  NOX:       0.94      1.06      1.43      1.17      3.85      1.07      1.22      6.86      0.77      1.576
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April 22, 1993

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1 NO I/M (DEFAULT LAP)
 MOBILE5a (26-Mar-93)
0................                            Minimum Temp:  72. (F)        Maximum Temp:  92. (F)
                    Period 1 RVP: 10.5       Period 2 RVP:  8.7       Period 2 Start Yr: 1992
0VOC HC emission factors include evaporative HC emission factors.
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2000          I/M Program: No       Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                    Anti-tam. Program: No     Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                     Reformulated Gas: No
0  Veh. Type:      LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV        MC   All Veh
+                ______    ______    ______    ______    ______    ______    ______    ______    ______    ______
 Veh. Speeds:      19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:     0.616     0.191     0.086               0.031     0.002     0.001     0.068     0.006
0Composite Emission Factors (Gm/Mile)
 VOC      HC:      2.56      2.93      3.90      3.23      7.14      0.65      0.87      2.23      5.53     2.877
 Exhaust  HC:      1.46      1.80      2.53      2.03      3.24      0.65      0.87      2.23      1.89     1.728
 Evaporat HC:      0.28      0.34      0.40      0.36      2.32                                    3.21     0.363
 Refuel L HC:      0.19      0.25      0.25      0.25      0.41                                             0.196
 Runing L HC:      0.57      0.48      0.66      0.54      1.05                                             0.529
 Rsting L HC:      0.06      0.06      0.06      0.06      0.10                                    0.43     0.062
 Exhaust  CO:     20.09     23.94     32.84     26.70     66.26      1.60      1.76     11.58     24.78    22.753
 Exhaust NOX:      1.43      1.67      2.27      1.86      4.82      1.37      1.51     10.69      0.77     2.274
 ---------------------------------------------------------------------------------------------------------------
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2001          I/M Program: No       Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                    Anti-tam. Program: No     Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                     Reformulated Gas: No
0  Veh. Type:      LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV        MC   All Veh
+                ______    ______    ______    ______    ______    ______    ______    ______    ______    ______
 Veh. Speeds:      19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:     0.613     0.192     0.086               0.031     0.001     0.001     0.069     0.006
0Composite Emission Factors (Gm/Mile)
 VOC      HC:      2.49      2.85      3.82      3.15      6.60      0.61      0.80      2.20      5.53     2.796
 Exhaust  HC:      1.44      1.75      2.50      1.98      2.95      0.61      0.80      2.20      1.89     1.692
 Evaporat HC:      0.27      0.32      0.37      0.34      2.15                                    3.21     0.344
 Refuel L HC:      0.19      0.25      0.25      0.25      0.41                                             0.195
 Runing L HC:      0.54      0.47      0.65      0.52      1.00                                             0.507
 Rsting L HC:      0.06      0.06      0.06      0.06      0.10                                    0.43     0.057
 Exhaust  CO:     19.92     23.43     32.36     26.20     57.38      1.55      1.69     11.49     24.78    22.228
 Exhaust NOX:      1.40      1.64      2.23      1.82      4.68      1.30      1.41      9.94      0.77     2.207
 ---------------------------------------------------------------------------------------------------------------
0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2003          I/M Program: No       Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                    Anti-tam. Program: No     Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                     Reformulated Gas: No
0  Veh. Type:      LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV        MC   All Veh
+                ______    ______    ______    ______    ______    ______    ______    ______    ______    ______
 Veh. Speeds:      19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:     0.606     0.194     0.087               0.031     0.002     0.002     0.072     0.006
0Composite Emission Factors (Gm/Mile)
