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Determination of Emissions Credit and Average Test Times for IM147 Testing

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Disclaimer

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Determination of Emissions Credit and Average Test Times for IM147 Testing

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1. SUMMARY

Background

Under the Clean Air Act Amendments of 1990, metropolitan areas with the most serious air quality problems are required to implement so-called "enhanced" I/M programs. Two different test procedures for exhaust emissions testing in enhanced programs have been approved by EPA: the "IM240" test, and the "Acceleration Simulation Mode" (ASM) test. With either procedure, the efficiency of the testing process depends on how quickly accurate decisions can be made as to whether a vehicle should pass or fail.

Efficiency is important to both the cost and the public acceptability of I/M programs. For this reason, methods that maintain the accuracy of the tests, but can reduce test time are important. This is especially true for programs that have been operating for a number of years and the capacity of the test networks is being consumed. The reduction in testing capacity is being caused by several reasons including (1) the increased failure rates that will occur as more stringent cutpoints are implemented, causing fewer fast-passes (i.e., longer tests) and also more after repair retests; and (2) increases in the number of vehicles subject to testing (the fleet is growing). Unless measures are taken in current programs to offset the overall impact of these factors, a substantial increase in the existing network capacities will be needed to keep wait times at acceptable levels. This, of course, would translate into increased per-test fees. The main goal of the present work was to evaluate means of reducing test times while maintaining the emissions benefits associated with the IM240 test.

The most significant challenge to reducing test time is the potential for false failures as a result of inadequate preconditioning. Before the vehicle is thoroughly warmed up, high emissions can be caused by air-fuel ratio enrichment or an inactive catalytic converter. In addition, increased emissions due to purging of loaded canisters may also be an issue associated with inadequate preconditioning prior to I/M testing. In back-to-back IM240 testing of 336 vehicles conducted in 1997 by Gordon-Darby at its test lanes in Arizona, 19% of the 1981 and later model passenger cars and light trucks failing the initial IM240 test (based on the startup cutpoints) passed when immediately retested; 6% would have passed the <u>final cutpoints</u> on the retest after failing the startup cutpoints on the initial test.[1*] For these reasons, attempts to shorten the test length need to carefully evaluate the effects of inadequate preconditioning on false failures.

During 1996 and 1997, Sierra conducted evaluations of preconditioning requirements using data obtained from samples of vehicles recruited from IM240 lanes in Phoenix, Arizona, and a laboratory test program at Sierra's facilities in Sacramento, California.

[*] Superscripts denote references listed in Section 6 of this report.

The conclusions from the two evaluations were that (1) a vehicle needing further preconditioning can be identified through modal analysis of the emissions recorded during the test; and (2) using the more aggressive portion of the IM240 (the last 147 seconds, often referred to as "Phase 2"*) may warm vehicles up faster while reducing test time.

Sierra performed an initial analysis of the IM240 Phase 2-only test option under contract to the State of Arizona Department of Environmental Quality (DEQ).[2] That study was based on a combination of data from the 2% random test sample (consisting entirely of full-duration tests) routinely collected in the Arizona IM240 program and a limited number (101 tests) of triplicate (back-to-back-to-back) tests of Phase 2 of the IM240 (herein after called the "IM147") conducted as part of the 1997 EPA evaluation. Cutpoints were developed for the full IM147 and the second half of the IM147 (seconds 67 to 147) to complement the full IM147 cutpoints. Fast-pass cutpoints for both the entire IM147 and Phase 2 of the IM147 were also developed. The present study was developed as a follow-up to verify the credit level estimates of the previous work and also provide a more robust estimate of average IM147 test times.

As the data from the test lanes were being analyzed to evaluate repeat or return tests, it was discovered that a significant fraction of vehicles never passed their final IM240 test. Even accounting for the issuance of program waivers, the incomplete repair rate ranged from 5% to 27% depending on model year range and vehicle type. Several possibilities were theorized to account for the high incomplete repair rate, including vehicles being scrapped, sold out of the area, registered illegally out of the area but continuing to operate within the area, or driven illegally without current registration. Part of the current study was to determine the fate of these vehicles with excess emissions to determine if they are still operating on the road.

Scope of Work

For this study, Sierra was to assist in the development and implementation of a testing program to collect sufficient data to throughly evaluate the IM147 relative to the IM240. Data were collected from over 300 randomly selected light-duty cars and trucks arriving at the test lane during normal queuing conditions. Data collected include triplicate Phase 2 test results, followed immediately by a full-duration IM240 test.

The first step in the analysis of the testing data was to use the data collected under Task 1 to revise the fast-pass cutpoints and algorithms previously developed for IM147 testing. Startup, alternative (or intermediate), and final standards were developed for both the full IM147 test and Phase 2 (the second half of the test). Excess emissions were calculated over the range of IM147 cutpoints developed by Sierra by summing the excess emissions

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* The second portion of the IM 240 (seconds 94 to 239) is herein after called the "end portion of the IM240." If those 147 seconds are used alone as a single test as opposed to the second portion of the IM240, it is designated as the "IM147." This has been done for clarification because "Phase 2" of the IM147 is discussed later in the report, which represents seconds 67 to 147 of the IM147 test. This will be referred to as "Phase 2."

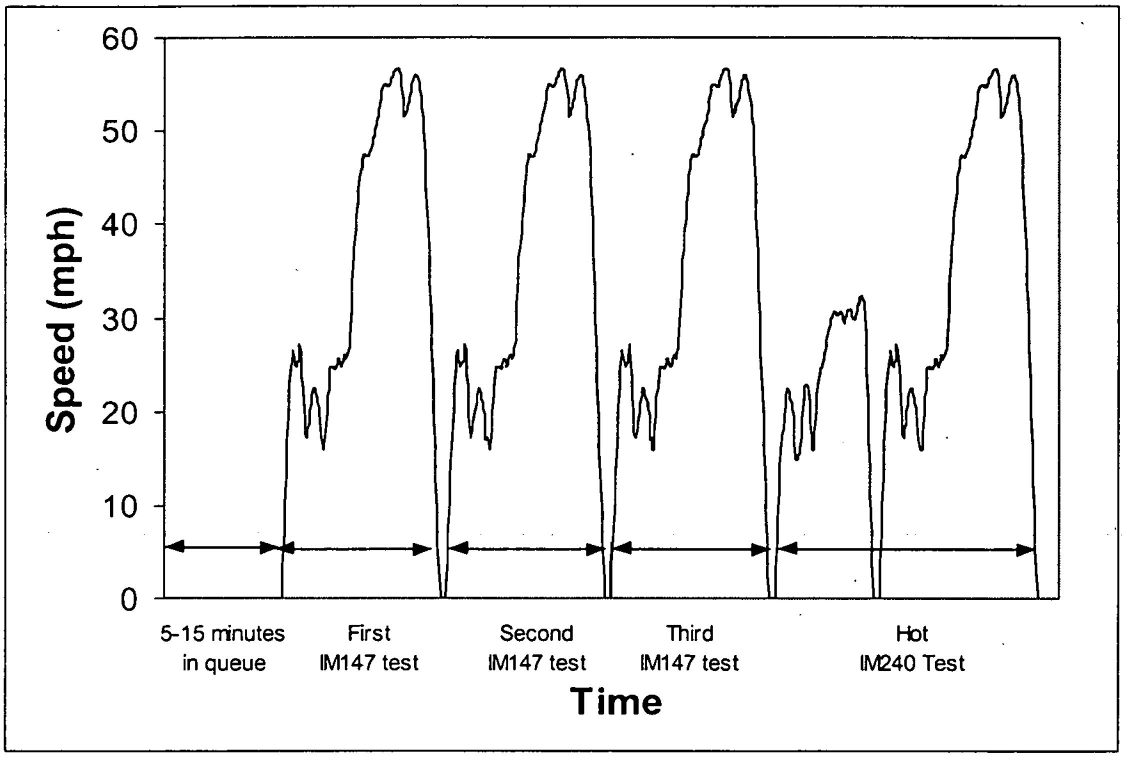
identified for the test fleet by the IM147 test and dividing by the sum of the excess emissions identified for the same vehicles by the subsequent IM240 test. The effect on excess emissions identification due to exempting up to 10 model years was also quantified. At the same time, the effect on average test times was estimated for the test fleet for each of the IM147 conditions considered. To determine the fate of the "disappearing" vehicles, Sierra analyzed historical I/M data combined with remote sensing data to quantify the air quality benefit impact of failing vehicles not receiving a passing IM240 test. The disposition of disappearing vehicles was evaluated by analyzing remote sensing data to see if these vehicles were still operating in the enhanced area. Based on the results of the above investigation, an analysis was conducted of the effect of such illegal vehicle operation on excess emissions. Suggested solutions are provided to address the problem from both a practical program implementation standpoint and a SIP credit allocation perspective.

Test Data Used in This Study

Gordon-Darby conducted the test program at its I/M lanes in Phoenix, Arizona, from March 2 to March 17, 1998. That program included 304 vehicles (193 cars and 111 light-duty trucks) tested over triplicate IM147 tests followed by a full IM240 test, as shown in Figure 1-1. The selection process used resulted in vehicles waiting in a queue for approximately 5 to 15 minutes prior to testing.

Initial analysis of the data reveals substantial reductions in mean IM147 scores between the first and second test in the sequence, with lesser reductions occurring between the second and third test in the sequence. There were a few vehicles in the sample that had inconsistent emissions across the series of four tests. There were 24 vehicles that fell into this group but there were four vehicles that stood out because they all had significantly higher HC and CO emissions during the full IM240 procedure than during the first three IM147 tests. After detailed analysis of the modal (second-by-second) data from each of these four vehicles, the cause of the inconsistent emissions from these vehicles could not be satisfactorily explained. Because the only IM240 used for evaluation of the IM147 is at the end of the testing, the simplistic analysis of excess emissions identified by the IM147 test using the final IM240 as the "gold standard" will cause IM147 testing to look poor by comparison since it would falsely pass several vehicles with very high CO emissions. However, it is apparent that the higher emissions certain vehicles exhibited during the IM240 are due to some anomaly and not to a fundamental problem with the IM147 trace. If these vehicles had been tested over three IM240 tests, they most likely would have also exhibited similar behavior. For these reasons, these four vehicles were removed from the analysis because equivalent (non-preconditioned) IM240 emissions information for these vehicles could not be determined.

Figure 1-1
Test Sequence Used to Investigate Triplicate IM147 Tests in Arizona Test Lanes



Development of IM147 Cutpoints

For the IM147, startup, intermediate, and final cutpoints were developed, as well as "two ways to pass" cutpoints. For each set of standards, an assessment of the excess emission losses using the IM147 versus the IM240 was performed and the potential effect on test time from using the IM147 was evaluated. The test time modeling was performed with the sample test fleet data using the IM147 (with a maximum of two retests) versus using the IM240 (with a maximum of one retest).

Next, methods to reduce the test time were evaluated. As mentioned previously, if test time can be reduced, this is equivalent to increasing the testing network's capacity at no additional cost. In addition, reductions in test time can also help to reduce wait times for consumers. Previous studies by Sierra have investigated several techniques that can be applied to the test data from vehicles while they are being tested to reduce the overall test time, with only minor losses in the excess emissions identified. The first method developed was fast-pass standards to allow very clean vehicles to exit the test early. The next method developed was retest algorithms that can predict if a failing vehicle would pass if retested. If a vehicle would not pass if retested, then retesting the vehicle is only increasing the test time with no benefit. The last technique evaluated was model year exemptions. Exempting newer model year vehicles from testing for their first four or five years can significantly reduce total test time for the fleet. Since new vehicles rarely fail I/M tests, the excess emissions lost from not testing these vehicles should be small.

Each of these techniques to reduce test time was also evaluated for its impact on reducing test time at the cost of potentially losing some excess emissions. The testing of each technique built on the previous technique, i.e., testing of the retest algorithms was done while first applying the fast pass criteria. There were several instances where this building- block approach produced unexpected but beneficial results.

<u>Cutpoint Selection</u> - Development of the cutpoints for the IM147 was based on linear regressions between full (composite) IM240 emission rates and emission rates for the IM147 portion of those same IM240 tests by model year group. The IM240 test data used were from the 304 vehicles described earlier with the four outliers removed from the data set. Using the regressions and then modifying the resulting cutpoints for discontinuities, startup, intermediate, and final cutpoints were developed for LDGVs, LDGT1s, and LDGT2s. The intermediate cutpoints were based on simply applying the regression equations to the average of the IM240 composite startup and the final cutpoints. The resulting standards are presented in Section 4 of this report.

To evaluate the impact of the new cutpoints on test time and excess emissions identified, the modal data from the 300 vehicles used to develop the standards were "tested" using the two-way-to-pass methodology for all three IM147s and the IM240 at the end of the testing pattern. The IM240 was used as the standard for comparing excess emissions identified, with excess emissions defined as emissions above the cutpoints on the IM240. If a vehicle failed the IM240 and the vehicle also failed the IM147, then the IM147 would be attributed with capturing the excess emissions from that vehicle, and those emissions would have a value equal to the IM240 emissions over the IM240 standard. If the IM147 did not fail a vehicle that failed the IM240, the excess emissions from the IM240 (emissions over the IM240 standard for the IM240 test) were considered excess emissions not identified. The ratio of excess emissions for vehicles failing the IM147 versus vehicles failing the IM240 is the percent of excess emissions identified.

Analysis of the new cutpoints shows there were a few excess emissions lost with the use of the IM147 versus the IM240. For startup standards, the IM147 identified all of the excess emissions the IM240 identified and only lost 0.8% of the excess HC emissions with the intermediate standards. The maximum loss was 1.8% of excess emissions for CO using the final standards. On an individual pollutant basis, HC and CO failure rates for LDT1s were underpredicted, while for NOx the failure rates were slightly overpredicted. LDT2s predicted well for CO from the first test; HC and NOx were overpredicted for the first test, but agreed well with IM240 failure rates for the third IM147 test. Looking at the failure rates by model year showed a similar trend between the pollutants, in that the first IM147 test failure rate is about 30% to 40% higher than the IM240, but agrees well after the second IM147 test. For 1981-1985 model year vehicles, the agreement for HC is good by the second IM147 test; however, the IM147 underpredicts the failure rates for CO, and the agreement for NOx is not good until the third IM147 test. For 1986-1989 model year vehicles, the third IM147 test for HC underpredicted failure rates and the second IM147 test overpredicted failure rates. NOx failure rates were overpredicted even for the third test. The failing sample for 1990-1993 model year vehicles was small, but the agreement was good after the third test for all three pollutants, with the largest variation in NOx emissions for the first IM147 test. There were too few failing 1994 and newer vehicles to determine if the cutpoints agree well.

Review of the test times show a 20% increase in test time going from startup cutpoints to final cutpoints. As expected, test times by model year group were higher for older model year vehicles, since these vehicles would have higher emissions and be more likely to fail the test, requiring another test.

Methods to Reduce Test Time

Fast-Pass - The first technique applied to the new IM147 test to help shorten test time was to apply fast pass standards to allow those vehicles that are functioning well below the standards to complete the test early. Development of fast-pass standards is based on regression models of the mean emissions of passing vehicles plus two times the standard error at 13 modes in the test. In all, 18 regression models were developed: six each for HC, CO, and NOx, with these six representing composite and the end portion (seconds 67 to 147) of the IM147 (herein after referred to as "Phase 2") standards for LDGVs, LDGT1s, and LDGT2s. For the IM147, the last 13 modes developed for the IM240 in the previous study were used and the last four of these modes were used for the Phase 2 portion.

Again, the vehicles from this study were used to calculate excess emissions identified and change in test time both with and without fast-pass regression. This analysis was performed using the startup, intermediate, and final IM240 HC, CO, and NOx standards.

The following overall reductions in test time were achieved: 58% for startup cutpoints, 51% for intermediate cutpoints, and 41% for final cutpoints. Comparison of these test times to test times for the use of fast-pass for IM240 testing previously reported to EPA shows the IM147 has lower test times for startup and intermediate cutpoints; however, test times for final cutpoints are almost the same.

Overall, the IM147 identified over 95% of excess emissions. There was, however, variation by model year group. The majority of the loss in excess emissions came from 1985 to 1989 model year LDGTs, the only group having an excess emissions identification rate below 95%.

Modal Predictive Retest Analysis - The second method of reducing test time involved the development of algorithms to predict if a vehicle would benefit from a retest due to lack of proper preconditioning. If a vehicle would continue to fail repeated tests then retesting the vehicle would be an inefficient use of testing time. If failing vehicles that will continue to fail can be discriminated from those vehicles that would benefit from another test (vehicles that failed due to a lack of preconditioning but would pass an additional test), retesting of the fail/fail vehicles could be avoided and average test time could be reduced.

The composite emission rate, the Phase 2 emission rate, and the concentrations during four sections of the test were evaluated to determine what relationships exist in the data that can help predict if a vehicle would benefit from a retest. Due to limited sample size, LDGT1s and LDGT2s were combined for this analysis and failures between either IM147 test one and two, or IM147 test two and three, were treated the same for developing the retest criteria. Using these conditions, data from 111 failed tests (75 LDGTs and 36 LDGTs) were used for development of the retest algorithms.

Criteria development was an empirical process, involving manual evaluation of the relationships between all the data. Under the first criterion applied, a vehicle would not be retested if it failed for all three pollutants. Additional criteria used the relationships between the entire test or Phase 2 of the test relative to the emissions standards or the ratio of concentrations between mode 1 and mode 4. Applying these criteria in combination to all of the vehicles in the sample fleet that failed, the overall ability for the algorithms to correctly predict a vehicle needing a retest was 90%; however, it was better for LDGTs than for LDGVs.

Addition of the retest algorithms showed significant reductions in test time. The use of fast-pass and retest algorithms showed overall reductions in test time of 68% (from 172 seconds per test to 55 seconds per test) for startup cutpoints, 64% (from 185 seconds per test to 66 seconds per test) for intermediate cutpoints, and 61% (from 206 seconds per test to 81 seconds per test) for final cutpoints. At the same time, the impact on excess emissions lost was minor. There were several cases where the retest logic prevented a vehicle from undergoing a second test and then being falsely fast-passed, which actually prevented excess emissions from being lost.

To more objectively evaluate the accuracy of the retest predictive algorithms, they (along with the fast-pass standards) were applied to another sample of 101 vehicles tested on the IM147 in previous study.[3] The testing evaluated the false-pass or false-fail occurrences, excess emissions lost, and average test times. The results are shown in Table 1-1.

The results show that the number of errors for LDGT1&2s were larger than for LDGVs. This is most likely due to the LDGT1&2 retest criteria being based on fewer data than the LDGV retest criteria.

The percent of excess emissions identified shows the largest emissions losses for HC, then CO. All NOx emissions were identified. The losses in excess HC emissions identified are much higher than for HC in the 304-vehicle sample; however, at the same time, the excess emissions NOx loss is lower and the CO loss is in the range of the other measurements.

Table 1-1
Evaluation of Retest Criteria with 101 Vehicle Sample
Based on Final Cutpoints and Exempting 1992+ Vehicles

	Sample Size (pre-1992 MY)	Percent Correct	Retested When Vehicle Would Still Fail	Did Not Retest When Vehicle Would Pass	Percent of Excess Emissions Identified		
					HC	CO	NOx
LDGV	31	80.6 %	3.2 %	16.1 %	94.1	98.6	100
LDGT1&2	14	64.2 %	14.3 %	21.4 %	30.6	30.4	71.1
Weighted average of LDGV and LDGT1&2	45	75.6 %	6.6 %	17.8 %	74.2	89.8	92.1

Model Year Exemptions - A very efficient method to reduce the overall average test time is to simply remove some vehicles from testing. Currently, EPA has published draft guidance[4] on the use of "Clean Screening" methods for identifying potentially clean vehicles to be exempted from testing. The methods discussed in the report and currently under evaluation include the use of model year exemptions, a low emitter profile, and remote sensing to identify likely clean vehicles.

Of the proposed methods, model year exemptions are the easiest to implement and should have virtually no direct cost to implement. Part of the reason for developing methods to reduce test time is to improve the efficiency and cost effectiveness of emissions testing. For this reason, model year exemptions seem to be a very reasonable method to use and were considered as part of the present study.

The first comparison of the potential excess emissions lost from model year exemptions was performed by removing the excess emissions that occurred in the IM240 from those identified by the IM147, for the model years being considered for exemption. Vehicles in the present study ranged from 1981 to 1998 model years. However, because only one 1998 model year vehicle was in the database, it was assumed that a "current plus five" model year exemption would include exempting 1997 through 1992 model year vehicles.

Reductions in total test time using fast-pass cutpoints, retest algorithms and exempting the current plus five model years reduced test times by 82% (from 172 seconds per test to 31 seconds per test) for startup cutpoints, 78% (from 185 seconds per test to 41 seconds per test) for intermediate cutpoints, and 73% (from 206 seconds per test to 55 seconds per test) for final cutpoints. For startup cutpoints, the excess emissions lost was greatest for CO; for the intermediate cutpoints, NOx was highest. For final cutpoints, the maximum excess emissions lost was for CO at 7.9%. Table 1-2 summarizes the excess emissions identified by model years exempted, for the final IM147 cutpoints. For exempting 1994+ vehicles, the excess emissions lost is less than 2% for each of the three pollutants.

Table 1-2 **Excess Emissions Identified by Model Years Exempted Based on Final IM247 Cutpoints**			
	HC	CO	NOx
1994 +	99.6 %	98.2 %	99.9 %
1993 +	99.6 %	98.2 %	92.6 %
1992 +	96.2 %	92.6 %	92.6 %
1991 +	87.1 %	88.4 %	72.8 %

Summary of Test Time Changes - Table 1-3 summarizes the changes in test time as each of the methods to reduce test time was applied. As the table shows, up to a 73% reduction in test time can be achieved from the final standards when using the test time reduction techniques, if the exempted 1992+ model-year vehicles are included in the analysis. When only those vehicles arriving at the test lanes are considered, the possible reduction in test time drops to 44%. The largest reduction was for use of fast-pass, which is probably due to the fact that many vehicles are very clean and can get out of the emissions test quickly.