 VOC      HC:      2.38      2.72      3.65      3.00      5.76      0.56      0.74      2.14      5.53     2.655
 Exhaust  HC:      1.41      1.69      2.43      1.92      2.50      0.56      0.74      2.14      1.89     1.639
 Evaporat HC:      0.24      0.29      0.30      0.29      1.87                                    3.21     0.307
 Refuel L HC:      0.19      0.25      0.25      0.25      0.41                                             0.195
 Runing L HC:      0.49      0.45      0.61      0.50      0.91                                             0.467
 Rsting L HC:      0.05      0.05      0.05      0.05      0.08                                    0.43     0.048
 Exhaust  CO:     19.73     22.72     31.27     25.35     43.09      1.48      1.63     11.36     24.78    21.410
 Exhaust NOX:      1.36      1.60      2.18      1.78      4.54      1.18      1.31      8.67      0.77     2.098
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0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2006        I/M Program: No        Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                  Anti-tam. Program: No      Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                   Reformulated Gas: No
0  Veh. Type:        LDGV      LDGT1      LDGT2       LDGT       HDGV       LDDV       LDDT       HDDV        MC     All Veh
+                   ______     ______     ______     ______     ______     ______     ______     ______     ______     ______
 Veh. Speeds:       19.6       19.6       19.6                  19.6       19.6       19.6       19.6       19.6
     VMT Mix:        0.599      0.197      0.087                 0.031      0.002      0.002      0.076      0.006
0Composite Emission Factors (Gm/Mile)
 VOC       HC:       2.25       2.58       3.47       2.85       5.20       0.51       0.71       2.11       5.53      2.519
 Exhaust   HC:       1.37       1.62       2.31       1.83       2.25       0.51       0.71       2.11       1.89      1.583
 Evaporat HC:        0.22       0.26       0.28       0.27       1.64                                         3.21      0.278
 Refuel L HC:        0.19       0.25       0.25       0.25       0.40                                                   0.194
 Runing L HC:        0.44       0.42       0.59       0.47       0.84                                                   0.425
 Rsting L HC:        0.04       0.04       0.04       0.04       0.07                                         0.43      0.038
 Exhaust   CO:      19.55      22.20      30.39      24.70      34.83       1.42       1.59      11.24      24.78     20.821
 Exhaust NOX:        1.32       1.56       2.16       1.74       4.30       1.10       1.25       7.74       0.77      2.015

0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2008        I/M Program: No        Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                  Anti-tam. Program: No      Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                   Reformulated Gas: No
0  Veh. Type:        LDGV      LDGT1      LDGT2       LDGT       HDGV       LDDV       LDDT       HDDV        MC     All Veh
+                   ______     ______     ______     ______     ______     ______     ______     ______     ______     ______
 Veh. Speeds:       19.6       19.6       19.6                  19.6       19.6       19.6       19.6       19.6
     VMT Mix:        0.594      0.199      0.088                 0.032      0.002      0.003      0.078      0.005
0Composite Emission Factors (Gm/Mile)
 VOC       HC:       2.20       2.54       3.42       2.81       4.99       0.50       0.69       2.11       5.53      2.466
 Exhaust   HC:       1.36       1.60       2.30       1.81       2.22       0.50       0.69       2.11       1.89      1.573
 Evaporat HC:        0.21       0.25       0.27       0.26       1.52                                         3.21      0.265
 Refuel L HC:        0.19       0.25       0.25       0.25       0.40                                                   0.194
 Runing L HC:        0.41       0.41       0.57       0.46       0.79                                                   0.401
 Rsting L HC:        0.03       0.04       0.04       0.04       0.06                                         0.43      0.033
 Exhaust   CO:      19.54      22.17      30.53      24.72      32.34       1.41       1.57      11.21      24.78     20.737
 Exhaust NOX:        1.30       1.53       2.15       1.72       4.14       1.08       1.22       7.29       0.77      1.973

0Emission factors are as of Jan. 1st of the indicated calendar year.
0Cal. Year: 2011        I/M Program: No        Ambient Temp: 87.5 / 87.5 / 87.5 (F) Region: Low
                  Anti-tam. Program: No      Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                   Reformulated Gas: No
0  Veh. Type:        LDGV      LDGT1      LDGT2       LDGT       HDGV       LDDV       LDDT       HDDV        MC     All Veh
+                   ______     ______     ______     ______     ______     ______     ______     ______     ______     ______
 Veh. Speeds:       19.6       19.6       19.6                  19.6       19.6       19.6       19.6       19.6
     VMT Mix:        0.588      0.201      0.088                 0.032      0.002      0.003      0.080      0.005
0Composite Emission Factors (Gm/Mile)
 VOC       HC:       2.14       2.48       3.34       2.74       4.26       0.51       0.69       2.10       5.53      2.387
 Exhaust   HC:       1.35       1.60       2.29       1.81       1.91       0.51       0.69       2.10       1.89      1.558
 Evaporat HC:        0.20       0.23       0.25       0.24       1.22                                         3.21      0.242
 Refuel L HC:        0.19       0.25       0.25       0.25       0.40                                                   0.194
 Runing L HC:        0.38       0.38       0.52       0.42       0.69                                                   0.368
 Rsting L HC:        0.02       0.03       0.03       0.03       0.04                                         0.43      0.025
 Exhaust   CO:      19.53      22.25      30.83      24.86      22.73       1.42       1.58      11.18      24.78     20.445
 Exhaust NOX:        1.29       1.53       2.14       1.71       4.03       1.07       1.22       6.86       0.77      1.940
```

Appendix J:

Emissions Analyzer Price Information from Horiba

HORIBA
HORIBA INSTRUMENTS INCORPORATED
3901 Varsity Drive, Ann Arbor, Michigan 48108
Telephone: 1(800) 3 HORIBA. In Mich. 1(800) 624-0899 or (313) 973-2171
Fax: (313) 973-7868

April 7, 1993

Environmental Protection Agency
2565 Plymouth Road
Ann Arbor, MI 48105

Attn: Mr. Bill Pidgeon

Re: IM 240 Analyzer Information

Dear Mr. Pidgeon:

This letter is a follow-up to prior discussions we've had regarding the list price of IM 240 Analyzer Systems. We would like to thank you for the opportunity of discussing our equipment and market with you and your staff.

We would like to make a clarification in reference to the IM 240 pricing. Horiba is actively working with six of the seven centralized contractors. Four of these contractors currently have IM 240 analyzers installed. The current list price for the Analyzer/CVS System is $75,515. It should be noted that this price does not include a blower or external sample line. As you can understand, this is a "single unit price" and does not reflect discounting for quantity orders. For long-term pricing considerations, it should be recognized that we also anticipate price reductions following improvements in manufacturing efficiencies.

Horiba's analytical system can be supplied with other options, such as; a driver's aid, purge and pressure equipment, data collection and processing capabilities.

<u>IM 240 Analyzer System</u>

HC - FID
CO - NDIR
CO_2 - NDIR
NOx - Chemiluminescent
CVS - 500-700 CFM

Total:	$75,515

We feel that our forte' is in the analytical and sample handling portion of the testing lane. For this reason, we are providing you with analytical system pricing only. Most of our customers have sourced or built the other components themselves.

If you should have any additional comments or questions, please feel free to contact me at 1-800-3HORIBA.