Table 1-3 **Average Test Time (seconds) by Standards and Test Time Reduction Methodology for the IM147**				
		Startup Cutpoints	Intermediate Cutpoints	Final Cutpoints
Cutpoint only, two possible retests		172	185	206
Added fast-pass		72	92	121
Added retest algorithm		55	66	81
Added exemption of 1992+ model years	All Vehicles	31	41	55
	Non-Exempt Vehicles	65	86	115
Overall % reduction in test time	All Vehicles	82%	78%	73%
	Non-Exempt Vehicles	62%	54%	44%

Summary of Excess Emissions Identified - Excess emissions identified for each pollutant are shown in Table 1-4 for each method to reduce test time and for each set of cutpoints by pollutant. Overall, total excess emissions lost by switching to the IM147 are low, up

Table 1-4
Test Time and Percent Excess Emissions Identified by the IM147 Test By Standards and Test Time Reduction Methodology

	Startup Cutpoints				Intermediate Cutpoints				Final Cutpoints			
	Test Time	HC	CO	NOx	Test Time	HC	CO	NOx	Test Time	HC	CO	NOx
Cutpoint only, two possible retests	172	100	100	100	185	99.2	100	93.6	206	99.6	98.2	99.6
Added fast-pass	72	96.5	95.1	100	92	98.8	97.8	89.5	121	99.6	95.5	99.6
Added retest algorithm	55	97.2	95.1	100	66	98.4	100	93.2	81	99.2	97.5	99.6
Added exempting 1992+ model years[a]	31	95.2	81.7	88.5	41	96.0	91.5	84.1	55	95.9	92.1	92.4

[a] Test time estimates are based on a weighted average for all vehicles, including a test time of 0 for 1992+ vehicles exempted from testing.

to the point where model years are exempted. However, for final cutpoints, the IM147 retains over 92% of the excess emissions identified by the IM240 even when exempting current plus five model years.

Disappearing Vehicles - To perform the analyses, data regarding vehicles subjected to I/M testing in Maricopa County from July through September 1997 were used to identify vehicles that initially passed or failed the I/M test. The initial test failures were tracked through the end of the year to determine which of these vehicles had still not passed an emissions test (Fail-Fail vehicles) within a three- to six-month time period following their initial test date (i.e., by December 31, 1997). To determine whether the Fail-Fail vehicles were still being operated in the area, the license plate numbers of these vehicles were compared to license plate data of vehicles identified by remote sensors in Maricopa County from January 1 through March 31, 1998. The percentages of vehicles observed in the RSD data in Fail-Fail and Fail-Pass categories are presented in Table 1-5 by model year groupings, as well as the ratio of the frequency that vehicles are seen on the road.

It was found that a smaller fraction of older vehicles were observed in the RSD data for both the Fail-Fail and the Fail-Pass categories. However, for all of the model year groups, the fraction of Fail-Fail vehicles observed by RSD is less than that of the Fail-Pass vehicles. About 50% of the Fail-Fail vehicles in the pre-1974 model year group have been removed from the road but only 9% of the 1992 and later model year Fail-Fail vehicles do not continue to operate on the road in Maricopa County. Waivered vehicles were not responsible for this difference, accounting for only 0.71% of the disappearing vehicles. In addition, further analysis indicates that about 20% of the Fail-Fail vehicles operating in the area continue to be tested in an attempt to receive a passing I/M score.

Table 1-5 Fraction of Vehicles Observed in the RSD Database that Initially Failed an I/M Test in Maricopa County					
Model Year Group	Fail-Fail July-Sept 1997	Fail-Fail Observed by RSD	Fail-Pass July-Sept 1997	Fail-Pass Observed by RSD	Ratio of Fail-Fail to Fail-Pass
Pre-1975	823	2.7%	2,657	5.3%	51%
1975-1980	2,512	4.4%	8,690	7.0%	63%
1981-1984	2,148	6.2%	4,935	8.8%	70%
1985-1987	2,279	7.8%	6,662	10.2%	77%
1988-1991	1,154	9.2%	5,432	13.0%	71%
1992 +	282	13.8%	2,645	15.2%	91%

As noted above, the issue of "disappearing" vehicles was first identified in a study performed by Sierra for DEQ. In that study, which was based on an analysis of the 2% Random Sample IM240 database, initial test results from January 1996 to December 1996 were merged with after-repair tests conducted from January 1996 through April 1997. Although a slightly different methodology was used in that analysis, similar results were obtained.

Summary - The analyses above indicate that vehicles that continue to fail the I/M test after a number of months (i.e., the Fail-Fail "disappearing" vehicles) are observed operating on the road less frequently than their counterparts that received an initial I/M test in the same time period. However, this is a function of vehicle age, with older vehicles being less likely to continue to be operated (possibly scrapped, parked, or sold outside the area) than newer vehicles. Using RSD data to infer operation frequency, it appears that about half of the pre-1975 model year Fail-Fail vehicles do not remain in operation six to nine months after their initial test, while nearly 90% of the 1992 and later model year Fail-Fail vehicles remain on the road. Of those vehicles that do remain on the road, approximately 20% continue to attempt to pass the I/M test.

The fraction of initial test failures not receiving complete repairs (i.e., the Fail-Fail vehicles) estimated in this analysis agreed very well with the results of Sierra's previous analysis prepared for DEQ. Both analyses showed that older vehicles are more likely to not be repaired completely, with about 30% of the 1981 to 1984 model year initial test failures not receiving a passing score on the last I/M test.

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2. INTRODUCTION

Background

Under the Clean Air Act Amendments of 1990, metropolitan areas with the most serious air quality problems are required to implement so-called "enhanced" I/M programs. One element of an enhanced program is a more effective test procedure than the simple idle tests used in "basic" I/M programs. Two different test procedures for exhaust emissions testing in enhanced programs have been approved by EPA: the "IM240" test, and the "Acceleration Simulation Mode" (ASM) test. Both of these procedures have been shown to be capable of separating vehicles with excessive exhaust emissions from other vehicles; however, the accuracy of the test depends on whether tested vehicles have been adequately preconditioned and whether the speed-time profile associated with each test procedure is closely followed. With either procedure, the efficiency of the testing process depends on how quickly accurate decisions can be made as to whether a vehicle should pass or fail.

Efficiency is important to both the cost and the public acceptability of I/M programs. For this reason, methods that maintain the accuracy of the tests while also reducing test time are important. This is especially true for programs that have been operating for a number of years and have reached the design capacity of the inspection network. This can be caused by several reasons, including (1) increased failure rates that will occur as more stringent cutpoints are implemented, causing fewer fast-passes (longer tests) and also more after-repair retests; and (2) increases in the number of vehicles subject to IM240 testing (i.e., the fleet is growing). Unless measures are taken in current programs to offset the overall impact of these factors, a substantial increase in existing network capacities will be needed to keep wait times at acceptable levels. The main goal of the present work was to evaluate means of reducing IM240 test times while maintaining the emissions benefits associated with this transient test.

The most significant challenge to reducing test time is the potential for a vehicle to be not properly preconditioned and thus falsely fail the emissions test. For example, Indiana has adopted the first 93 seconds of the IM240 trace, which it calls the IM93. Unfortunately, this test cycle consists of the low-speed portion of the IM240 test, and may not be aggressive enough (require enough power to drive) to fully warm up the vehicle. Inadequate preconditioning of vehicles prior to testing is a potential cause of inaccurate or inconsistent test results because exhaust emission levels depend on how thoroughly a vehicle has been warmed up. Before the vehicle is thoroughly warmed up, high emissions can be caused by air-fuel ratio enrichment or an inactive catalytic converter. In addition, increased emissions due to purging of loaded canisters may also be an issue associated with inadequate preconditioning prior to I/M testing. In back-to-back IM240 testing of 336 Arizona vehicles conducted in 1997 by Gordon-Darby, 19% of the 1981 and later model passenger cars and light trucks failing the initial IM240 test (based on the startup cutpoints) passed when immediately retested; 6% would have passed the final cutpoints on the retest after failing the startup cutpoints on the initial test.[5] For these reasons, attempts to shorten the test length, such as the IM93, need to carefully evaluate the effects of inadequate preconditioning, and address them in the analysis of the testing results.

Under current EPA guidance, IM240 preconditioning procedures are woven into the "two-ways-to-pass" standards. Vehicles that exceed the emissions standards established for the entire 240-second test are passed or failed based on emissions occurring during the last 147 seconds of the test. The separate set of standards that apply to the IM147 is slightly more stringent. For vehicles that initially demonstrate high emissions, the first 93 seconds (Phase 1) of the test are used to precondition the vehicle for the second phase of the test. In addition, EPA calls for a "second-chance" test whenever a vehicle fails the initial test by less than 50% of the standard and was in a queue for more than 20 minutes before being tested.

Considerable data have already been collected regarding the preconditioning requirements for IM240 testing. During 1996 and 1997, Sierra conducted evaluations of this issue using data obtained from samples of vehicles recruited from IM240 lanes in Phoenix, Arizona, and a laboratory test program at Sierra's facilities in Sacramento. The results of the 1996 analysis were reported in SAE Paper No. 962091. The 1997 evaluation also included an analysis of the effect on test duration of adopting EPA-recommended "final" IM240 cutpoints. Preliminary conclusions from the two evaluations are summarized below.

1. Using the current IM240 test procedures, it is estimated that 25% of the vehicles failing the final IM240 standards would pass with further preconditioning.

2. Vehicles that would benefit from further preconditioning can be identified through modal analysis of the emissions recorded during the IM240 test.

3. Two possible approaches to modifying the current preconditioning procedures would be to:

    a. retain existing IM240 test procedure and two-ways-to-pass standards, with the entire IM240 to be repeated if the IM147 emissions failure is marginal, emissions near end of the IM147 are relatively low, or emissions during the IM147 are significantly lower than during Phase 1; or

    b. eliminate Phase 1 and make the initial pass/fail decision based on running only the IM147 (which is more aggressive and thereby possibly warms the vehicles sooner), with a second-chance test (another IM147) for all vehicles that initially fail, and a third-chance IM147 test if emissions during the second-chance test are significantly lower than emissions during the initial test.

4. Adoption of final cutpoints and more effective preconditioning procedures involving a second full-IM240 (Option 3.a. above) will increase the portion of the test involving dynamometer operation by more than 100%.

As a follow-on to the 1997 evaluation for EPA, Sierra subsequently conducted an analysis for the Arizona DEQ of the effect on failure rates, I/M program benefits, and test duration of the following changes to the current IM240 procedure: (1) implementation of the Option 3.b. preconditioning procedures summarized above; (2) adoption of "intermediate" cutpoints designed to maximize the CO emission reduction benefits being achieved by the program; and (3) the exemption of either the first four or first five model years from program requirements.

Due to concerns that past CO attainment demonstrations for Maricopa County have not been realized due to inaccuracies in the MOBILE models used to generate emissions projections, a non-MOBILE-based analysis methodology was used for the DEQ analysis. To analyze the IM147 preconditioning option, Sierra used a combination of data from the 2% random test sample (consisting entirely of full-duration tests) that is routinely collected in the Arizona IM240 program and a limited number (101 tests) of triplicate (back-to-back-to-back) tests of the IM147 that were conducted as part of the 1997 EPA evaluation. A key element of the analysis methodology involved the development of cutpoints for the second half of the IM147 (Phase 2) to complement the full IM147 cutpoints. (The Phase 2 cutpoints were applied in a manner similar to the current IM240 procedure in which vehicles passing in Phase 2 are considered passing for the entire test.) Fast-pass cutpoints for both the entire IM147 and Phase 2 were also developed.

A second issue of importance in the analysis was the discovery of a significant fraction of vehicles failing on their initial test that never passed their final IM240 test. Even accounting for the issuance of program waivers, the incomplete repair rate ranged from 5% to 27% depending on model year range and vehicle type. Discussions with DEQ staff revealed that this incomplete repair rate had previously been identified as an issue of concern based on an analysis conducted by Arizona's I/M contractor, Gordon-Darby. According to DEQ staff, several possibilities have been theorized to account for the high incomplete repair rate, including vehicles being scrapped, sold out of the area, registered illegally out of the area but continuing to operate within the area, or driven illegally without current registration. Notwithstanding this speculation, no data are currently available to support any assumed distribution of the "disappearing" vehicles among these potential outcomes. In the absence of such data, it was conservatively assumed that all the disappearing vehicles (with the exception of those obtaining a program waiver) continue to operate illegally within the program area. If an analysis can show that these vehicles are not still operating on road, then there is less of a SIP credit loss from these vehicles.

As noted above, while the 1997 EPA study involved the analysis of a considerable amount of IM240 data, only a small subset (101 vehicles) was of use in projecting credit levels and test times for an IM147 test program. An additional concern is that the 101-vehicle study was not specifically designed to determine excess emission identification rates and SIP credit levels. As a result, EPA only conditionally approved the emission credits developed by Sierra in the DEQ analysis. The present study was therefore completed as a follow-up to verify this credit level and also provide a more robust estimate of average IM147 test times.

Scope of Work

Work Assignment 0-02 called for Sierra to complete the following objectives:

1. Verify the preliminary excess emission identification rates and average test time estimates that have been projected for the Arizona IM program from existing IM147 and IM240 data sets collected in previous studies; and

2. Estimate the emission benefits lost due to failing vehicles not being retested per the program specifications.

Four tasks were identified to accomplish these objectives.

Task 1, Test Plan Development and Data Collection - This task involved working with Gordon-Darby to develop and implement a plan for collecting the test data needed to complete Task 2, Excess Emissions Identification. Emissions data were collected from over 300 randomly selected light-duty cars and trucks arriving at the test lane during normal queuing conditions. Data collected include triplicate IM147 test results, followed immediately by a full-duration IM240 test.

Data collection, driver participation incentives, and other program-related details were performed under the guidance of DEQ and Gordon-Darby and were not Sierra's responsibility. However, as part of this work assignment, Sierra reimbursed Gordon-Darby for driver participation incentives and other costs associated with collecting the required data. It was planned that the data would be submitted by Gordon-Darby to Sierra on a regular basis to identify any potential problems (e.g., the lack of a representative cross-section of vehicles subject to inspection); however, due to the speed in which the data were collected, no feedback occurred.

Task 2, Excess Emissions Identification - After completion of the vehicle testing described under Task 1, Sierra analyzed the resulting data. The analysis included an evaluation of the effectiveness of the IM147 test procedures previously recommended by Sierra relative to the current IM240 test procedure. The first step in the analysis was to use the data collected under Task 1 to revise the fast-pass cutpoints and algorithms previously developed for IM147 testing. Startup, alternative (or intermediate), and final standards were developed for both the full IM147 test and Phase 2.

Using the data collected under Task 1, excess emissions were calculated over the range of IM147 cutpoints developed by Sierra. The percent excess emissions identified were calculated by summing the excess emissions identified for the test fleet by the IM147 test and dividing by the sum of the excess emissions identified for the same vehicles by the subsequent IM240 test. For the purposes of this calculation, IM240 excess emissions are defined as the difference between the vehicle's IM240 emissions and the respective EPA-recommended final IM240 cutpoint for that make and model year. If this difference was negative, i.e., the vehicle passes the IM240 cutpoint, the excess emissions are zero. The IM147 excess emissions are defined in the same way; however, this calculation is done only for those vehicles that fail the IM147 cutpoint. For each IM147 cutpoint combination considered, the false failure and false pass rates were determined. The effect of exempting up to 10 model years on excess emissions identification was also quantified.

Task 3, Test Duration - Test times for IM147 testing were estimated for the test fleet. The impact of using fast-pass IM147 cutpoints and the second-chance algorithms developed based on the 1997 analysis for EPA and the subsequent DEQ analysis, which were refined in this study under Task 2 above, were included in this evaluation. The impact of exempting up to the first 10 model years on IM147 test times was also quantified.

Task 4, Retest Non-Compliance - Sierra analyzed historical I/M data combined with remote sensing data to quantify the air quality impact of failing vehicles never receiving a passing IM240 score after being repaired. The disposition of such "disappearing" vehicles was investigated by analyzing remote sensing data to determine the fraction of those vehicles still operating in the enhanced area. Based on the results of the above investigation, an analysis was conducted of the effect of such illegal vehicle operation on excess emissions. Suggested solutions are provided to address the problem from both a practical program implementation standpoint and from a SIP credit allocation perspective.

Organization of the Report

Following this introduction, Section 3 describes data collection and the data set used in the development of alternative cutpoints, failure rates, and test times for the IM147 testing. Section 4 describes the development of IM147 standards (composite and Phase 2 for startup, intermediate, and final use), the development of a modal predictive model for determining fast pass, and the development of retest criteria for IM147 testing. The excess emissions from the use of the final standards, the fast pass, and the retest criteria are compared to the IM240 tests results. In addition, the effect on overall test time due to the use of the new standards, fast pass model, and retest criteria was determined. The addition of model year exemptions on excess emissions lost was determined for the first ten model years. Section 5 presents the analysis of the fate of disappearing vehicles and provides estimates of the excess emissions lost by disappearing vehicles not being repaired. Section 6 lists the references cited in the report. A set of appendices provides more detailed graphic and tabular presentations of data results.

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3. IM147 TEST DATA

Gordon-Darby conducted the test program under Task 1 of Work Assignment #0-02 at its I/M lanes in Phoenix, Arizona from March 2 to March 17, 1998. The program included 304 vehicles (193 cars and 111 light-duty trucks) tested over triplicate IM147 tests followed by a full IM240 test. The test sequence is illustrated in Figure 3-1. The model year distribution of the fleet is shown in Figure 3-2.

Each test center was given a $150 bonus for performing the testing, and all 10 different I/M test centers located in the Phoenix area participated. One inspector and lane in each test facility were designated as the study lane. Vehicles were tested when the facility manager determined the alternative testing would not have a negative impact on wait time. The criterion for this decision was that the number of vehicles per lane in the non-study lanes needed to be less than four.

To ensure random selection of the test, the Study Inspector would scan the queue for the closest white vehicle waiting in the lanes. If there were no white vehicles in the queue, the Inspector would look for the palest, closest vehicle waiting in the lanes. The inspector approached the first 1981 or newer vehicle following that vehicle, checked to make sure the vehicle had at least one-half of a tank of gas, and asked the vehicle owner if he or she was interested in participating in a study that would take approximately 30 minutes, for which they would receive $50. The selection process resulted in vehicles waiting in a queue for approximately 5 to 15 minutes prior to testing. Most of the vehicles participating in the program were receiving their initial test; however, 12 vehicles in the database were being re-tested after an initial failing score.

This section of the report summarizes the IM147 test results and discusses issues related to the analysis of those results.

Summary Statistics

Table 3-1 presents a summary of the mean IM147 emission rates for the vehicles tested in this program. Results are presented separately for cars versus light-duty trucks and for the following model year groups:

- 1981 - 1985;
- 1986 - 1989;
- 1990 - 1993; and
- 1994 and later.

Figure 3-1
Test Sequence Used to Investigate Triplicate IM147 Tests in Arizona Test Lanes

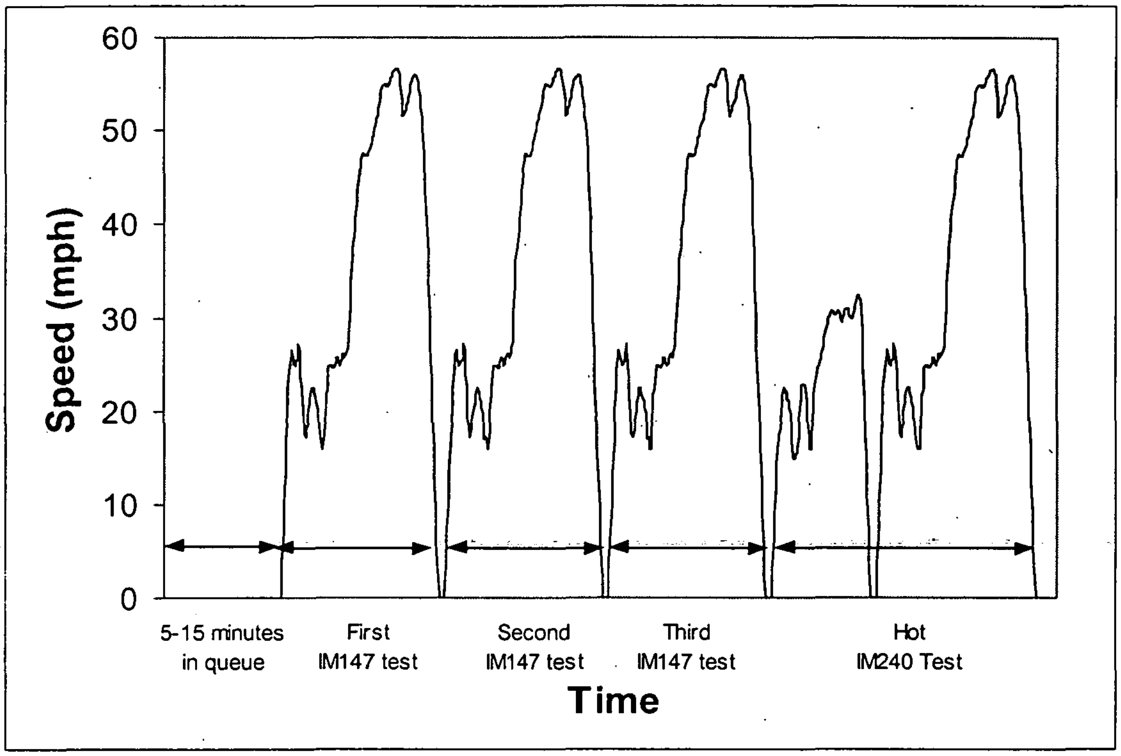


Figure 3-2
Model Year Distribution of Sample Fleet and AZ Overall Fleet

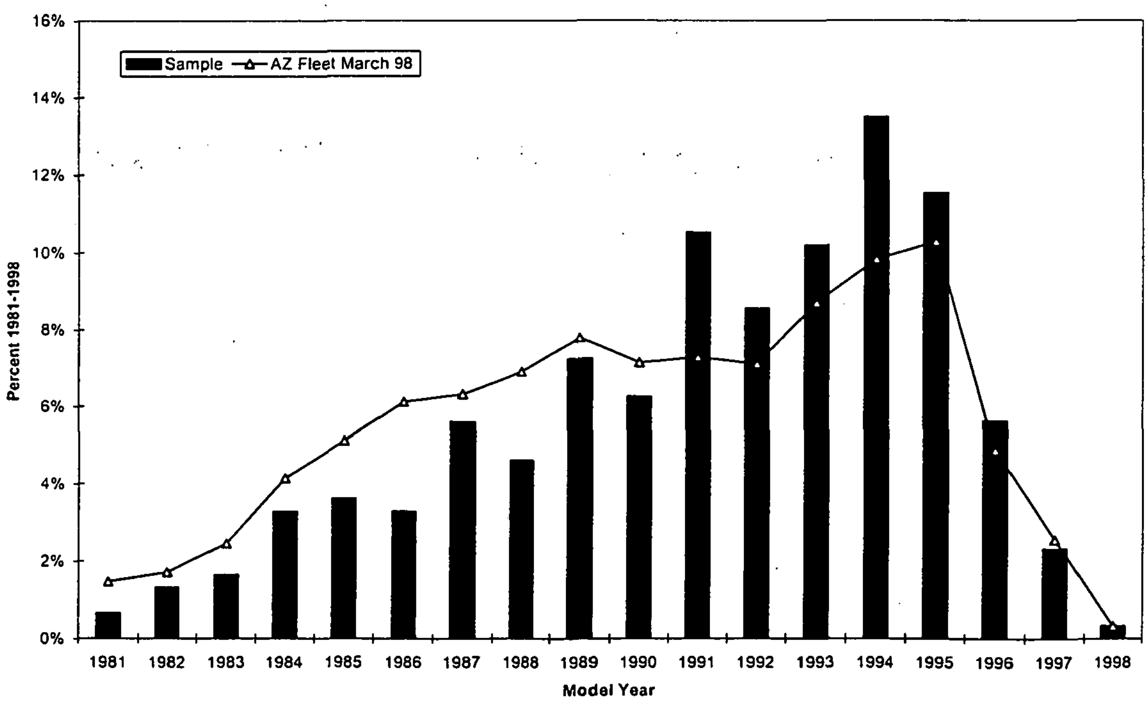


Table 3-1

Summary of Triplicate IM147 Scores by Test Sequence

Vehicle Class	MY Group	Sample Size	IM147 Sequence	Phase 2 Test Score (g/mi)		
				HC	CO	NOx
LDV	81-85	20	1	1.27	14.85	2.84
			2	0.94	13.20	2.46
			3	0.86	13.50	2.35
			IM240-Ph 2	0.83	12.47	2.28
	86-89	40	1	0.72	8.87	1.54
			2	0.47	7.26	1.33
			3	0.44	8.34	1.24
			IM240-Ph 2	0.49	10.70	1.18
	90-93	67	1	0.38	5.23	1.33
			2	0.25	4.62	1.00
			3	0.24	4.21	0.94
			IM240-Ph 2	0.22	4.10	0.92
	1994+	66	1	0.13	1.50	0.46
			2	0.05	1.06	0.35
			3	0.05	1.00	0.33
			IM240-Ph 2	0.04	0.95	0.32
LDT	81-85	12	1	1.98	23.47	4.59
			2	1.51	22.20	4.26
			3	1.36	20.90	4.09
			IM240-Ph 2	1.31	21.14	3.98
	86-89	23	1	1.37	18.43	2.29
			2	0.97	16.41	2.06
			3	0.84	15.59	2.00
			IM240-Ph 2	0.85	15.08	2.02
	90-93	41	1	0.51	6.74	1.58
			2	0.28	5.19	1.22
			3	0.25	4.38	1.21
			IM240-Ph 2	0.24	5.24	1.10
	1994+	35	1	0.25	3.77	1.05
			2	0.15	2.59	0.83
			3	0.14	2.44	0.78
			IM240-Ph 2	0.13	2.86	0.72

In addition to the triplicate IM147 emission rates (presented separately for test sequence 1 to 3), Table 3-1 contains the mean score for the end portion of the IM240 test that was conducted after the third IM147 test.