Sincerely,

Kenneth W. Thomas
Marketing Manager,
IM Systems

KWT/pm

cc: Neal Harvey
Andy Marko

kt041.ltr

Appendix K:

Centrifugal Blower Price Quotation from Combined Fluid Products Company

COMBINED
FLUID
PRODUCTS
COMPANY

QUOTATION

ISSUED FROM

☐ **805 Oakwood Rd., Lake Zurich, IL 60047**
Phone (708) 540-0054 FAX (708) 540-0513

☐ **125 N. Executive Dr., Brookfield, WI 53005**
Phone (414) 258-7770 FAX (414) 821-1492

☐ **P.O. Box 216, 24 S. Green St., Brownsburg, IN 46112**
Phone (317) 852-3961 FAX (317) 852-2337

☒ **5025 Venture Dr., Ann Arbor, MI 48108**
Phone (313) 930-2024 FAX (313) 747-7040

Please Note:
A/R Dept. is located in Lake Zurich, Illinois

TO: Environmental Protection Agency
2565 Plymouth Road
Ann Arbor, Michigan 48105

ATTENTION: Mr. Dan Sampson

EFFECTIVE DATE: January 27, 1993

REFERENCE:

EXPIRATION DATE: February 27, 1993

QUOTATION NO.: AA408

In Compliance With Your Request. We Are Pleased to Quote You As Follows:

QUANTITY	DESCRIPTION	PRICE
1-10	Paxton Centrifugal Blower Model RM-87, including: 10 HP electric motor running at 3,600 RPM on 230/460 volt vacuum, three-phase, 60 Hz, TEFC motor. - Inlet Filter/Silencer	$3,320.00 Per Unit Net
11-100	....	$2,656.00 Per Unit Net

DELIVERY: Six to eight weeks F.O.B. Santa Monica, California (Delivery Subject to Prior Sale)

TERMS: Net 30 Days, Subject To Credit Approval

COMBINED FLUID PRODUCTS CO.

Scott P. Corrunker, Sales Engineer

This quotation subject to standard terms and conditions of sale as stated on reverse side.
Please use the Acceptance form to place your order.

Appendix L:

Average IM240 Test Time Utilizing Preliminary Fast-Pass and Fast-Fail Algorithms

Average IM240 Test Time Utilizing Preliminary Fast-Pass and Fast-Fail Algorithms

The objective of this analysis was to estimate the average IM240 test time using algorithms that allow vehicles with very low emissions to fast-pass and vehicles with very high emissions to fast-fail. This reduces the average time required for the IM240, allowing higher throughput, which reduces the number of inspection lanes required. The reduced number of lanes lowers equipment and personnel costs, having the potential to significantly improve the cost effectiveness of the I/M program.

This analysis describes the fast-pass and fast-fail algorithms used to estimate the average IM240 test time. The results are preliminary, representing what could be achieved in time to comply with the court ordered deadline for this rulemaking. Developing these algorithms requires using second-by-second data for HC, CO, NOx, and purge, which is very time consuming, given the huge amount of data per vehicle.

The ideal fast-pass/fast-fail algorithm consists of two continuous functions. One function represents emission levels at each second of the IM240 that reliably predict a passing result while the other function represents emission levels that reliably predict a failing result. Because this requires evaluating the results at each second of the test for each of the vehicles, we determined that this could not be achieved under the time constraint. Instead, we evaluated nine segments (modes) of the IM240, which significantly reduces the burden, but gives a less than optimal result.

So, additional fast-pass and fast-fail algorithms will be evaluated in the future, and additional vehicles will be available for those analyses, so these results should be regarded as preliminary. For example, very low emitters or extremely high emitters can be fast-passed or fast-failed early in the IM240 cycle, while vehicles near the certification emission levels will require more time to accurately predict a passing or failing result. The emission reduction benefits, obtained from repairing vehicles whose emission levels are slightly dirtier than their certification standards, are not very cost effective. Similarly, it also may not be cost effective to run the full IM240 as required to accurately distinguish marginal emitters that pass the full IM240 from marginal emitters that fail. This can be evaluated by comparing IDRs, failure rates, and error of commission rates for each second of the IM240 to determine the best tradeoff.

Another consideration is the IM240 reversed. The IM240 was designed as a two-mode test. The second mode includes the maximum speed of 56.7 mph. The

IM240-reversed starts with this high speed mode, then is followed by the low speed mode. This may further reduce the average test time required to distinguish malfunctioning cars from properly functioning cars. It should be especially helpful in rapidly determining whether the purge system is performing adequately.

The algorithm used in this analysis was comparatively crude due to time and data handling constraints. Several discrete modes of the IM240 were selected for determining passing and failing emission levels. These modes were selected to avoid ending the test during an acceleration or deceleration and to provide a reasonable duration for each of the nine modes. The average IM240 test time was calculated as the average of the selected mode times weighted by the number of vehicles passing or failing at each mode. A more detailed description of the data and methodology used as well as the results are included in the following sections.