Substantial reductions in mean IM147 scores are observed between the first and second test in the sequence, with lesser reductions occurring between the second and third test in the sequence. For most model year groups and pollutants, emissions in the end portion of the IM240 continue to decline, although the reductions are diminished relative to those observed during the triplicate IM147 testing. In some cases, the end portion of the IM240 shows an increase in emissions relative to the third IM147. This is most pronounced for the 1986 to 1989 model year passenger car group, which shows an increase of 11% for HC and an increase of 28% for CO between the third IM147 and the end portion of the IM240. However, as discussed below, this effect is primarily the result of two vehicles that had much higher HC and CO emissions in the IM240 portion than in the IM147 portions of the test sequence.

Comparison of Failure Rates

As part of the recent DEQ project, Sierra developed alternative IM240 and IM147 cutpoints that resulted in similar failure rates.[6] Consistent with the requirements of that project, the "Alternative #2" IM240 cutpoints selected in the DEQ study were designed to maximize potential CO benefits while keeping failure rates (particularly for older model year vehicles) at an acceptable level (e.g., an approximate 50% failure rate for 1981 to 1985 model year vehicles). These cutpoints generally fall between the EPA start-up and final cutpoints, but in some cases (particularly for the light truck categories) the CO cutpoints are more stringent than the final EPA cutpoints.

The cutpoints developed for the DEQ project were used with the current test results to make a first-cut comparison in failure rates between IM147 testing and full IM240 testing. A summary of those cutpoints is given in Tables 3-2 and 3-3 for full IM240 testing and IM147 testing, respectively.

As reflected in Table 3-2, the full IM240 procedure incorporates a "two-ways-to-pass" methodology (i.e., separate cutpoints apply to the end portion of the IM240 or IM147, and if a vehicle passes the IM147, it passes the test). This approach allows for the first part of the test to serve as a preconditioning cycle for cases in which the IM147 emissions are below the IM147 cutpoints. In our previous analysis of IM147-only testing, it was necessary to also develop criteria for a two-ways-to-pass approach for that test. This was accomplished by establishing IM147 Phase 1 and Phase 2 components of the test and developing separate cutpoints for Phase 2. The test cycle is illustrated in Figure 3-3.

Cutpoints for Phase 2 were generated through a regression analysis relating Phase 2 to the entire IM147 emission rates. These correlation equations were then applied to the full IM147 cutpoints in Table 3-3. For this evaluation, the Phase 2 cutpoints were developed in terms of total mass of HC, CO, or NOx in Phase 2, but g/mi cutpoints could also be established if desired.

The following Phase 2 correlation equations were used to determine the Phase 2 cutpoints:

$$HC_{Phase\ 2} = 0.880 \times HC_{IM\ 147} - 0.002 \quad (3\text{-}1)$$

$$CO_{Phase\ 2} = 0.934 \times CO_{IM\ 147} - 0.689 \quad (3\text{-}2)$$

$$NOx_{Phase\ 2} = 1.034 \times NOx_{IM\ 147} - 0.064 \quad (3\text{-}3)$$

Table 3-2
DEQ "Alternative #2" Full-Cycle IM240 Cutpoints
(Composite/IM147 Cutpoints in g/mi)

Vehicle Class	Model Years	HC	CO	NOx[a]
LDGV	1981-82	3.00/1.88	25.0/20.0	3.0
	1983-85	2.20/1.38	16.0/12.8	3.0
	1986-89	1.50/0.94	15.0/12.0	2.5
	1990-93	1.00/0.63	12.0/9.6	2.5
	1994+	0.80/0.50	12.0/9.6	2.0
LDGT1	1981-85	4.00/2.50	30.0/24.0	5.0
	1986-89	3.00/1.88	25.0/20.0	4.5
	1990-93	2.00/1.25	20.0/16.0	4.0
	1994+	1.60/1.00	20.0/16.0	3.0
LDGT2	1981-85	4.40/2.75	50.0/40.0	6.0
	1986-87	4.00/2.50	40.0/32.0	5.5
	1988-89	3.00/1.88	25.0/20.0	5.5
	1990-93	3.00/1.88	25.0/20.0	5.0
	1994+	2.40/1.50	25.0/20.0	4.0

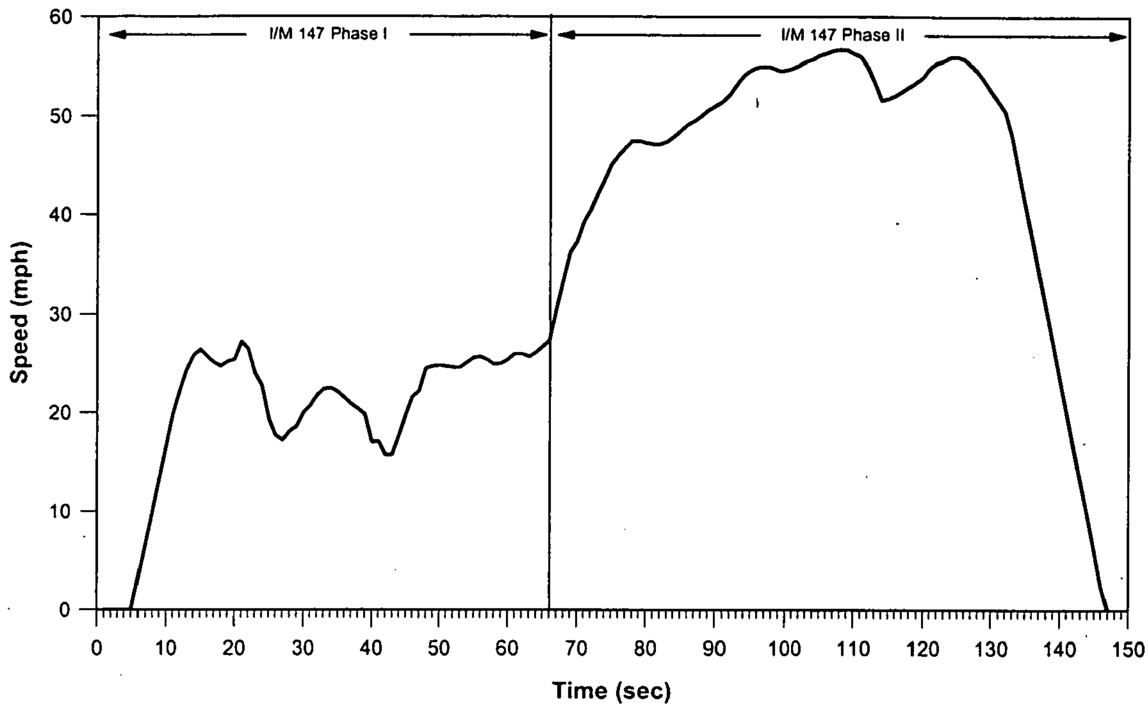
[a] NOx IM147 cutpoints are equal to the NOx composite cutpoints.

Table 3-3 DEQ "Alternative #2" IM147 Cutpoints (g/mi)				
Vehicle Class	Model Years	HC	CO	NOx
LDGV	1981-82	3.0	25	3.5
	1983-85	2.4	20	3.5
	1986-89	1.6	15	2.5
	1990-93	1.0	12	2.5
	1994+	0.8	12	2.0
LDGT1	1981-85	4.0	40	5.5
	1986-89	3.0	25	4.5
	1990-93	2.0	20	4.0
	1994+	1.6	20	3.0
LDGT2	1981-85	4.4	48	7.0
	1986-87	4.0	40	5.5
	1988-89	3.0	25	5.5
	1990-93	3.0	25	5.0
	1994+	2.4	25	4.0

Thus, the Phase 2 cutpoint for a IM147 HC cutpoint of 0.8 g/mi would simply be:

$$HC_{\text{Phase 2}} = (0.880 \times 0.8 \text{ g/mi}) - 0.002 = 0.702 \text{ grams} \quad (3\text{-}4)$$

Figure 3-3
IM147 Trace Showing Phases 1 and 2



Using the cutpoints in Tables 3-2 and 3-3 in conjunction with the test scores from the triplicate IM147 testing, failure rates were calculated for each IM147 and for the full IM240. The results of this analysis are presented in Table 3-4. As observed in that table, the failure rates for the IM147 testing generally drop from the first to the second test.

Table 3-4
IM147 and IM240 Failure Rates
Based on DEQ "Alternative #2" Cutpoints

Model Year Group	IM147 Failure Rates			IM240 Failure Rates
	First	Second	Third	
1981 - 1985	31.3%	31.3%	31.3%	37.5%
1986 - 1989	20.6%	15.9%	17.5%	19.1%
1990 - 1993	11.1%	8.3%	7.4%	8.3%
1994+	1.0%	1.0%	1.0%	2.0%
All Vehicles	11.8%	9.9%	9.9%	11.5%

Between the second and the third IM147, the failure rate for the 1986 - 1989 model year group actually increases. For the most part, this is a result of vehicles being just under the cutpoints for the second test and just over the cutpoint for the third test. Comparing the full IM240 failure rates to the IM147 failure rates, one observes that the full IM240 failure rates are slightly higher relative to the second and third IM147 tests. (This is the fairest comparison, since the first IM147 test represents vehicles in a different state of warm-up.) Inspection of the test results indicates that this is a result of imperfections in developing the IM147 cutpoints for the DEQ project. A number of the vehicles that failed the full IM240 test and passed the second or third IM147 test were just over the IM147 cutpoint, either for the full IM147 or Phase 2.

Of particular interest in the analysis of data from the triplicate IM147 testing are the vehicles that had inconsistent pass/fail scores across the series of four tests. These vehicles are highlighted in Table 3-5, which shows HC, CO, and NOx emissions results and the pass/fail status (based on the DEQ Alternative #2 cutpoints) for each test. In total, there were 24 vehicles that fell into this group. Eight of those vehicles failed the first IM147 or the first and second IM147 and then went on to pass the remaining tests in the series (i.e., record numbers 1, 6, 11, 12, 16, 20, 21, and 22 in Table 3-5). It is likely that these vehicles were not sufficiently preconditioned at the start of testing. (Later in this report, the development of an algorithm to identify such vehicles as needing a retest is described.)

Several other vehicles in Table 3-5 are very close to the cutpoints and, after passing the first test, went on to fail the second and third IM147 as well as the full IM240 test (e.g., record numbers 2 and 4). One of these vehicles (number 2) appears to have passed the Phase 2 portion of the test on the first test, but failed the remaining tests. This indicates that it may be appropriate to build in a safety margin in the Phase 2 cutpoints. Consistent with the approach used with the IM240 test, that approach was considered in the full set of IM147 cutpoints developed later in this effort. Finally, there are a few vehicles that passed all three IM147 tests but failed the full IM240. This points to an imperfection in matching failure rates for the IM147 and the full IM240.

There are four vehicles in Table 3-5 that stand out: record numbers 14, 15, 23, and 24. All of these vehicles had significantly higher HC and CO emissions during the full IM240 procedure than during the first three IM147 tests. To better understand what is happening to these vehicles, it is instructive to review the second-by-second results from the series of tests. The results for CO are shown in Figures 3-4, 3-5, 3-6, and 3-7 for record numbers 14, 15, 23, and 24, respectively. Below is a brief discussion of each vehicle.

- Record 14, a 1988 Pontiac Bonneville, had relatively low CO emissions during the first and second IM147 test (1.35 and 3.42 g/mi, respectively). However, CO emissions during the third IM147 increased substantially (to 55.72 g/mi) and were higher still during the IM240 following the IM147 testing. It is interesting to note that CO was emitted in measurable quantities throughout the test, and the large increases are not attributable to a specific section of the trace. It thus appears that the gradual émissions increase could be attributable to excessive purge as the vehicle warmed up or to some kind of catalyst protection scheme.

Table 3-5

Summary of Vehicles in the Triplicate IM147 Test Program with Non-Matching Pass/Fail Results Based on ADEQ Alternative #2 Cutpoints

Record	Model	Veh	First IM147				Second IM147				Third IM147				Full IM240 - Composite and IM147 Scores						
Number	Year	Type	HC	CO	NOx	P/F	HC	CO	NOx	P/F	HC	CO	NOx	P/F	CHC	CCO	CNOX	P2HC	P2CO	P2NOX	P/F
1	1981	LDGV	1.68	15.17	3.89	F	1.59	14.26	3.55	P	1.27	12.76	3.28	P	0.86	11.38	2.89	0.91	11.02	3.15	P
2	1984	LDGV	1.63	20.63	1.94	P	1.51	20.24	1.85	F	1.46	24.42	1.72	F	1.46	25.76	1.46	1.46	26.90	1.62	F
3	1984	LDGT1	2.51	43.33	2.64	P	2.56	41.09	2.31	P	2.35	41.42	2.58	P	3.38	59.47	1.70	2.54	48.78	2.11	F
4	1984	LDGT1	3.49	37.04	3.91	P	3.10	43.21	3.40	F	3.13	45.33	3.31	F	2.79	42.40	3.00	2.96	51.42	3.06	F
5	1985	LDGV	1.04	17.69	0.81	P	0.81	18.60	0.62	P	0.74	17.64	0.67	P	0.88	20.15	0.60	0.99	19.76	0.71	F
6	1985	LDGT2	1.56	1.70	7.68	F	1.04	1.22	5.25	P	0.77	1.16	2.86	P	0.74	0.84	2.35	0.69	0.64	2.82	P
7	1986	LDGV	2.12	29.95	0.80	F	1.03	17.54	0.62	P	0.70	17.62	0.55	F	0.69	16.56	0.36	0.60	15.58	0.36	F
8	1986	LDGT1	1.55	20.32	1.08	P	1.27	21.03	0.81	P	1.39	25.86	1.12	F	1.68	26.86	1.25	1.63	26.99	1.48	F
9	1987	LDGV	0.21	3.70	2.65	P	0.41	12.66	3.04	F	0.07	2.42	2.22	P	0.04	0.94	1.77	0.05	1.21	1.94	P
10	1987	LDGV	0.34	1.02	2.93	F	0.24	1.07	2.73	F	0.21	0.85	2.67	F	0.21	0.95	2.45	0.20	0.92	2.68	P
11	1987	LDGV	0.69	15.71	1.61	F	0.56	8.98	1.75	P	0.56	13.40	1.54	P	0.44	8.46	1.47	0.49	9.41	1.70	P
12	1987	LDGV	0.93	5.47	3.19	F	0.20	1.57	1.54	P	0.13	1.21	1.56	P	0.12	0.95	1.61	0.13	1.10	1.51	P
13	1987	LDGT2	4.70	22.63	7.31	F	3.43	16.98	7.68	F	2.01	10.54	5.16	P	2.51	14.22	6.09	2.60	13.94	6.73	F
14	1988	LDGV	0.13	1.35	0.33	P	0.14	3.42	0.19	P	1.49	55.72	0.58	F	2.36	96.25	0.35	2.16	88.69	0.47	F
15	1989	LDGV	0.47	15.03	2.15	F	0.76	17.82	1.88	P	0.45	14.37	1.70	P	2.64	83.25	0.76	3.35	105.61	0.65	F
16	1990	LDGV	0.49	20.61	0.30	F	0.48	13.33	0.31	P	0.42	10.57	0.44	P	0.29	11.51	0.35	0.36	11.32	0.35	P
17	1991	LDGV	0.87	6.53	3.23	F	0.87	6.84	2.81	F	0.79	7.23	2.78	F	0.76	6.85	2.43	0.77	6.85	2.70	P
18	1991	LDGV	0.49	5.95	1.74	P	0.33	9.66	1.04	P	0.31	10.04	0.97	P	0.48	13.82	0.94	0.46	11.62	1.00	F
19	1992	LDGV	1.66	15.26	1.57	F	0.87	8.24	1.31	P	1.42	10.74	1.25	F	1.10	8.27	1.13	1.01	10.84	1.28	F
20	1992	LDGT1	0.65	20.32	1.09	F	0.57	26.21	0.99	F	0.34	17.03	0.90	P	0.23	13.06	0.69	0.31	16.99	0.82	P
21	1993	LDGV	0.64	18.26	1.57	F	0.35	11.28	1.52	P	0.44	12.38	1.60	P	0.13	7.68	1.52	0.10	7.13	1.70	P
22	1993	LDGV	0.72	7.27	3.84	F	0.04	0.28	2.70	F	0.01	0.56	1.80	P	0.01	0.29	2.11	0.00	0.16	2.85	P
23	1993	LDGT1	0.15	10.80	1.60	P	0.10	8.29	1.30	P	0.10	9.16	0.99	P	0.39	32.09	0.62	0.54	44.29	0.64	F
24	1995	LDGT1	0.08	2.72	0.51	P	0.05	0.84	0.35	P	0.04	0.72	0.44	P	0.40	20.28	0.42	0.55	27.99	0.49	F

Figure 3-4

Second-by-Second CO Emissions from Triplicate IM147 Testing 1988 Pontiac Bonneville (Record No. 14)

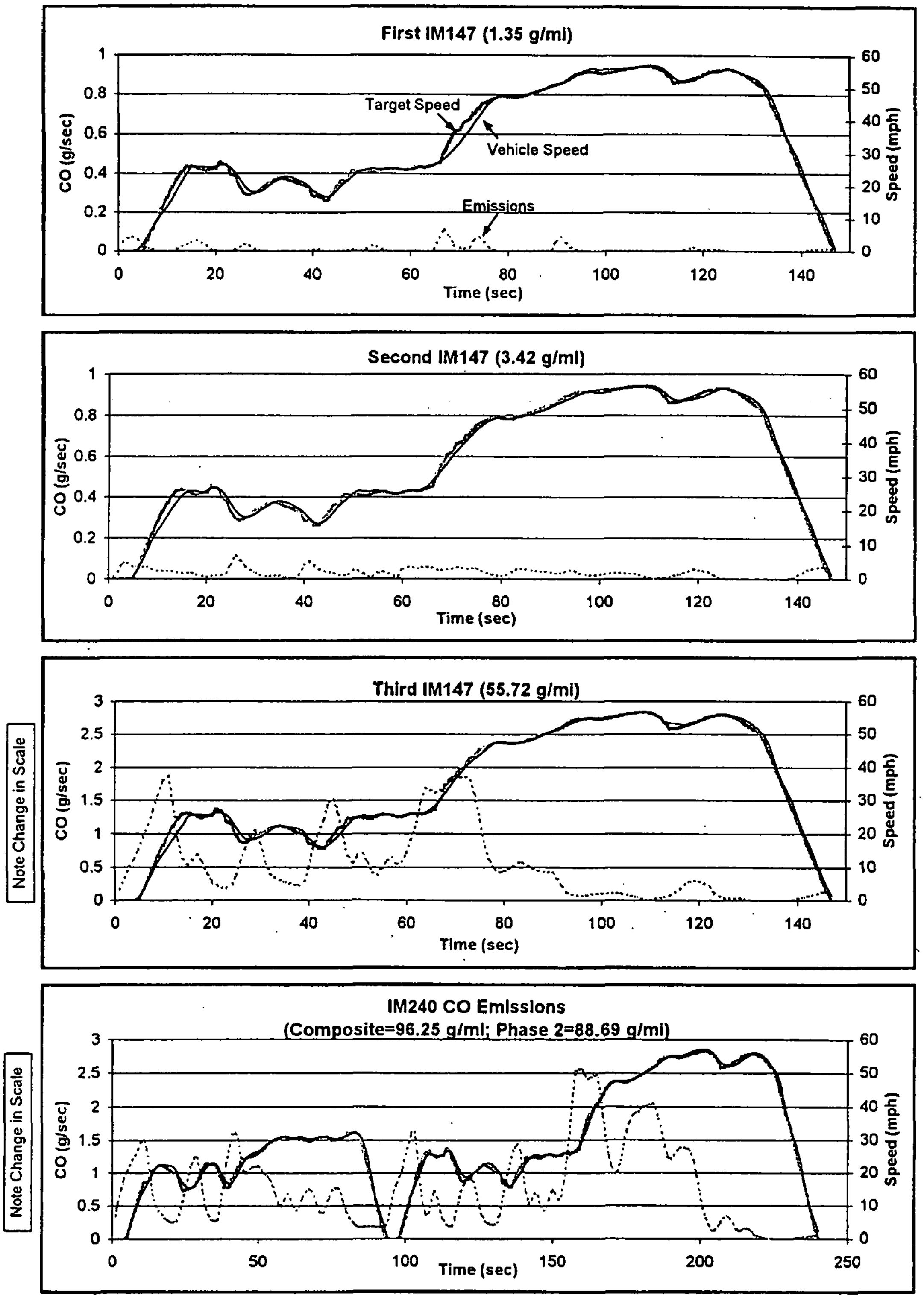


Figure 3-5

Second-by-Second CO Emissions from Triplicate IM147 Testing
1989 Dodge Dynasty (Record No. 15)

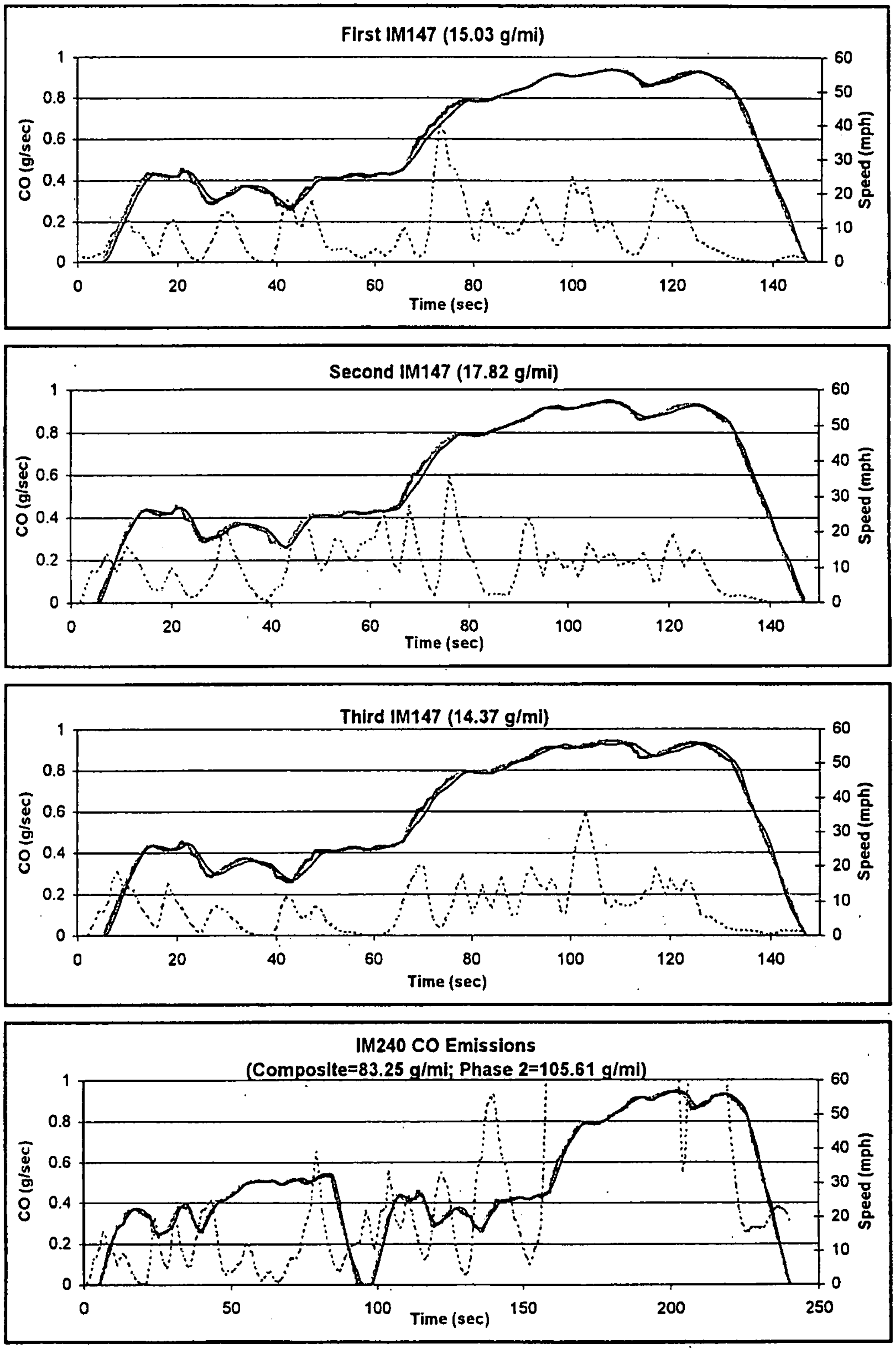


Figure 3-6

Second-by-Second CO Emissions from Triplicate IM147 Testing
1993 Ford Ranger (Record No. 23)

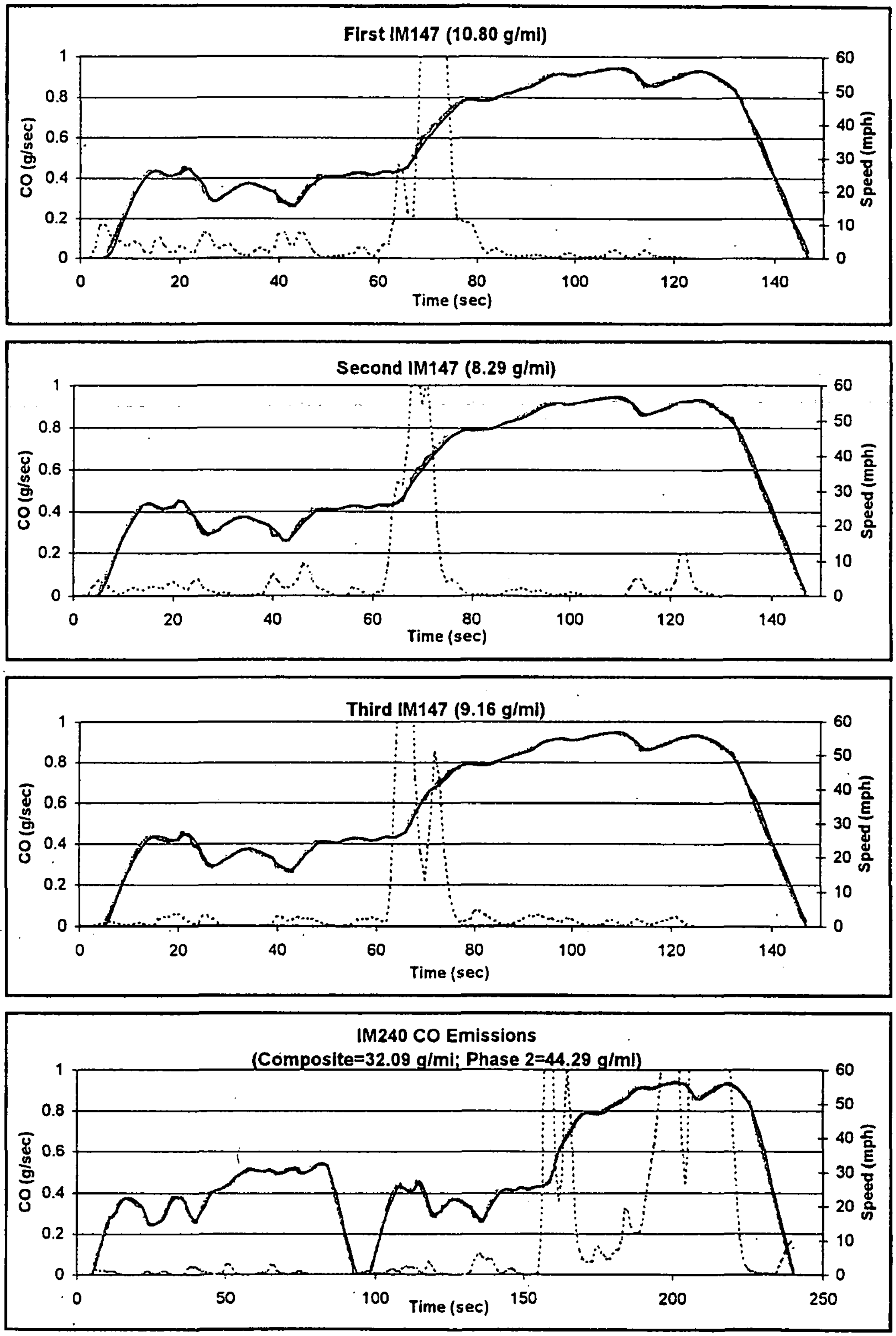
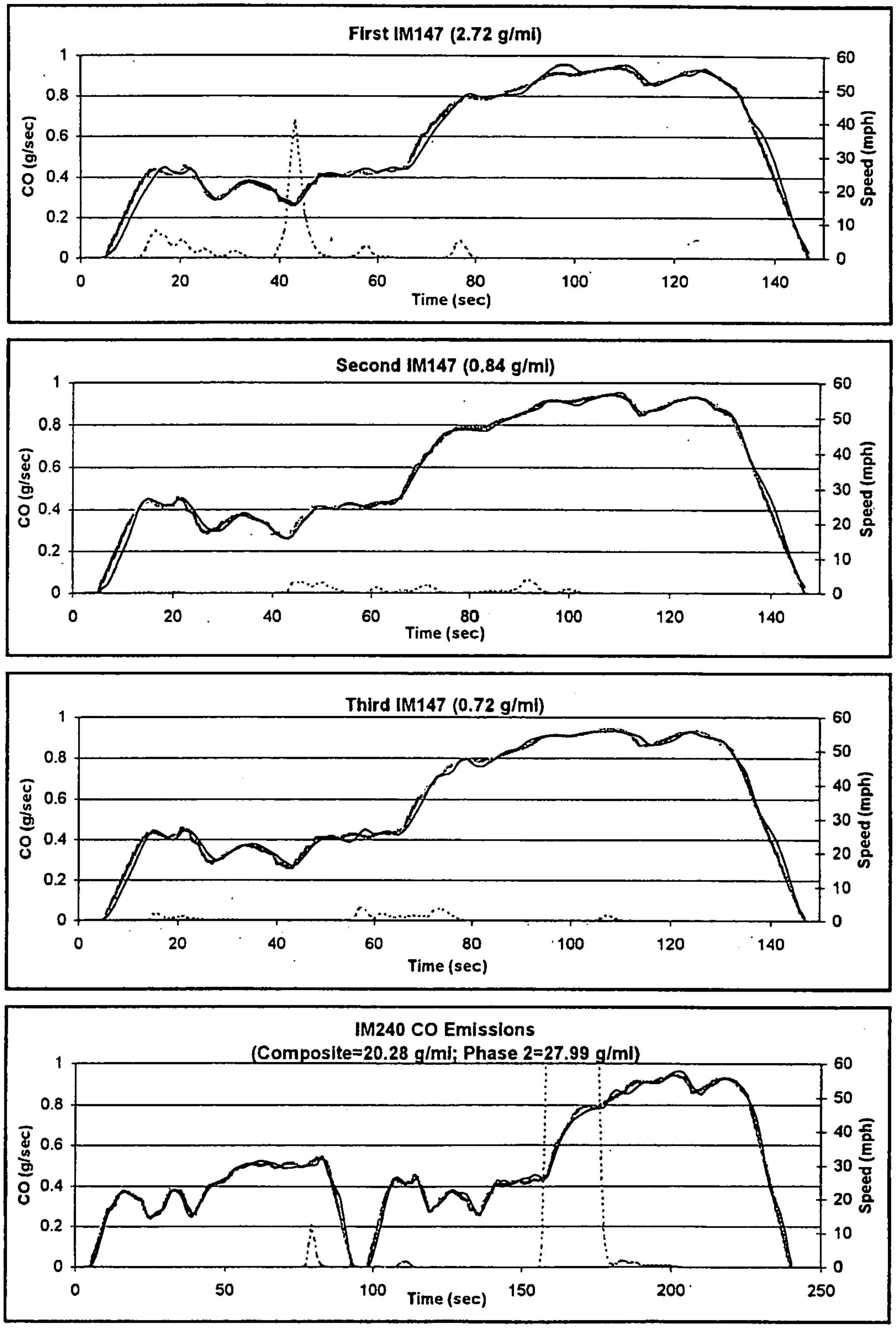


Figure 3-7

Second-by-Second CO Emissions from Triplicate IM147 Testing
1995 Toyota 4Runner (Record No. 24)



- Record 15, a 1989 Dodge Dynasty, had moderate CO emissions during the first three IM147 tests (14 to 18 g/mi), but emissions during the IM240 test were excessive, particularly during the end portion of that test (106 g/mi). Reviewing the modal CO emissions in Figure 3-5, one observes that the vehicle appears to go into open-loop operation at the start of the large hill of the end portion of the test (i.e., beginning at about second 160 of the IM240). Although CO emissions accrue throughout this test, the period from 160 to 230 comprises the bulk of the emissions.

- Record 23, a 1993 Ford Ranger, shows a very similar emissions response throughout the three IM147 tests. As seen in Figure 3-6, most of the CO emissions occur during seconds 62 to 75 of the IM147. During the end portion of the IM240, a similar pattern is observed. In that test, however, substantial CO is also emitted during the high-speed portion of the trace. It is not entirely clear what has caused this, but it appears that the vehicle did not follow the speed-time trace as smoothly during the end portion of the IM240 as it did during the first three IM147 tests.

- Record 24, a 1995 Toyota 4Runner, had decreasing emissions throughout the first three IM147 tests, emitting only 0.72 g/mi CO during the third IM147. However, the composite IM240 CO emission rate for this vehicle was 20.28 g/mi and the emissions reading during the end portion of the IM240 was 27.99 g/mi. As observed in Figure 3-7, the bulk of the emissions for this test occur during seconds 160 to 180 where it appears that the vehicle went into open-loop operation. Overall, this vehicle did not follow the speed-time profile as closely as the vehicles shown in Figures 3-4 to 3-6.

Three of the four vehicles identified above had similar emissions characteristics in that the bulk of the emissions during the IM240 was related to apparent open-loop operation during part of the end portion of the test that was not observed during the first three IM147 tests. Record 14 was unusual in that CO emissions continually increased throughout the series of tests. Overall, the addition of the Phase 1 portion of the IM240 did little in terms of contributing to the high emissions observed in the IM240.

It was not possible to satisfactorily resolve what is happening with these vehicles. Because the only IM240 that is used for comparison is at the end of the testing, the analysis of excess emissions identified by the IM147 test that uses the final IM240 as the "gold standard" will reflect poorly on IM147 testing since it would falsely pass several vehicles with very high CO emissions. (Just considering the 1988 Bonneville and the 1989 Dynasty above would reduce the effectiveness of the IM147 procedure to unacceptable levels.) However, it is apparent that the higher emissions certain vehicles exhibited during the IM240 are due to some anomaly and not to a fundamental problem with the IM147 trace. For these reasons, test results for the four vehicles described above are considered outliers and were not used in the remaining analyses of IM147 testing.

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4. IM147 CUTPOINT ANALYSIS

This section of the report presents the results of Sierra's development of IM147 cutpoints, development of fast pass criteria, and development of predictive criteria that can be used to determine if a retest is warranted for a failure. In addition, the effect of exempting up to the first 10 model years of vehicles from testing was evaluated.

The following three sets of cutpoints were developed:

- Startup cutpoints;
- Intermediate cutpoints;
- Final cutpoints.

For each cutpoint, both overall and "two ways to pass" ("Phase 2") standards were developed. For each set of standards, an assessment of the excess emission losses using the IM147 versus the IM240 was performed, and the potential effect on test time from using the IM147 was evaluated. The test time modeling was performed with the sample test fleet data using the IM147 (with a maximum of two retests) versus using the IM240 (with a maximum of one retest).

Next, methods to reduce the test time were evaluated. If test time can be reduced, this is equivalent to increasing the testing network's capacity at no additional cost. In addition, reductions in test time can also help to reduce wait times for consumers. Previous studies by Sierra have investigated several techniques that can be applied to the test data from vehicles while they are being tested to reduce the overall test time with only minor losses in the excess emissions identified. The first method developed was fast-pass standards to allow very clean vehicles to exit the test early. The next method developed was retest algorithms that predict if a failing vehicle would pass if retested. If a vehicle would not pass if retested, then retesting the vehicle is not warranted (since it would be increasing the test time with no benefit). The last technique evaluated was model year exemptions. Exempting newer model year vehicles from testing for their first four or five years can significantly reduce total test time for the fleet. Since new vehicles rarely fail I/M tests, the excess emissions lost from not testing these vehicles should be small.

In this section of the report, the methodology used to develop the standards is discussed, and the effects on test time and excess emissions identified for the IM147 and the IM240 are compared. The development of fast pass cutpoint coefficients that allow the prediction of full test results from various designated modes on the test are then presented, followed by the retest algorithms and model year exemptions. Each of these techniques to reduce test time was also evaluated for its impact on reducing test time at the cost of potentially losing some excess emissions. Testing of each technique built on the previous technique; i.e., testing of the retest algorithms was done while first applying the fast pass criteria. It is important for the reader to keep this in mind because there are several instances where this building-block approach produces unexpected but beneficial results.

Cutpoint Selection

Development of the cutpoints for the IM147-only test was based on linear regressions between full (composite) IM240 emission rates and emission rates for the end portion of the same IM240 tests.* The IM240 test data used were from the 304 vehicles described in Section 3, with the four outliers removed from the data set. (As noted in Section 3, these vehicles were removed from all further analyses.) These data were used because the IM240 tests were conducted after the three IM147 tests, so all vehicles should have been adequately warmed up and there should have been no preconditioning effects. Linear regressions were performed for each model of four year groups. The results are shown in Table 4-1.

Table 4-1
Regression Coefficients of IM240 Versus IM147 Emission Rates

	1981 - 85		1986 - 89		1990 - 1993		1994 +	
	Slope (m)	y-Intercept (b)	Slope (m)	y-Intercept (b)	Slope (m)	y-Intercept (b)	Slope (m)	y-Intercept (b)
HC	0.884	0.110	1.05	0.00968	1.09	0.00242	0.994	0.0151
CO	0.928	1.86	1.07	0.271	1.02	0.106	1.02	0.152
NOx	1.06	0.156	0.976	0.185	0.106	0.0216	1.08	0.0408

The regression equations were applied to the composite IM240 emissions standards using the following equation to develop the IM147 composite emissions standards.

$$\text{IM147 standard (g/mi)} = (m \times \text{IM240 cutpoint (g/mi)}) + b \qquad (4\text{-}1)$$

where: m = slope of regression equation
b = y intercept of regression equation

* The IM147 portion of the same IM240 was used to develop initial sets of cutpoints to ensure an equal level of preconditioning. If the cutpoints were instead developed using the first IM147 versus the IM240 that was conducted after the triplicate IM147s, it is likely that preconditioning issues would have clouded the results. Use of the first IM147 for the correlation analysis would also have introduced a difficulty in how to deal with the second and third IM147s in the series.

The correlation results were used as a general guide regarding where to set the cutpoints, with minor subsequent adjustments being made to better match IM240 and IM147 failure rates. In some cases, use of these regressions yielded cutpoints that were discontinuous (e.g., some newer model years yielded higher emissions rates than older years). This was because the relationships between the composite IM240 and the IM147 emission rates were developed using real data in which the ratio of emissions varied by model year. In these cases, the cutpoints were modified to decrease with newer model years. The cutpoint categories were then modified to match as close as possible the EPA model year categories, but in some cases a few new categories were added due to significant changes between model years.

Using the regressions and then modifying the resulting cutpoint as described above to account for discontinuities, startup, intermediate, and final cutpoints were developed for LDGVs, LDGT1s and LDGT2s. The intermediate cutpoints were based simply on applying the regression equations to the average of the IM240 composite startup and the final cutpoints. The resulting standards are shown in Table 4-2 through Table 4-4 for startup standards, intermediate standards, and final standards, respectively.

To evaluate the impact of these new cutpoints on test time and excess emissions identified, the data from the 300 vehicle data set used to develop the standards were "tested" using the two-way-to-pass methodology for <u>all three IM147s</u> (i.e., if a vehicle failed the first IM147, the data from the second test were evaluated to see if the vehicle would pass or fail; if it failed the second test, the data from the third test were evaluated). The IM240 at the end of the testing pattern was used as the standard for comparing excess emissions identified, with excess emissions defined as emissions above the cutpoints on the IM240. If a vehicle failed the IM240 and the vehicle also failed the IM147, then the IM147 would be attributed with identifying the excess emissions from that vehicle, and those emissions would have a value equal to the IM240 emissions over the IM240 standard. If the IM147 did not fail a vehicle that failed the IM240, the excess emissions from the IM240 (emissions over the IM240 standard for the IM240 test) were considered excess emissions not identified by the IM147. The results of the analysis are presented in Table 4-5.

The ratio of excess emissions for vehicles that failed the IM147 versus those failing the IM240 is the percent excess emissions identified.

As can be seen in the Table 4-5, there were few excess emissions "lost" (i.e., the IM147 failed almost all of the vehicles that the IM240 failed). For startup standards, the IM147 identified all of the excess CO and NOx emissions the IM240 identified and almost all of the HC. Only 1.5% of the excess HC emissions were lost with the intermediate standards and 6.8% of the NOx. The maximum loss using the final standards was 2.5% of excess CO emissions.