The database used for this analysis conformed to the model I/M program, so it was limited to 1986 and newer vehicles with second-by-second IM240 results - 494 vehicles. These vehicles were tested between June 4, 1992 and August 4, 1992. Data were only used if the composite results calculated from the second-by-second data had passed EPA's quality control measures. Due to the volume of second-by-second data and the time constraints involved, the second-by-second data were not QC'd separately.

The following nine modes were selected for pass/fail determinations:

Modes For Evaluating Fast-Pass And Fast-Fail

Mode (#)	IM240 Mode (secs.)	IM240 Speed @ End of Mode (mph)
1	0 - 34	22.6
2	0 - 60	30.4
3	0 - 74	29.8
4	0 - 93	0.0
5	0 - 113	27.2
6	0 - 154	26.0
7	0 - 173	47.2
8	0 - 206	51.6
9	0 - 239	0.0

To determine the passing and failing emission levels for each mode, the sample was divided into passing and failing vehicles. The pass/fail determination was made based on the "two ways to pass" criteria with 0.8 g/mi

HC, 15.0 g/mi CO and 2.0 g/mi NOx as composite IM240 cutpoints and, 0.5 g/mi HC and 12.0 g/mi CO bag 2 cutpoints. One liter of purge volume was used as the cutpoint for purge flow. These criteria are illustrated below.

Pass/Fail Decisions Based On Two-Ways-To-Pass-Criteria

Decision	IM240 HC g/mi	IM240 CO g/mi	Bag 2 HC g/mi	Bag 2 CO g/mi	IM240 NOx g/mi	Purge liters	Comments
Fail	> **0.8**	≤ 15.0	> **0.5**	≤ 12.0	≤ 2.0	≤1.0	Must fail HC on both Composite & Bag 2 to fail.
Fail	≤ 0.8	**>15.0**	≤ 0.5	**>12.0**	≤ 2.0	≤1.0	Must fail CO on both Composite & Bag 2 to fail.
Fail	≤ 0.8	≤ 15.0	≤ 0.5	≤ 12.0	> **2.0**	≤1.0	Only 1 way to Pass: Composite NOx ≤ 2.0 to pass.
Fail	≤ 0.8	≤15.0	≤0.5	≤12.0	≤ 2.0	**≥1.0**	
Pass	≤ 0.8	≤ 15.0	≤ 0.5	≤ 12.0	≤ 2.0	≤1.0	
Pass	> **0.8**	**>15.0**	≤ 0.5	≤ 12.0	≤ 2.0	≤1.0	
Pass	≤ 0.8	≤ 15.0	> **0.5**	**>12.0**	≤ 2.0	≤1.0	
Pass	> **0.8**	≤ 15.0	≤ 0.5	≤ 12.0	≤ 2.0	≤1.0	
Pass	≤ 0.8	≤ 15.0	> **0.5**	≤ 12.0	≤ 2.0	≤1.0	
Pass	≤ 0.8	**>15.0**	≤ 0.5	≤ 12.0	≤ 2.0	≤1.0	
Pass	≤ 0.8	≤ 15.0	≤ 0.5	**>12.0**	≤ 2.0	≤1.0	

The minimum emission levels and maximum purge volume for failing vehicles at each mode were used as fast-pass cutpoints. Conversely, the maximum emission levels for passing vehicles at each mode were used as fast-fail cutpoints. Vehicles were not fast-failed based on purge results since many vehicles purge late in the IM240 cycle. As mentioned, the IM240-reversed may help rapidly determine if the purge system is functioning adequately.

The modal cutpoint levels, the number of vehicles fast-passing or fast-failing at each mode and the average IM240 test time as a result of the application of this fast-pass/fast-fail algorithm are displayed in the following table.