To more objectively evaluate their impact, it would be preferable to test the cutpoints on a separate data set. However, the only such sample is the 101 vehicles previously tested in Arizona using triplicate IM147s after a <u>30-minute idle</u>. These data are not considered representative of average IM240 testing in Arizona, which typically involves wait times

Table 4-2
Startup IM240 Cutpoints and IM147 Cutpoints Developed in This Study
(Composite/Phase 2 Cutpoints in g/mi, IM240 - IM147)

Model Years	HC	CO	NOx[a]
LDGV			
1981-82	2.00/1.25 - 2.00/1.20	60.0/48.0 - 58.0/30.0	3.0 - 3.3/1.2
1983-85	2.00/1.25 - 2.00/1.20	30.0/24.0 - 30.0/15.0	3.0 - 3.3/1.2
1986-90	2.00/1.25 - 2.00/1.00	30.0/24.0 - 30.0/10.0	3.0 - 3.0/1.2
1991-93	1.20/0.75 - 1.30/0.60	20.0/16.0 - 21.0/10.0	2.5 - 2.9/1.0
1994-95	1.20/0.75 - 1.20/0.60	20.0/16.0 - 21.0/10.0	2.5 - 2.7/1.0
1996+ (Tier 1)[b]	0.80/0.50 - 0.80/0.50	15.0/12.0 - 15.0/ 7.0	2.0 - 2.1/0.9
LDGT1			
1981-83	7.50/5.00 - 6.70/4.70	100.0/80.0 - 95.0/50.0	7.0 - 7.6/2.9
1984-85	3.20/2.00 - 2.90/2.00	80.0/64.0 - 76.0/40.0	7.0 - 7.6/2.9
1986-87	3.20/2.00 - 2.90/1.60	80.0/64.0 - 76.0/31.0	7.0 - 7.0/2.7
1988-90	3.20/2.00 - 2.90/1.60	80.0/64.0 - 76.0/31.0	3.5 - 3.6/1.3
1991-93	2.40/1.50 - 2.60/1.20	60.0/48.0 - 61.0/31.0	3.0 - 3.4/1.1
1994-95	2.40/1.50 - 2.40/1.20	60.0/48.0 - 61.0/29.0	3.0 - 3.2/1.1
1996+ (Tier 1)[b,c]	1.00/0.63 - 1.0/0.60	20.0/16.0 - 21.0/10.0	2.5 - 2.7/1.1
LDGT2			
1981-83	7.50/5.00 - 6.70/4.70	100.0/80.0 - 95.0/50.0	7.0 - 7.6/2.9
1984-86	3.20/2.00 - 2.90/2.00	80.0/64.0 - 76.0/40.0	7.0 - 7.6/2.9
1987	3.20/2.00 - 2.90/1.60	80.0/64.0 - 76.0/31.0	7.0 - 7.6/2.7
1988-90	3.20/2.00 - 2.90/1.60	80.0/64.0 - 76.0/31.0	5.0 - 5.1/1.9
1991-93	2.40/1.50 - 2.60/1.20	60.0/48.0 - 61.0/31.0	4.5 - 5.1/1.9
1994-95	2.40/1.50 - 2.40/1.20	60.0/48.0 - 61.0/29.0	4.5 - 4.8/1.9
1996+ (Tier 1)[b,c]	2.40/1.50 - 2.40/1.20	60.0/48.0 - 61.0/29.0	4.0 - 4.3/1.7

[a] NOx Phase 2 cutpoints are equal to the NOx composite cutpoints for the IM240.

[b] Because there is no way to discern Tier 1 and Tier 0 vehicles in the Arizona database, the Tier 1 IM240 cutpoints were not implemented until model year 1996, when all vehicles must certify to the Tier 1 standards.

[c] To be conservative, the Tier 1 LDGT1 and LDGT2 cutpoints used for this analysis reflect the cutpoints recommended by EPA for the heavier vehicles in each class.

Table 4-3
Intermediate IM240 Cutpoints and IM147 Cutpoints Developed in This Study
(Composite/Phase 2 Cutpoints in g/mi, IM240 - IM147)

Model Years	HC	CO	NOx[a]
LDGV			
1981-82	1.40/0.88 - 1.40/0.90	45.0/36.0 - 44.0/23.0	2.3 - 2.8/1.0
1983-85	1.40/0.88 - 1.40/0.90	23.0/18.0 - 23.0/12.0	2.3- 2.8/1.0
1986-90	1.40/0.88 - 1.40/0.70	23.0/18.0 - 23.0/9.0	2.3 - 2.6/1.0
1991-93	1.00/0.63 - 1.10/0.50	18.0/14.0 - 18.0/9.0	2.3 - 2.6/0.9
1994-95	1.00/0.63 - 1.00/0.50	18.0/14.0 - 18.0/9.0	2.3 - 2.5/0.9
1996+ (Tier 1)[b]	0.70/0.45 - 0.80/0.40	13.0/10.0 - 15.0/6.0	1.8 - 2.2/0.8
LDGT1			
1981-83	5.50/3.50 - 4.90/3.40	85.0/68.0 - 81.0/43.0	5.8 - 6.3/2.4
1984-85	2.40/1.50 - 2.30/1.50	60.0/48.0 - 60.0/30.0	5.8 - 6.3/2.4
1986-87	2.40/1.50 - 2.30/1.20	60.0/48.0 - 60.0/26.0	5.8 - 5.8/2.2
1988-89	2.40/1.50 - 2.30/1.20	60.0/48.0 - 60.0/26.0	3.0 - 3.3/1.2
1990	2.40/1.50 - 2.30/1.20	60.0/48.0 - 59.0/26.0	3.0 - 3.3/1.2
1991-93	2.00/1.25 - 2.10/1.00	50.0/40.0 - 51.0/26.0	2.8 -3.2/1.1
1994-95	2.00/1.25 - 2.00/1.00	50.0/40.0 - 51.0/25.0	2.8 - 3.0/1.1
1996+ (Tier 1)[b,c]	0.90/0.57 - 1.30/0.60	17.0/13.0 - 31.0/8.0	2.2 - 2.7/1.0
LDGT2			
1981-83	5.50/3.50 - 4.90/3.40	85.0/68.0 - 81.0/43.0	5.8 - 6.3/2.4
1984-86	2.40/1.50 - 2.30/1.50	60.0/48.0 - 60.0/30.0	5.8 - 6.3/2.4
1987	2.40/1.50 - 2.30/1.20	60.0/48.0 - 60.0/26.0	5.8 - 6.3/2.2
1988-90	2.00/1.50 - 2.30/1.20	60.0/48.0 - 60.0/26.0	4.3 - 4.6/1.6
1991-93	2.00/1.25 - 2.20/1.00	50.0/40.0 - 51.0/26.0	4.0 - 4.6/1.6
1994-95	2.00/1.25 - 2.00/1.00	50.0/40.0 - 51.0/25.0	4.0 - 4.3/1.6
1996+ (Tier 1)[b,c]	1.60/1.00 - 2.00/0.90	38.0/30.0 - 51.0/18.0	3.0 - 4.1/1.3

[a] NOx Phase 2 cutpoints are equal to the NOx composite cutpoints for the IM240.

[b] Because there is no way to discern Tier 1 and Tier 0 vehicles in the Arizona database, the Tier 1 IM240 cutpoints were not implemented until model year 1996, when all vehicles must certify to the Tier 1 standards.

[c] To be conservative, the Tier 1 LDGT1 and LDGT2 cutpoints used for this analysis reflect the cutpoints recommended by EPA for the heavier vehicles in each class.

Table 4-4
Final IM240 Cutpoints and IM147 Cutpoints Developed in This Study
(Composite/Phase 2 Cutpoints in g/mi, IM240 - IM147)

Model Years	HC	CO	NOx[a]
LDGV			
1981-1982	0.80/0.50 - 0.80/0.50	30.0/24.0 - 30.0/15.0	2.0 - 2.3/0.8
1983-1985	0.80/0.50 - 0.80/0.50	15.0/12.0 - 16.0/8.0	2.0 - 2.3/0.8
1986-1989	0.80/0.50 - 0.80/0.40	15.0/12.0 - 16.0/8.0	2.0 - 2.2/0.8
1990-1993	0.80/0.50 - 0.80/0.50	15.0/12.0 - 15.0/8.0	2.0 - 2.2/0.7
1994-1995	0.80/0.50 - 0.80/0.50	15.0/12.0 - 15.0/7.0	2.0 - 2.2/0.7
1996+ (Tier 1)[b]	0.60/0.40 -0.80/0.30	10.0/8.0 - 15.0/5.0	1.5 - 2.2/0.6
LDGT1			
1981-83	3.40/2.00 - 3.10/2.10	70.0/56.0 - 67.0/35.0	4.5 - 4.9/1.8
1984-85	1.60/1.00 - 1.70/1.00	40.0/32.0 - 43.0/20.0	4.5 - 4.9/1.8
1986-87	1.60/1.00 - 1.70/0.80	40.0/32.0 - 43.0/20.0	4.5 - 4.6/1.7
1988-1989	1.60/1.00 - 1.70/0.80	40.0/32.0 - 43.0/20.0	2.5 - 2.9/1.0
1990-1993	1.60/1.00 - 1.60/0.80	40.0/32.0 - 41.0/20.0	2.5 - 2.9/1.0
1994-1995	1.60/1.00 - 1.60/0.80	40.0/32.0 - 41.0/20.0	2.5 - 2.7/1.0
1996+ (Tier 1)[b,c]	0.80/0.50 - 1.60/0.50	13.0/10.0 - 41.0/ 6.0	1.8 - 2.7/0.8
LDGT2			
1981-83	3.40/2.00 - 3.10/2.10	70.0/56.0 - 67.0/35.0	4.5 - 4.9/1.8
1984-86	1.60/1.00 - 1.70/1.00	40.0/32.0 - 43.0/20.0	4.5 - 4.9/1.8
1987	1.60/1.00 - 1.70/0.80	40.0/32.0 - 43.0/20.0	4.5 - 4.9/1.7
1988-1991	1.60/1.00 - 1.70/0.80	40.0/32.0 -43.0/20.0	3.5 - 4.0/1.3
1992-1993	1.60/1.00 - 1.70/0.80	40.0/32.0 - 41.0/20.0	3.5 - 4.0/1.3
1994-1995	1.60/1.00 - 1.70/0.80	40.0/32.0 - 41.0/20.0	3.5 - 3.8/1.3
1996+ (Tier 1)[b,c]	0.80/0.50 - 1.60/0.50	15.0/12.0 - 41.0/ 7.0	2.0 - 3.8/0.9

[a] NOx Phase 2 cutpoints are equal to the NOx composite cutpoints for the IM240.

[b] Because there is no way to discern Tier 1 and Tier 0 vehicles in the Arizona database, the Tier 1 IM240 cutpoints were not implemented until model year 1996, when all vehicles must certify to the Tier 1 standards.

[c] To be conservative, the Tier 1 LDGT1 and LDGT2 cutpoints used for this analysis reflect the cutpoints recommended by EPA for the heavier vehicles in each class.

Table 4-5
Evaluation of Emissions Standards for the IM147
Impact on Test Time and Excess Emissions Lost

Vehicle Class	Model Year Group	IM147				
		Number in Test Sample	Mean Test Time (seconds)	% Excess Emissions Identified[a]		
				HC	CO	NOx
Startup Cutpoints						
LDGV	81 - 84	13	294	100	100	100
	85 - 89	45	180	100	100	-
	1990+	133	159	100	100	100
LDGT 1&2	81 - 84	8	239	93.8	-	100
	85 - 89	27	185	100	100	-
	1990+	74	159	-	-	100
Sum / Weighted average		300	172	97.2	100	100
Intermediate Cutpoints						
LDGV	81 - 84	13	328	100	100	98.1
	85 - 89	45	209	100	100	98.1
	1990+	133	166	95.3	100	100
LDGT 1&2	81 - 84	8	294	100	100	76.1
	85 - 89	27	201	90.3	100	0
	1990+	74	163	100	-	100
Sum / Weighted average		300	185	98.5	100	93.2
Final Cutpoints						
LDGV	81 - 84	13	362	100	100	100
	85 - 89	45	255	98.3	100	95.9
	1990+	133	171	100	100	96.4
LDGT 1&2	81 - 84	8	368	100	100	100
	85 - 89	27	289	97.2	89.2	100
	1990+	74	165	100	-	100
Sum / Weighted average		300	206	99.2	97.5	99.4

[a] "-" indicates there were no failures in this group for the IM240 and therefore no excess emissions for the IM147 to identify.

of no more than 5-15 minutes. For this reason, no evaluation of the cutpoints was performed using the previously collected data.

The results of the third IM147 test versus the IM240 were the same for 295 of the 300 vehicles that were tested using the final standards. The third IM147 was used for this comparison because it was assumed the vehicle was completely warmed up at this point in the testing. A total of only 45 vehicles (15%) failed either the IM240 or the IM147 cutpoints, with 40 of these vehicles failing both the IM240 and IM147 cutpoints. There are five vehicles for which the results did not agree: three that failed the IM240 and passed the IM147 cutpoints (errors of omission, the cause of the excess emissions not identified); and two that passed the IM240 and failed the IM147 cutpoints (errors of commission, with the IM147 having higher excess emissions identified than the IM240). The data for each of these five vehicles are presented in Table 4-6 and discussed in detail below.

The first two vehicles in Table 4-6 failed the IM240 but did not fail the IM147 cutpoints. These are referred to as Type I errors in the table.

- The first vehicle was a LDGV that failed for NOx, and was approximately 5% over the IM240 cutpoint but 18% below the IM147 cutpoint for the third test. The NOx emissions from the first three tests were dropping quickly and the vehicle did not pass the IM147cutpoints until the last test. This vehicle may have been fairly cold at the beginning of the testing, but was warming up as the testing continued.

- The second vehicle was a LDGT1 that failed for HC and was also 5% over the IM240 cutpoint, but had been below the IM147 cutpoint for all three tests. However, this vehicle showed a decrease in emissions from the first to the second test, then an increase to the third of the three IM147 tests. In fact, the emissions of all three pollutants increased from the second to the third test, indicating that the vehicle may have had some sort of transient emissions control problem that led to enough variability in the vehicle's emissions to cause differing results.

The last three vehicles in Table 4-6 are all LDGVs and passed the IM240 but failed the IM147 cutpoints. These are referred to as Type II errors in the table.

- The first vehicle failed the IM147 CO cutpoint by 0.01 g/mi, which is less than the probable sampling error in the measurement. In addition, if the test lane software rounds or truncates the result, the vehicle could have passed. The data from the three IM147 tests show the emissions rate between the three tests first went down and then back up (the vehicle first failed the IM147 cutpoint, then passed, then failed). In actual testing, this vehicle would have passed the second test and not been tested again (the third time), giving the same result as the IM240.

Table 4-6

Tests with Type I and Type II Errors (IM240 and Third IM147 Test Results Differ)

Test	VIN	Vehicle Type	Model Year	HC (g/mi)	IM240 Standard	IM147 Standard	CO (g/mi)	IM240 Standard	IM147 Standard	NOx (g/mi)	IM240 Standard	IM147 Standard
IM240 Fail - Third IM147 Test Pass (Type I Errors)												
IM147, test 1	3G4AG54N5PS614754	LDGV	90-93	0.72		0.8	7.27		15	3.84		2.2
IM147, test 2	3G4AG54N5PS614754	LDGV	90-93	0.04		0.8	0.28		15	2.7		2.2
IM147, test 3	3G4AG54N5PS614754	LDGV	90-93	0.01		0.8	0.56		15	1.8		2.2
IM240 test	3G4AG54N5PS614754	LDGV	90-93	0.01	0.8		0.29	15		**2.11**	**2**	
IM147, test 1	JT4RN50R4G0121113	LDGT1	86-89	1.55		1.7	20.32		43	1.08		2.9
IM147, test 2	JT4RN50R4G0121113	LDGT1	86-89	1.27		1.7	21.03		43	0.81		2.9
IM147, test 3	JT4RN50R4G0121113	LDGT1	86-89	1.39		1.7	25.86		43	1.12		2.9
IM240 test	JT4RN50R4G0121113	LDGT1	86-89	**1.68**	**1.6**		26.86	40		1.25	4.5	
IM240 Pass - Third IM147 Test Fail (Type II Errors)												
Test	VIN	Vehicle Type	Model Year	HC (g/mi)	IM240 Standard	IM147 Standard	CO (g/mi)	IM240 Standard	IM147 Standard	NOx (g/mi)	IM240 Standard	IM147 Standard
IM147, test 1	1MEBP95F9EZ649996	LDGV	81-85	0.88		0.8	19.25		16	2.26		2.3
IM147, test 2	1MEBP95F9EZ649996	LDGV	81-85	0.43		0.8	12.57		16	1.76		2.3
IM147, test 3	1MEBP95F9EZ649996	LDGV	81-85	0.42		0.8	**16.01**		**16**	1.72		2.3
IM240 test	1MEBP95F9EZ649996	LDGV	81-85	0.38	0.8		12.77	15		1.43	2	
IM147, test 1	1G1AW81R9H6121416	LDGV	86-89	0.21		0.8	3.7		16	2.65		2.2
IM147, test 2	1G1AW81R9H6121416	LDGV	86-89	0.41		0.8	12.66		16	3.04		2.2
IM147, test 3	1G1AW81R9H6121416	LDGV	86-89	0.07		0.8	2.42		16	**2.22**		**2.2**
IM240 test	1G1AW81R9H6121416	LDGV	86-89	0.04	0.8		0.94	15		1.77	2	
IM147, test 1	1B3XC56R8LD901740	LDGV	90-93	0.37		0.8	4.72		15	2.71		2.2
IM147, test 2	1B3XC56R8LD901740	LDGV	90-93	0.16		0.8	4.07		15	2.38		2.2
IM147, test 3	1B3XC56R8LD901740	LDGV	90-93	0.16		0.8	5.14		15	**2.45**		**2.2**
IM240 test	1B3XC56R8LD901740	LDGV	90-93	0.15	0.8		4.28	15		1.95	2	

- The emissions for the second vehicle were within 0.02 g/mi of the IM147 NOx cutpoint, but the emissions of the vehicle were fluctuating. The emissions first increased from the first to the second test, and then decreased again. As can be seen from the HC and especially the CO emissions rates, there was significant variability in all pollutants.

- The last vehicle in this group was over the IM147 NOx cutpoint by more than 10% and passed the IM240 cutpoint by 2.5%. This vehicle also had fluctuations in emissions, decreasing from the first to the second IM147 test, and then increasing between the second and third tests.

The impact these five vehicles had on the differences in failure rates between the IM147 and IM240 can be seen in Figures 4-1 and 4-2. The figures show the failure rates as a function of vehicle type and model year groupings for all three pollutants, and overall* for the three IM147 tests and the IM240 using final standards. In Figure 4-1, the overall failure rates for all pollutants by the second IM147 test are very close the IM240. It is not expected that the failure rates will be the same on the first IM147 test as on the IM240 because the vehicle may still be warming up; however, the agreement should improve as the vehicle warms up, as observed in the results. LDGV failure rates for all three pollutants decreased from the first IM147 test to the third, as expected. LDT2s predicted well for CO from the first test, overpredicted for the first test for HC and NOx, but agreed well with IM240 failure rates for the third IM147 test.

Looking at the failure rates by pollutant and model year (Figure 4-2), a similar trend is seen among the pollutants, in that the first IM147 test failure rate is about 30% to 40% higher than the IM240, but agrees well after the second IM147 test. For 1981-1985 model year vehicles, the agreement for HC is good by the second IM147; however, the IM147 has lower failure rates for CO, and the agreement for NOx is not good until the third IM147 test. For 1986-1989 model year vehicles, there was a drop from the first to second test, but no change between the second and third tests. The failing sample for 1990-1993 model year vehicles was small, but the agreement was good after the third test for all three pollutants, with the largest variation in NOx emissions for the first IM147 test. There were too few failing 1994 and newer vehicles to determine if the cutpoints agree well.

The impact of changes in test times can also be seen in Table 4-5 by the cutpoints that are applied. The sample-weighted average test time for the three groups increased with the stringency of the standards. The overall average test times for the three groups were 172 seconds per test for the startup cutpoints, 185 seconds for the intermediate cutpoints, and 206 for the final cutpoints. This is a 20% increase in test time going from startup cutpoints to final cutpoints. Note, however, that those test times do not include the

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* Because of the small sample size, some of the failures are represented by only a few vehicles, especially for the LDGT2 vehicle type. It is important to note that the failure rates shown for the "all" categories in both figures were computed by simple averaging of the test results from the 300 vehicles contained in the sample. Thus, they reflect the distribution of vehicle model years and vehicle types included in the sample, and have not been adjusted for the fleet characteristics in Arizona.

Figure 4-1
Failure Rates for Three Consecutive IM147 Tests Followed by an IM240 Test
by Vehicle Type Using Final Cutpoints

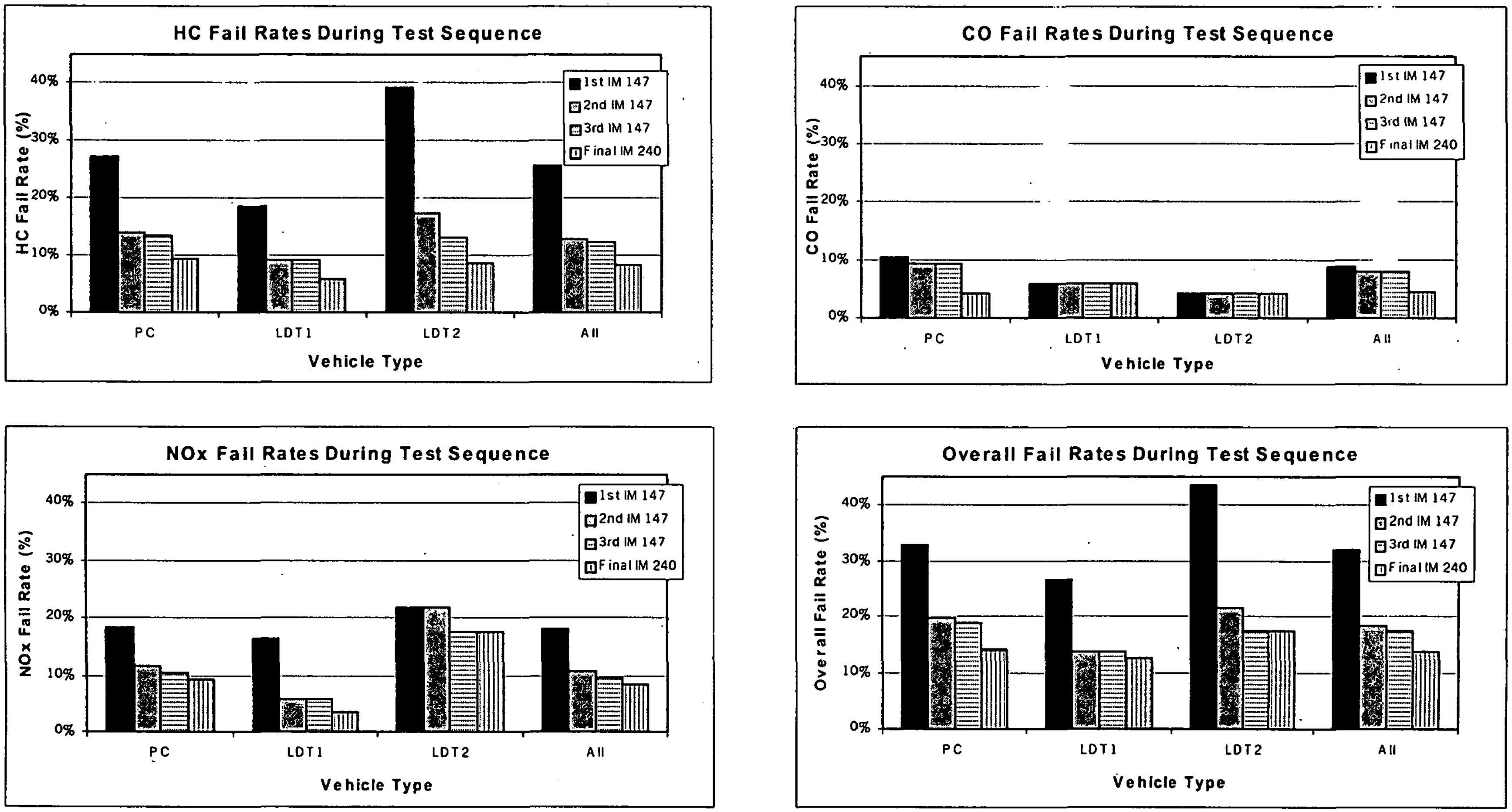
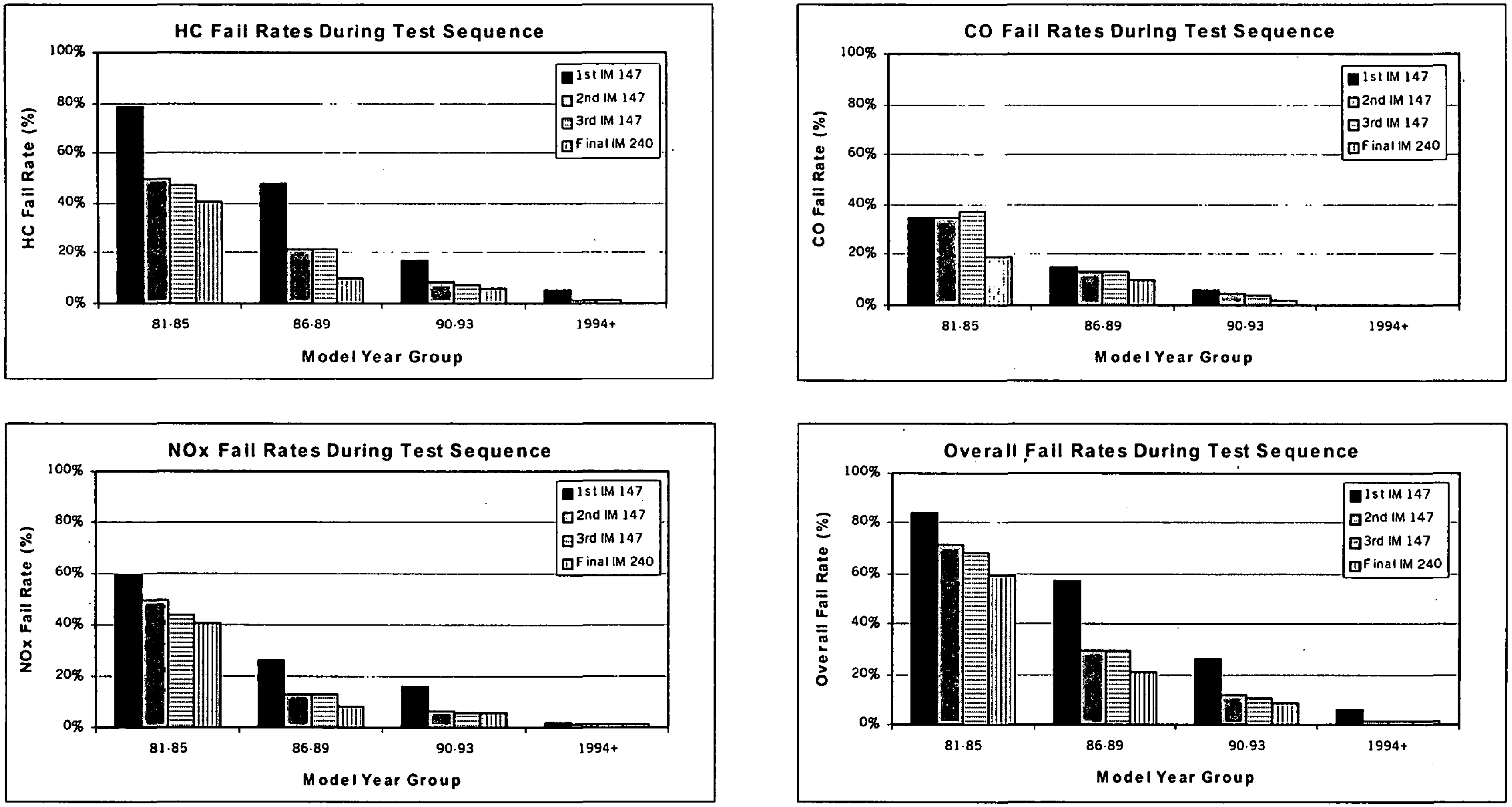


Figure 4-2
Failure Rates for Three Consecutive IM147 Tests Followed by an IM240 Test
by Model Year Group Using Final Cutpoints



impacts of fast-pass methodologies, nor do they incorporate the impact of a retest algorithm to identify vehicles inadequately preconditioned.

As expected, test times by model year group were higher for older model year vehicles, since these vehicles have higher emissions and are more likely to fail the test, requiring another test. For startup and intermediate cutpoints, the test time for newer vehicles was 40% lower than for older vehicles; for final cutpoints, newer vehicles' test times were over than 50% lower than test times for older vehicles.

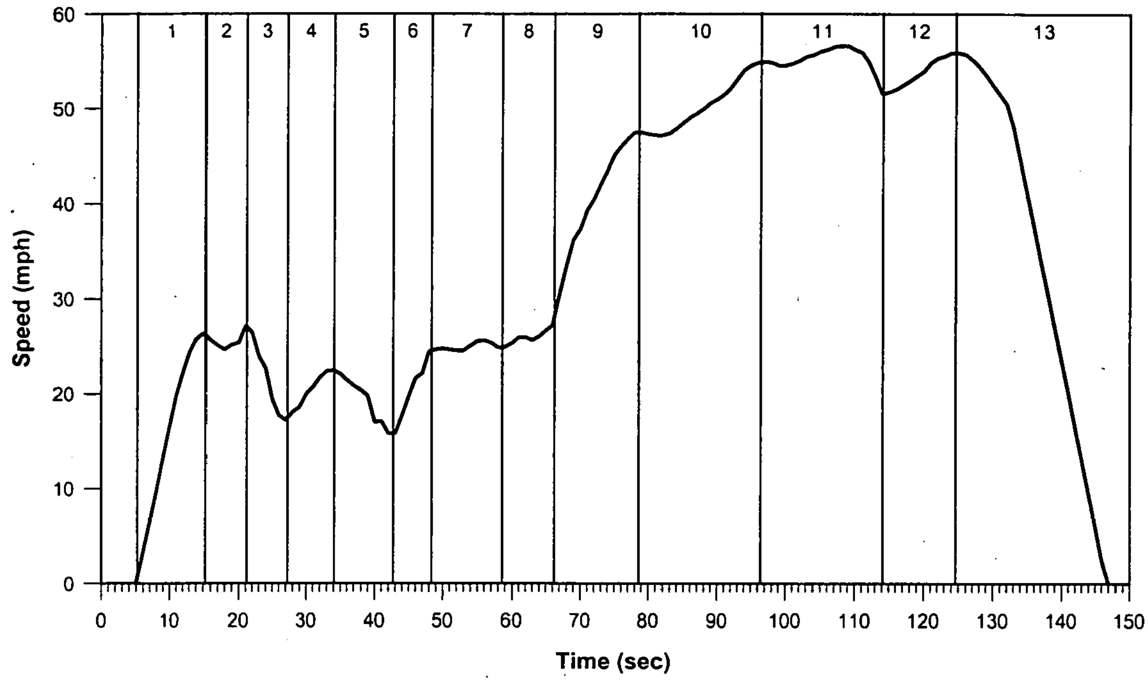
Modal Predictive Fast Pass Analysis

The first technique applied to the new IM147 test to help shorten test time was to apply fast pass standards to allow those vehicles with emissions well below the standards to complete the test early. Currently, every I/M program performing IM240 testing is using a fast-pass algorithm to reduce average test time. In previous work for EPA,[7] Sierra evaluated methodologies used to develop fast pass standards, adopted the most reasonable approach, and modified it slightly to improve its performance. The methodology for development of fast-pass standards is reviewed briefly here because it is important for understanding its application. In that approach, full-duration test scores are regressed against emissions during particular segments, or modes, of the IM147. Thus, at the conclusion of each mode of the test, the full-duration score can be estimated by applying the coefficients developed from the regression analysis. In all, 18 regression models were developed in this effort: six each for HC, CO, and NOx, with these six representing composite and Phase 2 IM147 standards for LDGVs, LDGT1s, and LDGT2s.

Although current methodologies used to develop fast-pass cutpoints provide workable solutions to establishing fast-pass cutpoints, they do not make full use of the information collected on a second-by-second basis as the test is occurring. Rather, the fast-pass decision is made simply by comparing cumulative emissions at each second to a particular emission standard at each second. With the intent of improving the performance of the current fast-pass methodology and standards (i.e., shorter test time and fewer false passes), alternative approaches from Resources for the Future[8] and the New York Department of Environmental Conservation[9] were evaluated. In reviewing these approaches, the method that had the most appeal (both from an engineering and a statistical perspective) was the modal regression technique developed by NYDEC. Thus, the methodology developed by NYDEC formed the basis of the approach adopted by Sierra and this approach was used to generate fast-pass IM147 standards in this study.

The methodology divides the test cycle into modes that are cumulatively evaluated as the test progresses. For the IM147, the last 13 modes that were developed for the IM240 in the previous study were used. The last four of these modes were used for the Phase 2 portion. These modes are illustrated in Figure 4-3.

Figure 4-3
IM147 Test Modes Used for Fast-Pass Cutpoint Development



The modal regression technique developed in the previous study was then applied to the 300 vehicles in the current data set to develop a set of fast-pass regression models for the IM147 test. Consistent with the methodology presented above, regression coefficients were generated separately for LDGVs and LDGT1&2s with model year groups to match the previous analyses.

As mentioned earlier, regression coefficients were developed for HC, CO, and NOx for both the composite IM147 and for Phase 2. The first mode at which a pass/fail decision was allowed was mode 4 (which ends at second 33 of the IM147) for a composite IM147 prediction, or mode 8 (which ends at second 67 of the IM147) for a Phase 2 prediction. The regression coefficients for HC, CO, and NOx are given in Appendix A for both the full IM147 and Phase 2 for all vehicle classes, model year groups, and pollutants.

The vehicles from this study were used to calculate excess emissions identified and change in test time both with and without the fast-pass regression models. This analysis was performed using the startup, intermediate, and final IM147 and IM240 HC, CO, and NOx standards. The results are shown in Table 4-7 for comparison. Test time comparison for IM147 tests was based on three tests in a row or until passing; IM240 was based on two tests in a row or until passing.

Excess emissions were calculated in the same manner as for development of new standards. Excess emissions identified were the emissions on the IM240 for failing vehicles above the standard and also failing the IM147.

Table 4-7
Comparison of Fast-Pass Effectiveness for the IM147
Impact on Test Time and Excess Emissions Lost

Vehicle Class	Model Year Group	IM147 Test Time without Fast Pass (seconds)	IM240 Test Time with Fast Pass (seconds)	IM147 with Fast Pass				
				Number in Test Sample	Mean Test Time (seconds)	% Excess Emissions Identified[a]		
						HC	CO	NOx
Startup Cutpoints								
LDGV	81 - 84	294	221	13	249	100	100	100
	85 - 89	180	114	45	86	100	100	-
	1990+	159	50	133	56	100	100	100
LDGT 1&2	81 - 84	239	138	8	146	93.8	-	100
	85 - 89	185	111	27	62	0.0	0.0	-
	1990+	159	53	74	56	-	-	100
Weighted average		172	75		72	93.8	95.1	100
Intermediate Cutpoints								
LDGV	81 - 84	328	270	13	289	96.9	91.4	98.1
	85 - 89	209	160	45	136	100	100	98.1
	1990+	166	71	133	64	95.3	100	100
LDGT 1&2	81 - 84	294	219	8	221	100	100	55.5
	85 - 89	201	160	27	109	90.3	100	0.0
	1990+	163	75	74	59	0	-	100
Weighted average		185	106		92	98.0	97.8	89.5
Final Cutpoints								
LDGV	81 - 84	362	308	13	348	100	100	100
	85 - 89	255	218	45	204	98.3	100	100
	1990+	171	77	133	78	100	100	96.4
LDGT 1&2	81 - 84	368	255	8	343	100	100	100
	85 - 89	289	195	27	159	97.2	77.3	100
	1990+	165	79	74	72	100	-	100
Weighted average		206	122		121	99.2	94.8	99.6

[a] "-" indicates there were no failures in this group for the IM240 and therefore no excess emissions for the IM147 to identify.

The non fast-pass test times are from the analysis of the new standards presented in the previous portion of this section (the fourth column in Table 4-5). Averaging these by the number of vehicles in each class in each model year group of the fleet, the overall effect on the total test time can be determined. Test times for the IM240 with fast-pass come from a previous analysis of 26,000 vehicles that were tested in Arizona as part of the "2% Random Sample."[10] Because the 2% random sample includes only initial tests, the test times had to be adjusted to include retests; this adjustment was based on analysis of Arizona test data.[11] On average, vehicles in the Arizona test data that failed the first IM240 test and were subjected to another test went 110 seconds on the retest, so this test time was added to the 240 seconds for all failing vehicles. In addition, the average IM240 test times by model year group were then weighted by the fleet distributions in the sample vehicle fleet from this study to allow for an even comparison of test times.

As shown in Table 4-7, substantial test time reductions occur as a result of implementing fast-pass algorithms. Reductions of 58% for startup cutpoints, 50% for intermediate cutpoints, and 41% for final cutpoints were observed. Comparison of these test times to test times for the use of fast-pass for IM240 testing previously reported to EPA shows the IM147 has lower test times for startup and intermediate cutpoints (72 seconds for the IM147 versus 75 seconds for the IM240 for startup cutpoints, and 92 seconds for the IM147 versus 106 seconds for the IM240 for intermediate cutpoints). Test times for final cutpoints were almost the same (121 seconds for the IM147 versus 122 seconds for the IM240).

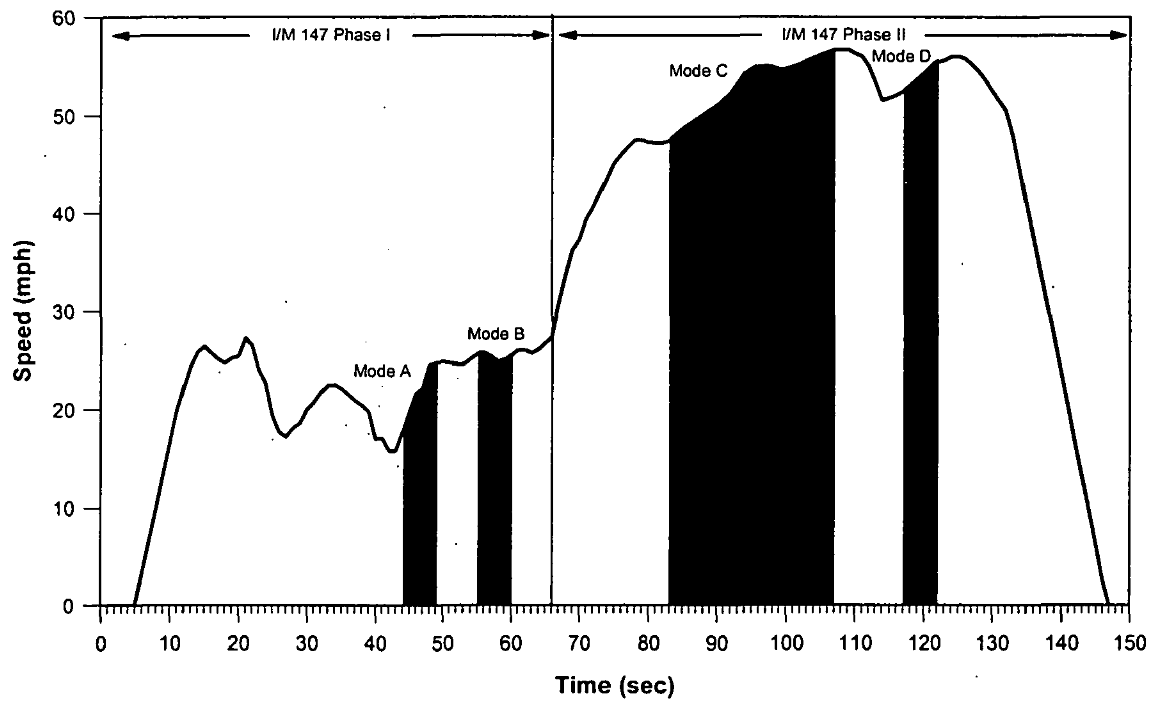
Overall excess emissions identified by the IM147 using the above fast-pass methodology were all above 95% with only one exception (for intermediate NOx cutpoints). At the same time, there were excess emissions for individual vehicle model years that the IM147 did not identify well. The majority of the loss in excess emissions was for LDGTs in the 1985 to 1989 range. For startup standards, the IM147 lost 100% of the excess emissions for this model year/vehicle type grouping. This was due to the small sample size used in this analysis. There was only one vehicle that failed the IM240; however, that vehicle falsely passed the IM147, and therefore there was a loss in excess emissions of 100%. However, the excess emissions lost for this vehicle were less than 5% of the overall excess HC and CO emissions of the fleet. If a larger sample were tested, it is expected that these types of anomalies would be eliminated.

Modal Predictive Retest Analysis

The second method evaluated to reduce test time was the development of algorithms to predict if a vehicle would benefit from a retest. If a vehicle were not adequately preconditioned (warmed up) before the test (e.g., due to being in a long queue), then the vehicle could falsely fail the emissions test. Although the "two-ways-to-pass" standards, which use the first portion of the IM test as preconditioning for the second half of the test, work for some vehicles, previous studies conducted by Sierra revealed that inadequate preconditioning can be responsible for up to 25% false failures.[12,13] As shown in those earlier studies, modal data from various sections of the test can be used to predict with at least 80% accuracy if a vehicle that fails would benefit from a retest due inadequate preconditioning. If a vehicle would continue to fail repeated tests (i.e., it did not fail due to a lack of preconditioning), then retesting the vehicle is an inefficient use of testing time. If failing vehicles that will continue to fail can be discriminated from those vehicles that would benefit from another test (i.e., vehicles that failed due to a lack of preconditioning but would pass an additional test), retesting of the fail/fail vehicles could be avoided and average test time could be reduced.

Using a similar approach as was used in the previous studies,[14] the composite emission rate, the Phase 2 emission rate, and the concentrations during certain sections of the test were evaluated to determine if relationships exist in the data that can help predict if a vehicle would benefit from a retest. To develop the algorithms for the IM147, the sections of the test that were initially evaluated based on both mass and concentration included seconds 43 to 48, 54 to 59, 82 to 106, and 116 to 121 (assuming the first second of the test is 0), as shown in Figure 4-4. Proposed final cutpoints were used to determine pass-fail status. Due to the limited sample size, LDGT1s and LDGT2s were combined for this analysis and failures between either IM147 test one and two, or IM147 test two and three, were treated the same for developing the retest criteria. Based on these conditions, data from 111 failed tests (75 LDGVs and 36 LDGTs) were used to develop the retest algorithms.

Figure 4-4
Modes Used For Development Of Retest Algorithms



The logic applied to LDGVs and LDGTs to determine if a vehicle should be retested is shown in the flow diagrams presented in Figures 4-5 and 4-6. The first criterion applied was that if a vehicle failing for all three pollutants would not be retested. This condition occurred in 6.7% of the failing LDGVs and 5.7% of the LDGTs.