Mode #	Time (sec)	Fast-pass Cutpoints <HC/CO/NOx >Purge	Number of Vehicles Fast-passing	Fast-fail Cutpoints >HC/CO/NOx	Number of Vehicles Fast-failing	Number of Vehicles Fast-passing and Fast-failing	Time * Number of Vehicles with Fast Result
1	0-34	<0.479/1.02/0.99 >0.1	16	>3.405/56.72/7.30	15	31	1054
2	0-60	<0.487/0.89/0.99 >0.3	2	>1.891/47.30/4.63	22	24	1440
3	0-74	<0.429/0.929/0.90 >0.3	1	>1.648/38.09/3.58	7	8	592
4	0-93	<0.377/0.921/0.84 >0.4	0	>1.536/41.09/3.19	9	9	837
5	0-113	<0.460/0.932/0.89 >0.5	3	>1.518/36.78/3.02	6	9	1017
6	0-154	<0.567/1.088/0.96 >0.6	3	>1.296/30.34/2.57	11	14	2156
7	0-173	<0.697/3.52/1.33 >0.7	65	>1.120/25.22/2.65	11	76	13148
8	0-206	<0.916/14.99/1.77 >0.8	210	>0.915/18.06/2.33	35	245	50470
9	0-239	≤0.805/15.05/2.05 ≥1.0	45	>0.805/15.05/2.05	33	78	18642
		Weighted Sum with Fast-pass Only	102410			Weighted Sum	89356
		Average IM240 Test Time with Fast-pass Only =	207 sec			Average IM240 Test Time =	180 sec

These results indicate that the test time for the IM240 can be reduced by 25% when fast-pass/fast-fail criteria are applied and a reduction of over half a minute occurs when only fast-pass criteria are applied. Using only fast-pass criteria allows for the collection of diagnostic data so that failing cars may be repaired more effectively.

Because Hammond cars with second-by-second data were typically shut off for 10 minutes, catalyst cool down could have caused high emissions during the early parts of the test and adversely affected fast-pass and fast-fail. Similarly, vehicles that drive a short distance to an I/M station may not be fully warmed up when they start the test. Therefore, additional analyses were performed without integrating over the first part of the IM240. In effect, utilizing the first segment of the IM240 as preconditioning. Three different integration starting points were used. Since the accelerations contribute the most toward catalyst light-off, these starting points follow the first three accelerations of the IM240 cycle. The integrations begin after 17, 35 and 47 seconds of the test. The results of these analyses are displayed here.

Mode #	Time (sec)	Fast-pass Cutpoints <HC/CO/NOx >Purge	Number of Vehicles Fast-passing	Fast-fail Cutpoints >HC/CO/NOx	Number of Vehicles Fast-failing	Number of Vehicles Fast-passing and Fast-failing	Time * Number of Vehicles with Fast Result
1	17-34	<0.525/0.95/1.33 >0.1	11	>2.643/76.94/10.33	19	30	1020
2	17-60	<0.504/0.54/1.10 >0.3	1	>1.892/53.86/5.11	11	12	720
3	17-74	<0.465/0.90/0.96 >0.3	4	>1.615/41.40/3.77	11	15	1110
4	17-93	<0.400/0.90/0.88 >0.4	0	>1.498/45.64/3.27	10	10	930
5	17-113	<0.486/0.91/0.93 >0.5	5	>1.484/40.16/3.08	7	12	1356
6	17-154	<0.593/1.09/1.00 >0.6	3	>1.265/32.27/2.66	10	13	2002
7	17-173	<0.641/3.08/1.38 >0.7	56	>1.080/26.48/2.71	10	66	11418
8	17-206	<0.826/15.33/1.82 >0.8	217	>0.936/18.44/2.32	37	254	52324
9	17-239	≤0.805/15.05/2.05 ≥1.0	48	>0.805/15.05/2.05	34	82	19598
		Weighted Sum with Fast-pass Only	103230			Weighted Sum	90478
		Average IM240 Test Time with Fast-pass Only	209 sec			Average IM240 Test Time	183 sec

Mode #	Time (sec)	Fast-pass Cutpoints <HC/CO/NOx >Purge	Number of Vehicles Fast-passing	Fast-fail Cutpoints >HC/CO/NOx	Number of Vehicles Fast-failing	Number of Vehicles Fast-passing and Fast-failing	Time * Number of Vehicles with Fast Result