Figure 4-5

I/M 147 Retest Predictive Model Logic
LDGV

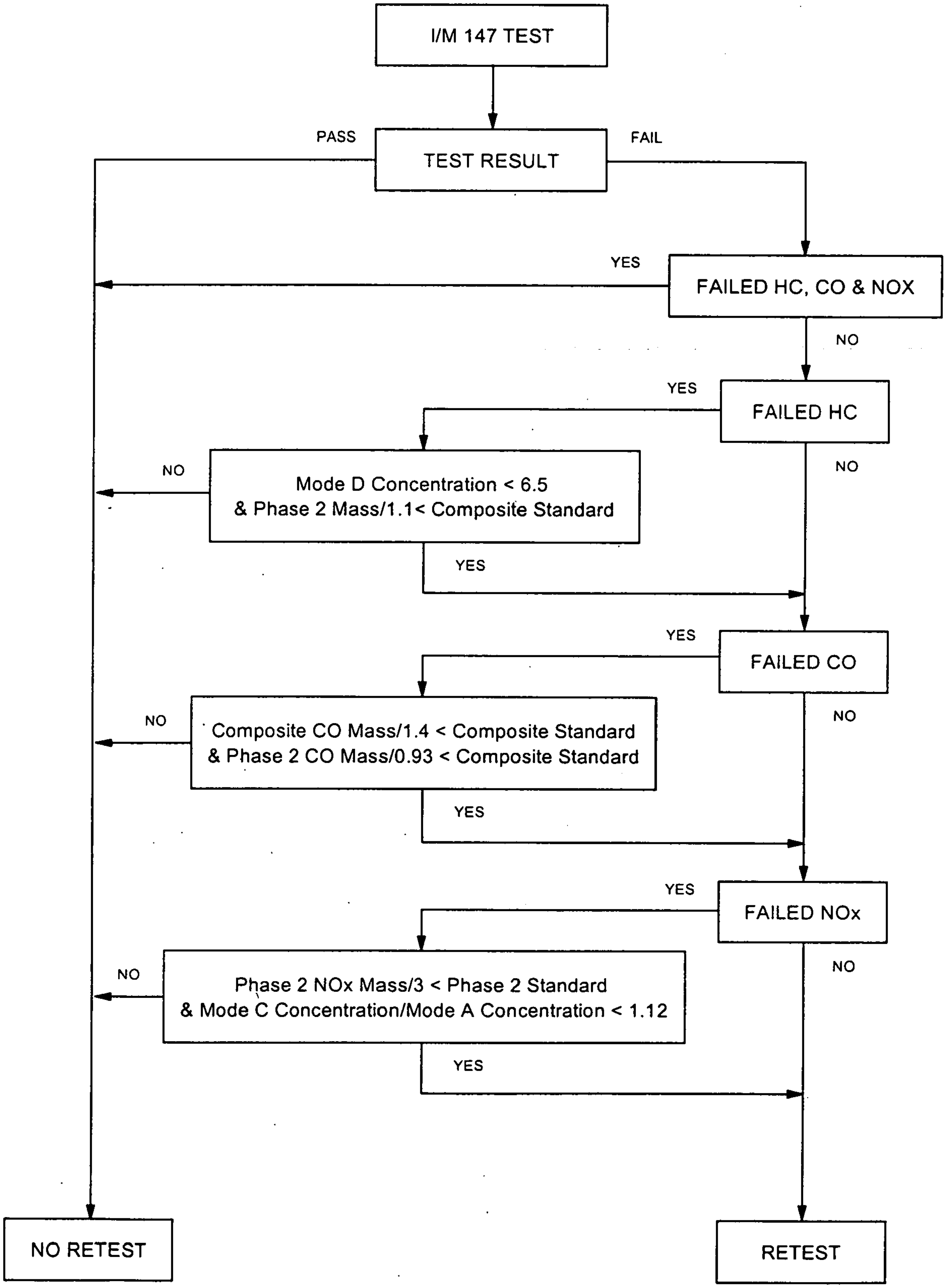
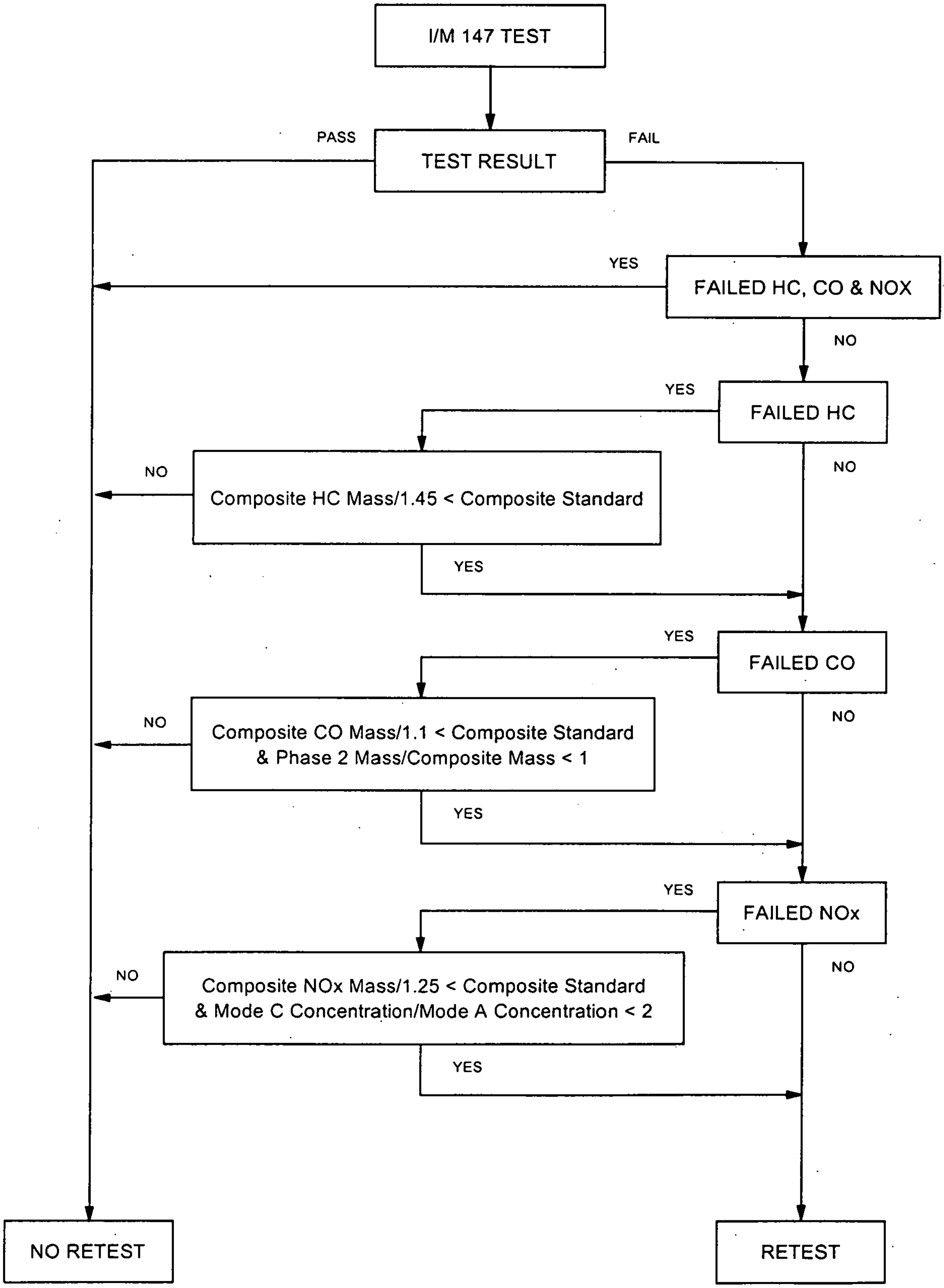


Figure 4-6

I/M 147 Retest Predictive Model Logic

LDGT 1 & 2



The next criterion was to evaluate emissions from the whole test or Phase 2 of the test, relative to the emissions standards. If the vehicle was within a certain percent of the standard, a retest was usually warranted. This worked well as an initial criterion for all vehicle classes and pollutants with the exception of HC for LDGVs. For LDGTs, this was the only criterion needed; all others had one additional criterion. The remaining HC and CO criteria were based on either Phase 2 or Phase 2 divided by the composite emissions compared to their standards. For NOx, the additional criterion was based on a percent concentration reduction between mode A and mode C (the ratio of the average concentration during mode 3 shown in Figure 4-4 and mode 1 shown in Figure 4-4), which was an indication of warm-up occurring as this percent decreased.

The final logic that was applied was that if a vehicle failed for more than one pollutant, a retest for every pollutant had to be indicated. Therefore, even if the vehicle appeared to be warming up, if it was not going to be enough to pass the standards for each pollutant, the vehicle was not retested.

The accuracy of these algorithms in predicting the need for a retest correctly is shown in Table 4-8.

Table 4-8
Evaluation of Retest Criteria (Based on Final Cutpoints)

	Sample size	% correct	Retested when vehicle would still fail	Did not retest when vehicle would pass
LDGV				
Fail HC, CO, & NOx	5	100 %	0.0 %	0.0 %
HC failures	48	95.8 %	2.1 %	2.1 %
CO failures	25	92.0 %	4.0 %	4.0 %
NOx failures	48	81.3 %	10.4 %	8.3 %
All criteria for all failures	75	86.6 %	6.7 %	6.7 %
LDGT				
Fail HC, CO, & NOx	2	100 %	0.0 %	0.0 %
HC failures	18	94.4 %	5.6 %	0.0 %
CO failures	9	100 %	0.0 %	0.0 %
NOx failures	24	95.8 %	4.2 %	0.0 %
All criteria for all failures	36	97 %	2.8 %	0.0 %
LDGV and LDGT (Sample Fleet Weighting)				
All criteria for all failures	111	90.0%	5.4 %	4.5 %

As shown in Table 4-8, applying the combined criteria to the failing vehicles in the sample fleet resulting in a overall correct prediction rate (of when a vehicle needed a retest) of 90%. The accuracy of the algorithms were, however, better for LDGTs than for LDGVs. This may be an artifact of having only a limited sample set to use to develop and evaluate the algorithms. Because there were fewer data for LDGTs, it was easier to fit a model with low or no false failures or false passes. As more test data become available, the criteria should be re-evaluated and revised.

The results on test time and excess emissions identified by applying the retest criteria to the full sample set are shown in Table 4-9. As shown in the table, application of the retest algorithms resulted in significant reductions in test time from the reductions produced by using fast-pass, including 24% for startup cutpoints, 28% for intermediate cutpoints, and 33% for final cutpoints. The trend of higher reductions in test times for the startup cutpoints that occurred with the application of fast-pass standards was reversed with the application of the retest algorithms. This caused the overall test time reductions for the three sets of cutpoints to come closer together. The reduction in test time from not using either fast-pass or retest algorithms to using both was 68% for startup cutpoints, 64% for intermediate cutpoints and 61% for final cutpoints.

As can be seen from Table 4-9, implementing the retest algorithm identified more excess emissions than did use of fast pass cutpoints alone. A retest algorithm cannot cause a loss in excess emissions identified because it does not make decisions about passing a vehicle, it is used only to determine if a failing vehicle should receive a retest. In fact, there were several cases with the current data set where the retest logic prevented a vehicle from undergoing a second test in which the vehicle would have been falsely fast-passed. This actually prevented excess emissions from being lost. An example is the intermediate CO cutpoints with and without the retest algorithm. With only fast pass procedures implemented, the excess emission identified for CO was 97.8%, but with the both fast pass and retest algorithms, the excess emissions identified returned to 100%.

To more objectively evaluate the accuracy of the retest predictive algorithms, they were applied to another sample of 101 vehicles tested on the IM147* in a previous study.[15] This evaluation included an assessment of false-pass or false-fail occurrences, as well as excess emissions lost and average test times. In this analysis, the fast-pass regressions were also used because it is assumed that both of these techniques will be used in real operations. The results of the evaluation are shown in Table 4-10.

* The incorporation of the retest algorithm will tend to minimize the impact of the 30-minute idle period prior to the testing of each of these vehicles. As a result, these data can be analyzed with less concern that the results (in terms of % excess emissions identified) will be significantly biased relative to the actual Arizona test fleet.

Table 4-9
Comparison of Retest Predictive Algorithm Effectiveness for the IM147
Impact on Test Time and Excess Emissions Lost

Vehicle Class	Model Year Group	Test Time Without Retest Algorithm (seconds)	IM147 with Retest Algorithm				
			Number in Test Sample	Mean Test Time (seconds)	% Excess Emissions Identified[a]		
					HC	CO	NOx
Startup Cutpoints							
LDGV	81 - 84	249	13	105	100	100	100
	85 - 89	86	45	63	100	100	-
	1990+	56	133	47	100	100	100
LDGT 1&2	81 - 84	146	8	109	100	-	100
	85 - 89	62	27	54	93.8	0.0	-
	1990+	56	74	48	-	-	100
Weighted average		72		55	97.2	95.1	100
Intermediate Cutpoints							
LDGV	81 - 84	289	13	125.15	100	100	98.1
	85 - 89	136	45	92.24	100	100	98.1
	1990+	64	133	53	95.3	100	100
LDGT 1&2	81 - 84	221	8	137	100	100	76.1
	85 - 89	109	27	79	90.3	100	0.0
	1990+	59	74	52	0		100
Weighted average		92		66	98.4	100	93.2
Final Cutpoints							
LDGV	81 - 84	348	13	167	100	100	100
	85 - 89	204	45	118	98.3	100	100
	1990+	78	133	61	100	100	96.4
LDGT 1&2	81 - 84	343	8	123	100	100	100
	85 - 89	159	27	118	97.2	89.2	100
	1990+	72	74	60	100	-	100
Weighted average		121		81	99.2	97.5	99.6

[a] "-" indicates there were no failures in this group for the IM240 and therefore no excess emissions for the IM147 to identify.

Table 4-10 Evaluation of Retest Criteria with 101 Vehicle Sample Based on Final Cutpoints and Exempting 1992+ Vehicles							
Vehicle class	Number in Test Sample	% correct	Retested when vehicle would still fail	Did not retest when vehicle would pass	% Excess Emissions Identified		
					HC	CO	NOx
LDGV	31	80.6 %	3.2 %	16.1 %	94.1	98.6	100
LDGT1&2	14	64.2 %	14.3 %	21.4 %	30.6	30.4	71.1
Weighted average of LDGV and LDGT1&2	45	75.6 %	6.6 %	17.8 %	74.2	89.8	92.1

The results show that the number of errors for LDGT1&2s were larger than for LDGVs. This is most likely because the LDGT1&2 retest criteria are based on fewer data than the LDGV retest criteria, so they do not work as well. Comparing the weighted average number of vehicles that were retested when the vehicle failed versus those that were not retested but that would have benefitted from a retest shows the criteria appear to be biased toward not testing vehicles that could benefit from another test. The impact of this may be to cause vehicle owners to obtain unnecessary vehicle repairs. These criteria for retest will need to be examined further when more data are available to further refine of the retest models.

The results of the analysis of the percent of excess emissions identified shows the largest emissions losses were for HC, then CO. All NOx emissions were identified in the small sample. The losses in excess HC emissions identified are much higher than in the 300 vehicle sample. The excess NOx emissions loss is less, and the CO loss is in the same range as for the other sample. Again, the variation is likely the result of the small sample size. Further improvement of the retest algorithms will require more data.

Model Year Exemptions

A very efficient method to reduce the overall test time is to simply remove from testing a portion of the fleet that would likely pass the emissions test anyway. Currently, EPA has published draft guidance[16] on the use of "Clean Screening" methods for identifying potentially clean vehicles to be exempted from testing. The methods discussed in the report and currently under evaluation including the use of model year exemptions, a low emitter profile, and remote sensing to identify likely clean vehicles. There has been much debate over the relative merits of these techniques, and the process is continuing.*

* See the U.S. EPA web site section on Clean Screening, http://www.epa.gov/orcdizux/rsd.htm for more details on the debate.

Of the proposed methods, a model year exemption is the easiest to implement and should have virtually no direct cost to implement. In addition, new vehicles are historically low emitters, in part because of emissions control system warranty requirements imposed on new vehicles and in-use compliance programs that are highly effective in enforcing emissions system durability requirements. A low emitter profile is an extension of a model year exemption, in which other characteristics of vehicles that are predictive of low emissions (e.g., make, model, engine family, etc.) are also used to determine which vehicles should be exempted from testing. This method can exempt more vehicles than a model year exemption alone (new vehicles plus older vehicles which the model believes are clean), but it requires a database of vehicle emissions tests in order to develop the profiles (which has some cost). The use of remote sensing to identify low emitting vehicles has both significant technical accuracy problems and program costs. Part of the reason for developing methods to reduce test time is to improve the efficiency and cost effectiveness of emissions testing. For this reason, a model year exemption seems to be a very reasonable method to use, and it was considered as part of the present study.

This issue was first analyzed by removing the excess emissions in the IM240 from the excess emissions identified by the IM147, for the model years being considered for exemption. All results are compared to a baseline that includes the fast-pass and retest algorithms. Vehicles in the present study ranged from 1981 to 1998 model years. However, because only one 1998 model year vehicle was included in the data set, it was assumed that a "current plus five" model year exemption would include model years 1997 through 1992. The results for exempting these model years (with the use of fast-pass and retest algorithms) is shown in Table 4-11.

When exempted vehicles are included in the analysis, the reductions in mean test time from the use of all three techniques are 82% (from 172 seconds per test to 31 seconds per test) for startup cutpoints, 78% (from 185 seconds per test to 41 seconds per test) for intermediate cutpoints, and 73% (from 206 seconds per test to 55 seconds per test) for final cutpoints. When only those vehicles arriving at the test lanes are considered (i.e., the exempted vehicles are not included with a "test time" of zero), the actual mean test times are 65 seconds for startup cutpoints, 86 seconds for intermediate cutpoints, and 115 seconds for final cutpoints. However, these results are for the sample fleet. The model year distribution of this fleet may not match the model year distribution of all fleets. It is important to note that the estimated change in test time will vary with different fleets due to differences in the vehicle age distribution.

For the test sample under the startup cutpoints, the excess emissions lost was greatest for CO; under the intermediate cutpoints, it was greatest for NOx. For final cutpoints, the maximum excess emissions lost (7.9%) was for CO.

Table 4-11
Comparison of Exempting 1992+ Model Years (Current + 5)
Impact on Test Time and Excess Emissions Lost

Vehicle Class	Model Year Group	Test Time Without Model Year Exemptions (seconds)	IM147 with Model Year Exemptions					
			Number in Test Sample	Mean Test Time (seconds)		% Excess Emissions Identified[a]		
				All Vehicles[b]	Non-Exempt Vehicles	HC	CO	NOx
Startup Cutpoints								
LDGV	81 - 84	105	13	105	105	100	100	100
	85 - 89	63	45	63	63	100	100	-
	1990+[b]	47	133/37[c]	-	57	89.8	36.3	100
LDGT 1&2	81 - 84	109	8	109	109	93.8	-	100
	85 - 89	56	27	54	54	100	0.0	-
	1990+[b]	48	74/14[c]	-	55	-	-	67.9
Weighted average[d]		55		31	65	95.2	81.7	88.5
Intermediate Cutpoints								
LDGV	81 - 84	125	13	125	125	100	100	98.1
	85 - 89	92	45	92	92	100	100	98.1
	1990+[b]	53	133/37[c]	-	68	79.6	39.4	100
LDGT 1&2	81 - 84	137	8	137	137	100	100	76.1
	85 - 89	79	27	79	79	90.3	100	0.0
	1990+[b]	52	74/14[c]	-	59	0.0	-	61.9
Weighted average[d]		66		41	86	96.0	91.5	84.1
Final Cutpoints								
LDGV	81 - 84	167	13	167	167	100	100	100
	85 - 89	118	45	118	118	98.3	100	100
	1990+[b]	61	133/37[c]	-	100	73.3	43.2	96.4
LDGT 1&2	81 - 84	123	8	123	123	100	100	100
	85 - 89	118	27	118	118	97.2	89.2	100
	1990+[b]	60	74/14[c]	-	87	100	-	58.3
Weighted average[d]		81		55	115	95.9	92.1	92.4

[a] "-" indicates there were no failures in this group for the IM240 and therefore no excess emissions for the IM147 to identify.
[b] Test time shown for 1990+ vehicles is for those that were tested and not exempted.
[c] Values represent the number of 1990+ vehicles in the sample / the number which were not excluded by the model year exemption.
[d] Weighted average for all vehicles includes a test time of 0 for vehicles exempted; weighted average for non-exempt vehicles does not include the newer models that have been exempted in the calculation of test time.

Table 4-12 summarizes the excess emissions identified by model years exempted for the final IM147 cutpoints. The excess emissions lost for all three pollutants are the same if 1994+ or 1993+ vehicles are exempted. This shows the effect of the small sample size – in a larger sample, some change would be expected between model years exempted.

Table 4-12
Excess Emissions Identified versus Model Years Exempted[a]

	HC	CO	NOx
1994 +	99.2 %	97.5 %	92.4 %
1993 +	99.2 %	97.5 %	92.4 %
1992 +	95.9 %	92.1 %	92.4 %
1991 +	86.8 %	87.9 %	87.9 %

[a] Based on final IM147 cutpoints.

In the present case, there were only a few vehicles of each model year, and it just happens that there were no 1993 vehicles with excess emissions.

Model Year Exemptions Over All Model Years

Since the I/M test data used in this project are from Arizona where IM240 testing is not conducted on 1980 and later model year vehicles, the percent of excess emissions lost from exempting newer model years as shown above, is based only on the 1981+ model years. A more representative comparison would be to consider these emissions losses relative to the total excess emissions identified for all vehicles in the I/M program, including pre-1981 model years. To evaluate the emissions impact based on the excess emissions of an entire fleet, data from the Wisconsin I/M program (where IM240 testing for 1968 and newer model year vehicles has been in effect since December 1995) were used. Because no IM147 data have been collected in Wisconsin, this analysis was based on the IM240 data. However, this analysis should serve as an indicator of the excess emissions lost when the entire fleet is considered.

In the Wisconsin IM240 program, fast-pass algorithms are used, and therefore a random sample of full duration IM240 tests is not available. Because of this, the partial test scores had to be adjusted to composite (full test) emissions. To calculate the composite emissions, cumulative 30-second HC, CO, and NOx emissions were tabulated for all of the two-percent random sample tests* conducted in Arizona from April through June

* A random sample of 1981+ LDVs are subjected to full-duration IM240 tests in the Arizona IM240 program.

1996, to be used in developing of the correlation equations. The April through June time period was selected because of the typically moderate range of temperatures seen in both Arizona and Wisconsin during that portion of the year. Next, linear regression equations defining the relationship between cumulative 30-second and composite gram-per-mile emissions were developed. Three sets of equations, which characterize the model year groupings used in the rest of the analysis, were developed using this methodology.

The regression equations developed from the Arizona data set were applied to the 30-second scores from the Wisconsin IM240 Program data* collected during the same April-June 1996 time frame. Composite (full duration) IM240 scores were extrapolated from the Wisconsin cumulative 30-second emissions using the equations described above. Excess emissions for each test were then determined by applying the appropriate model-year EPA final cutpoints to the composite IM240 estimates. The excess emissions were then averaged by model year, and weighted using MOBILE5a travel fractions.

Figure 4-7 graphically displays the results of the analysis. As shown in the figure, exempting the latest five model years (1991-1995) has a relative insignificant effect (i.e., approximately 2% or less of each pollutant) on the cumulative excess HC, CO, and NOx emissions identified when all model years are considered. The figure also shows that these five model years account for roughly 45% of the total 1968 and later LDV population subject to the program.