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	35-60	<0.493/0.79/0.90 >0.3	19	>1.983/41.71/3.71	41	60	3600
3	35-74	<0.403/0.73/0.79 >0.3	4	>1.499/31.32/3.08	8	12	888
4	35-93	<0.340/0.69/0.75 >0.4	2	>1.450/55.71/3.09	5	7	651
5	35-113	<0.454/0.91/0.82 >0.5	5	>1.406/47.21/3.07	3	8	904
6	35-154	<0.585/1.10/0.93 >0.6	2	>1.299/35.99/2.59	7	9	1386
7	35-173	<0.575/2.85/1.37 >0.7	48	>1.061/28.83/2.81	7	55	9515
8	35-206	<0.795/15.17/1.84 >0.8	221	>0.966/19.48/2.37	35	256	52736
9	35-239	≤0.805/15.05/2.05 ≥1.0	44	>0.805/15.05/2.05	43	87	20793
		Weighted Sum with Fast-pass Only	102452			Weighted Sum	90473
		Average IM240 Test Time with Fast-pass Only	207 sec			Average IM240 Test Time	183 sec

Mode #	Time (sec)	Fast-pass Cutpoints <HC/CO/NOx >Purge	Number of Vehicles Fast-passing	Fast-fail Cutpoints >HC/CO/NOx	Number of Vehicles Fast-failing	Number of Vehicles Fast-passing and Fast-failing	Time * Number of Vehicles with Fast Result
1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	47-60	<0.458/0.40/1.05 >0.3	6	>2.089/37.20/3.67	41	47	2820
3	47-74	<0.375/0.46/0.83 >0.3	9	>1.282/33.21/2.99	14	23	1702
4	47-93	<0.310/0.52/0.76 >0.4	5	>1.737/67.22/3.10	0	5	465
5	47-113	<0.434/0.94/0.85 >0.5	15	>1.619/54.68/3.08	2	17	1921
6	47-154	<0.594/1.14/0.96 >0.6	4	>1.355/39.55/2.55	8	12	1848
7	47-173	<0.550/2.88/1.43 >0.7	48	>1.095/30.98/2.82	4	52	8996
8	47-206	<0.751/14.82/1.91 >0.8	220	>1.004/20.39/2.42	35	255	52530
9	47-239	≤0.805/15.05/2.05 ≥1.0	38	>0.805/15.05/2.05	45	83	19837
		Weighted Sum with Fast-pass Only	102119			Weighted Sum	90119
		Average IM240 Test Time with Fast-pass Only	207 sec			Average IM240 Test Time	182 sec

These results indicate, that for the data used in this analysis, preconditioning has little effect on the average test time of the fast-pass/fast-fail algorithm used. In spite of this, these estimates are considered conservative for several reasons. First, older cars are excluded from the analysis. Since most grossly emitting vehicles are older vehicles, the inclusion of these cars would be expected to increase the number of fast-failing vehicles and reduce the test time further. However, this reduction may be offset by a reduction in the percentage of vehicles fast-passing. More important than the vehicle sample is the algorithm used. If a continuous function were used, actual test times could be used to calculate the average. This should lead to significant time savings compared to using the last second of a particular mode as the required test time for all vehicles that pass or fail during that mode. It is unlikely that all the vehicles failing or passing a particular mode would have required the full mode to determine their outcome. Therefore, average test times for vehicles passing the IM240 at second 60 would be significantly less than 60 seconds. Likewise, this would be true for each mode. On-going analyses are being performed to investigate this and other alternatives such as the IM240-reversed. Finally, EPA will continue to develop alternative algorithms which are also expected to reduce the average test time for the IM240.