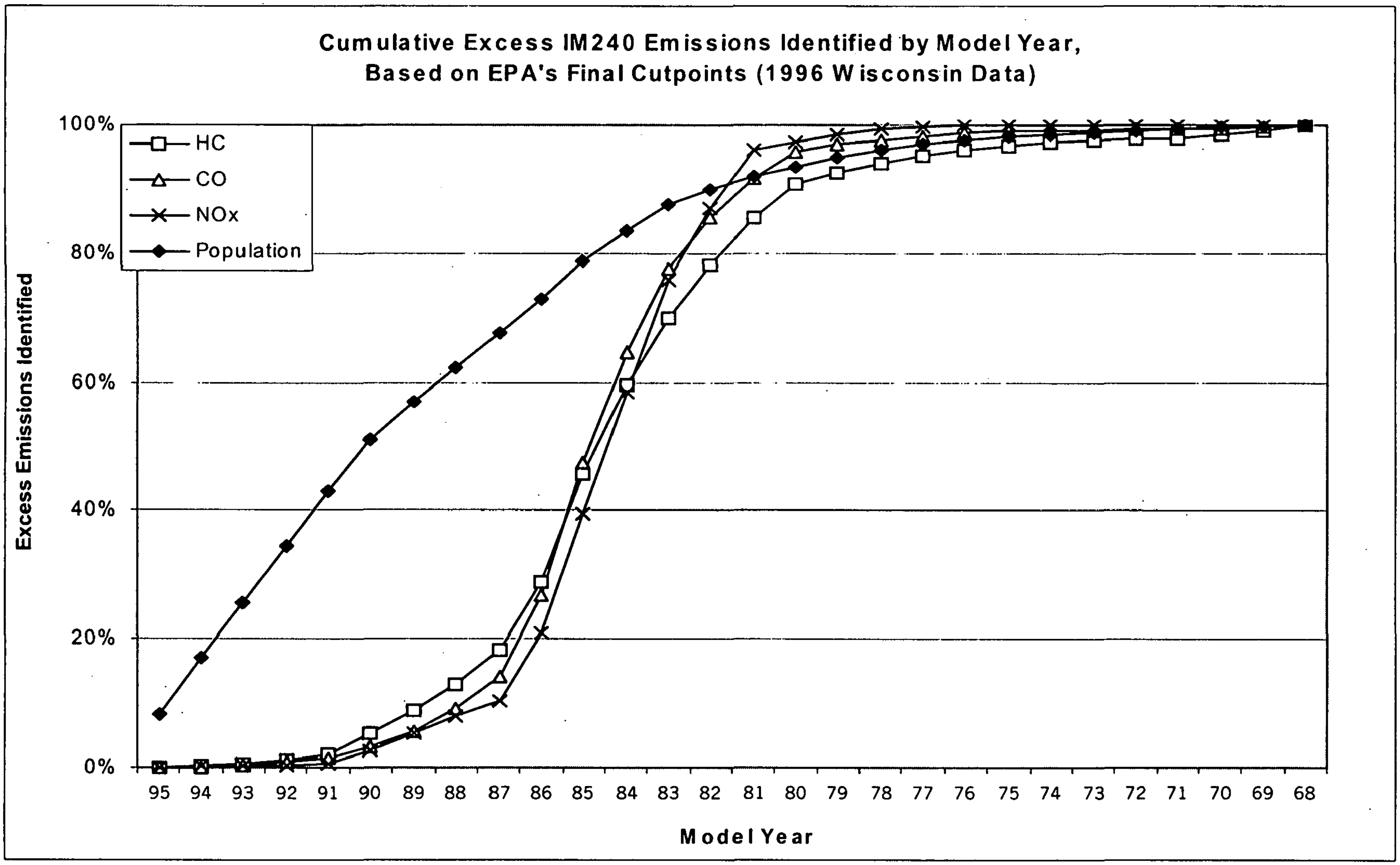
The fraction of excess emissions identified begins to decline more rapidly with the exemption of the 1990 model year. However, up to nine model years (1987-1995) can be exempted before the decline steepens appreciably for all three pollutants with decreasing model year. This effect on cumulative excess emissions identified is also shown tabularly in Table 4-13 for the latest 10 model years. The data presented in both the table and the figure provide an approximation of the relative effect on excess emissions identification due to exempting various ranges of newer model year vehicles from IM240 testing, when all model years are considered. Effects of a similar magnitude would be expected in a program utilizing the IM147 test procedure.

Summary

The IM147 can produce significant reductions in test times compared to the IM240, especially with the use of fast-pass procedures, retest algorithms, and new model year vehicle exemptions. The overall losses in emissions are small and therefore the IM147 can produce cost-effective reductions in test time.

* The Wisconsin IM240 sample included roughly 127,000 vehicles.

Figure 4-7



Cumulative Excess IM240 Emissions Identified by Model Year,
Based on EPA's Final Cutpoints (1996 Wisconsin Data)
HC
CO
NOx
Population
100%
80%
60%
40%
20%
0%
Excess Emissions Identified
95 94 93 92 91 90 89 88 87 86 85 84 83 82 81 80 79 78 77 76 75 74 73 72 71 70 69 68
Model Year

Table 4-13 Effect of LDV Model Year Exemptions on Excess Emissions Identification				
Model Year	Cumulative % of Excess Emissions			% of Vehicle Population
	HC	CO	NOx	
1995	0.1%	0.0%	0.1%	8.3%
1994	0.3%	0.1%	0.2%	17.1%
1993	0.5%	0.3%	0.2%	25.7%
1992	1.2%	0.8%	0.4%	34.5%
1991	2.1%	1.4%	0.5%	43.1%
1990	5.2%	3.3%	2.6%	51.2%
1989	8.9%	5.6%	5.3%	57.1%
1988	13.1%	9.2%	7.8%	62.3%
1987	18.3%	14.2%	10.5%	67.7%
1986	28.9%	26.8%	20.9%	72.9%

Test Times - The changes in test time as each of the methods to reduce test time were applied can be seen in Table 4-14. As the table shows, up to a 68% reduction in test time can still be achieved under the final standards, when using all three test time reduction techniques (i.e., fast-pass, retest algorithm, and model year exemptions). The largest reduction was achieved by implementing fast-pass procedures. This is because the majority of vehicles pass, and many are very clean and can pass out of the emissions test quickly.

Excess Emissions Identified - Excess emissions identified for each pollutant are shown in Table 4-15. There are some cases where excess emissions were "lost" by using one method to reduce test time, and then "gained" back by the next technique that was applied. This was in part because the techniques overlap in the way they work, i.e., the fast-pass procedures could have resulted in a loss of excess emissions from a retest, but the retest algorithm did not allow for the retest to occur.

Overall, total excess emissions lost by switching to the IM147 are low, up to the point where model years are exempted. Even if the current plus five model years are exempted, the IM147 retains over 92% of the excess emissions identified by the IM240 under final cutpoints.

Table 4-14 Average IM147 Test Time (seconds)				
		Startup Cutpoints	Intermediate Cutpoints	Final Cutpoints
Cutpoint only, two possible retests[a]		172	185	206
Added fast-pass		72	92	121
Added retest algorithm		55	66	81
Added exemption of 1992+ model years	All Vehicles	31	41	55
	Non-Exempt Vehicles	65	86	115
Overall % reduction in test time	All Vehicles	82%	78%	73%
	Non-Exempt Vehicles	62%	54%	44%

[a] If the vehicle fails the IM147, it is retested up to two more times to ensure the failure was not due to a lack of preconditioning.

Table 4-15 Percent Excess Emissions Identified by the IM147 Test									
	Startup Cutpoints			Intermediate Cutpoints			Final Cutpoints		
	HC	CO	NOx	HC	CO	NOx	HC	CO	NOx
Cutpoint only, two possible retests	100	100	100	99.2	100	93.6	99.6	98.2	99.6
Add fast-pass	96.5	95.1	100	98.8	97.8	89.5	99.6	95.5	99.6
Add retest algorithm	97.2	95.1	100	98.4	100	93.2	99.2	97.5	99.6
Add exemption of 1992+ model years	95.2	81.7	88.5	96.0	91.5	84.1	95.9	92.1	92.4

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5. DISAPPEARING VEHICLES

It is estimated that roughly 20% of vehicles that fail the Arizona IM240 test do not receive a passing test, resulting in a significant loss of potential SIP credit for the program. In a previous study performed by Sierra for DEQ, it was discovered that a significant fraction of vehicles failing the initial I/M test did not pass on a retest within a four- to sixteen-month window following their initial test.[17] The goal of this portion of the work assignment was to evaluate the disposition of such disappearing vehicles, estimate their excess emissions lost, and suggest solutions to address the problem. These results will help to better define the nature and extent of the problem of retest noncompliance in the Arizona program, which likely occurs in every other I/M program in the U.S.

The first step in the analysis was to determine the fraction of those vehicles that continue to be operated in the program area without receiving a passing I/M score. We had hoped to receive information from the Arizona Motor Vehicle Department (through DEQ) regarding whether those vehicles were being registered outside the area, or if their registrations had lapsed. Unfortunately, the Motor Vehicle Department (MVD) was less than cooperative in this request. As an alternative, remote sensing device (RSD) data from Arizona's "Smog Dog" program were used to determine the fraction of non-complying vehicles that continue to operate in the program area.

Definition of Data Groups

To perform the analyses that follow, Arizona I/M data collected from July to December 1997 were divided into three categories:

- Pass: Vehicles that passed the I/M test on the first attempt (initial test dates from July 1, 1997, to September 30, 1997);
- Fail-Pass: Vehicles that failed the initial test (conducted between July 1, 1997, and September 30, 1997), and passed within the next three to six months (i.e., by December 31, 1997); and
- Fail-Fail: Vehicles that failed the initial test (conducted between July 1, 1997, and September 30, 1997), and did not pass within three to six months of their

initial test (i.e., by December 31, 1997). These vehicles are assumed to be driving unregistered, and are considered the so-called "disappearing" vehicles.

This nomenclature is used through the rest of this discussion to describe the vehicles in the study.

Comparison of I/M Data To RSD Observations

As outlined above, data regarding vehicles subjected to I/M testing in Maricopa County from July through September of 1997 were used to identify vehicles that initially passed or failed the I/M test. The initial test failures were tracked through the end of the year to determine which of these vehicles had still not passed an emissions test (Fail-Fail vehicles) within a three- to six-month time period following their initial test date (i.e., by December 31, 1997). To determine whether the Fail-Fail vehicles were still being operated in the area, the license plate numbers of these vehicles were compared to license plate data of vehicles identified by remote sensors in Maricopa County from January 1 through March 31, 1998. The percentages of vehicles observed in the RSD data in Fail-Fail and Fail-Pass categories are presented in Table 5-1 by model year groupings. Table 5-1 also presents the frequency that vehicles are seen on the road.

Table 5-1
Fraction of Vehicles Observed in the RSD Database that Initially Failed an I/M Test in Maricopa County

Model Year Group	Fail-Fail July-Sept 1997	Fail-Fail Observed by RSD	Fail-Pass July-Sept 1997	Fail-Pass Observed by RSD	Ratio of Fail-Fail to Fail-Pass
Pre-1975	823	2.7%	2,657	5.3%	51%
1975-1980	2,512	4.4%	8,690	7.0%	63%
1981-1984	2,148	6.2%	4,935	8.8%	70%
1985-1987	2,279	7.8%	6,662	10.2%	77%
1988-1991	1,154	9.2%	5,432	13.0%	71%
1992 +	282	13.8%	2,645	15.2%	91%

A number of points can be made in reference to the data presented in Table 5-1:

- A smaller fraction of older vehicles were observed in the RSD data for both the Fail-Fail and the Fail-Pass categories. This was expected because older vehicles are driven less than newer vehicles, making them less likely to be identified by RSD.

- For all of the model year groups, the fraction of Fail-Fail vehicles observed by RSD is less than that of the Fail-Pass vehicles. This implies that a certain fraction of the Fail-Fail vehicles have been scrapped, parked, or otherwise removed from the road. (Alternatively, the frequency of operation of these vehicles may have been reduced.)

- The fraction of Fail-Fail vehicles not observed to be operating in the area increases with vehicle age. Based on the results presented in Table 5-1, it appears that about 50% of the Fail-Fail vehicles in the pre-1974 model year group have been removed from the road. However, only 9% of the 1992 and later model year Fail-Fail vehicles do not continue to operate on the road in Maricopa County.

- Although not presented in Table 5-1, the fraction of Pass vehicles (initial tests from July 1997 to September 1997) observed in the January 1998 to March 1998 RSD data matched very closely the results for the Fail-Pass category. This would appear to validate the use of the I/M data and the RSD data for this purpose.

An important element not considered in the analysis presented in Table 5-1 is waivered vehicles. It is quite likely that a number of the Fail-Fail vehicles included in this analysis did not receive a final passing score because they were granted a waiver. Data were received late in the analysis regarding the waiver status of vehicles during the study period so it could be determined if waivered vehicles accounted for a significant fraction of the vehicles. Comparison of the data on waivered vehicles in Arizona to the disappearing vehicles shows the waivered vehicles were not responsible. Waivered vehicles accounted for only 0.71% of the disappearing vehicles.

An item of interest related to the analysis presented in Table 5-1 is whether the Fail-Fail vehicles observed in the RSD database (and, therefore, operating in the area) continue to make attempts to pass the I/M test. This was determined by merging the license plate data from the Fail-Fail vehicles observed by RSD in the January 1998 to March 1998 time frame with the Arizona I/M database for the same time period. If vehicles appeared in both databases, it was an indication that the vehicles were continuing with the I/M process. The results of that analysis are summarized in Table 5-2, which indicates that about 20% of the Fail-Fail vehicles operating in the area continue to be tested in an attempt to receive a passing I/M score.

Table 5-2 **Fail-Fail Vehicles in the RSD Database that Continue to Attempt to Pass an I/M Test**			
Model Year Group	# of Fail-Fail Observed by RSD	Fail-Fail RSD Hits I/M Tested Jan to Mar 1998	Fraction of Fail-Fail Continuing to be I/M Tested
Pre-1975	22	4	18%
1975-1980	111	31	28%
1981-1984	134	18	13%
1985-1987	177	45	25%
1988-1991	106	27	25%
1992 +	39	3	8%

Comparison of Current Disappearing Vehicle Estimates to Previous Estimates

As noted above, the issue of "disappearing" vehicles was first identified in a study performed by Sierra for DEQ. In that study, which was based on an analysis of the 2% Random Sample IM240 database, initial test results from January 1996 to December 1996 were merged with after-repair tests conducted from January 1996 through April 1997. (It was assumed that motorists intending to fully repair their vehicles would have done so within a four-month time frame.) Based on an analysis of vehicles that received at least one retest,* the following non-passing after-repair percentages were obtained for vehicles failing the initial test:

Fraction of Incomplete Repairs Based on DEQ Analysis

Model Year	LDGV	LDGT1	LDGT2
1981-1984	33%	20%	16%
1985-1989	23%	19%	15%
1990+	9%	6%	7%

Although a slightly different methodology was used in the analysis presented in Table 5-1 (i.e., the entire database was analyzed rather than only the 2% Random Sample of IM240 tests, a minimum of one retest was not required, and a different time period was

* Sierra chose to limit this analysis to vehicles that received at least one retest because of concerns over whether the vehicles were coded correctly as being in the "Repair Sample" on their retest. If they received at least one retest, then it is likely they were properly flagged on ensuing tests. However, this approach may understate the magnitude of vehicles not receiving complete repairs in the Arizona program.

analyzed), similar results were obtained. Using the model year groupings in Table 5-1, the fraction of vehicles not passing their final test is summarized below.

Fraction of Incomplete Repairs Based on Current Analysis

Model Year	All Vehicle Classes
Pre-1975	24%
1975-1980	22%
1981-1984	30%
1985-1987	25%
1988-1991	18%
1992+	10%

Although the model year groupings do not match exactly (a broader range of model years was used in the DEQ analysis because of sample size considerations), similar results are observed when comparing the two analyses. It is interesting to note that there is a peak in incomplete repairs observed in the Table 5-1 data for the 1981-1984 model year group. That is likely because those vehicles are subject to a more stringent I/M test than the older vehicles (i.e., IM240 versus an idle/loaded test) and the waiver cost limit is greater (i.e., $100 for pre-1975; $300 for 1975-1979; and $450 for 1980 and later model year vehicles), making it more difficult and more expensive to pass an I/M test. Given the relative value of a 1981 model year vehicle, some motorists may choose to scrap or park their vehicles (or continue to operate them unregistered), rather than perform the repairs needed to pass an I/M test.

Conclusions

The analyses discussed above indicate that vehicles that continue to fail the I/M test after a number of months (i.e., the Fail-Fail "disappearing" vehicles) are observed operating on the road less frequently than their counterparts that received an initial I/M test in the same time period. However, this is a function of vehicle age, with older vehicles being less likely to continue to be operated (possibly scrapped, parked, or sold outside the area) than newer vehicles. Using RSD data to infer operation frequency, it appears that about half of the pre-1975 model year Fail-Fail vehicles do not remain in operation six to nine months after their initial test, while nearly 90% of the 1992 and later model year Fail-Fail vehicles remain on the road. Of those vehicles that do remain on the road, approximately 20% continue to attempt to pass the I/M test.

The fraction of initial test failures not receiving complete repairs (i.e., the Fail-Fail vehicles) estimated in this analysis agreed very well with the results of Sierra's previous analysis prepared for DEQ. Both analyses showed that older vehicles are more likely to not be repaired completely, with about 30% of the 1981 to 1984 model year initial test failures not receiving a passing score on the last I/M test.

Areas that may be investigated further to better define and develop recommendations to reduce the number of Fail-Fail vehicles operating in the enhanced area include (1) evaluating the potential effect of changes in the registration enforcement criteria in

Arizona (currently they include a $300 fine with no "grace period"); (2) determining if receiving a waiver is so difficult that motorists are driving unregistered instead of attempting to receive a waiver; (3) determining if Fail-Fail vehicles are eventually being registered out of the area but still driven in the area (there is anecdotal evidence of this); and (4) continuing to work with DEQ to enlist the assistance of MVD to track down the Fail-Fail vehicles. Unfortunately, Sierra's last correspondence with DEQ indicated that it is unlikely that information from MVD will be forthcoming in the near future.

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6. REFERENCES

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Appendix A

Regression Coefficients for Predicting Fast-Pass
HC, CO and NOx
1981-1985, 1986-1989, 1990 +
LDGV, LDGT1&2
IM147 Composite and IM147 Phase 2

IM147 Composite Regression Coefficients, HC, 1981 to 1984 Model Year LDGVs															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	0.28302	0.49292	12.2873	.	.	.	.	.	.	.	.	.	.	.	.
2	0.22087	0.27692	3.2873	3.8277	.	.	.	.	.	.	.	.	.	.	.
3	0.20626	0.2453	2.3395	2.7004	3.2789	.	.	.	.	.	.	.	.	.	.
4	0.2025	0.23726	1.7016	2.6934	2.2595	1.8199	.	.	.	.	.	.	.	.	.
5	0.19674	0.23191	0.7267	2.1947	1.8508	0.9417	3.2711	.	.	.	.	.	.	.	.
6	0.19371	0.22842	-1.267	2.2279	1.7198	0.6659	2.2869	2.394	.	.	.	.	.	.	.
7	0.18738	0.21202	-0.6231	1.7266	1.5146	0.8648	0.7315	2.1029	3.5094	.	.	.	.	.	.
8	0.18284	0.20824	-0.687	1.7643	1.2784	0.7029	0.02	1.611	2.2764	2.4076	.	.	.	.	.
9	0.17769	0.19322	-1.3178	1.6712	1.053	1.0174	0.4016	0.8538	1.6285	2.0881	1.7321	.	.	.	.
10	0.13615	0.09383	0.4577	0.6228	1.0161	0.4833	1.0706	1.5597	0.8105	1.8333	1.0468	1.2416	.	.	.
11	0.09167	0.05089	1.0299	0.48	0.7316	0.8687	0.7352	1.3107	0.8971	1.067	0.9405	0.5907	1.4934	.	.
12	0.05768	0.02128	1.0603	0.5538	0.6507	0.8006	1.0811	0.9603	0.8179	0.8284	0.5147	0.7446	0.6189	1.5707	.
13	0.04274	0.01042	1.2346	0.5575	0.7831	0.7967	0.7346	1.1164	0.5348	0.8189	0.5691	0.7167	0.5419	0.9427	1.1583

IM147 Phase 2 Regression Coefficients, HC, 1981 to 1984 Model Year LDGVs															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	0.20703	0.20953	.	.	.	.	.	.	.	.	.	2.0143	.	.	.
11	0.13389	0.09921	.	.	.	.	.	.	.	.	.	0.8473	2.2185	.	.
12	0.08219	0.03676	.	.	.	.	.	.	.	.	.	1.0326	0.8734	2.2399	.
13	0.06134	0.01912	.	.	.	.	.	.	.	.	.	0.9799	0.7426	1.3775	1.5991

IM147 Composite Regression Coefficients, HC, 1985 to 1989 Model Year LDGVs

Mode Number	RMS Error	Reg Constant	Regression Coefficients												
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	0.2766	0.34656	13.6824	.	.	.	.	.	.	.	.	.	.	.	.
2	0.20812	0.16873	2.8674	4.3117	.	.	.	.	.	.	.	.	.	.	.
3	0.19563	0.14463	2.3164	3.1348	3.175	.	.	.	.	.	.	.	.	.	.
4	0.19112	0.1363	1.6523	3.1427	1.874	2.2098	.	.	.	.	.	.	.	.	.
5	0.18367	0.1339	1.0144	2.4615	1.5573	0.9572	3.7335	.	.	.	.	.	.	.	.
6	0.17993	0.13253	-0.7224	2.4585	1.4487	0.6521	2.5769	2.6014	.	.	.	.	.	.	.
7	0.17293	0.12064	-0.1377	2.0423	1.1284	0.6939	1.2277	2.0519	3.6615	.	.	.	.	.	.
8	0.16757	0.11845	-0.1218	2.0933	0.8965	0.3231	0.5267	1.6047	2.2931	2.5007	.	.	.	.	.
9	0.15987	0.10456	-0.8348	1.9171	0.7991	0.6696	0.7616	0.787	1.6851	1.8453	2.3036	.	.	.	.
10	0.11866	0.04344	0.6913	0.7331	0.8232	0.419	1.2369	1.4124	0.9527	1.7448	1.2797	1.2607	.	.	.
11	0.07898	0.02878	1.0914	0.5395	0.6123	0.8408	0.9244	1.1702	0.8734	0.9789	1.0522	0.5826	1.5578	.	.
12	0.05069	0.01474	1.0422	0.5726	0.666	0.783	1.1483	0.8874	0.779	0.8472	0.558	0.7298	0.6519	1.5595	.
13	0.03552	0.00709	1.2462	0.5894	0.7478	0.8463	0.7814	0.9755	0.537	0.8335	0.6423	0.7001	0.5807	0.8694	1.1763

IM147 Phase 2 Regression Coefficients, HC, 1985 to 1989 Model Year LDGVs

Mode Number	RMS Error	Reg Constant	Regression Coefficients												
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	0.18785	0.12625	.	.	.	.	.	.	.	.	.	2.1945	.	.	.
11	0.11651	0.06121	.	.	.	.	.	.	.	.	.	0.8484	2.3783	.	.
12	0.07269	0.02771	.	.	.	.	.	.	.	.	.	1.0188	0.9382	2.2443	.
13	0.05129	0.01542	.	.	.	.	.	.	.	.	.	0.9743	0.8068	1.2835	1.6409

IM147 Composite Regression Coefficients, HC, 1990+ Model Year LDGVs

Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	0.29616	0.11159	23.1504	.	.	.	.	.	.	.	.	.	.	.	.
2	0.20623	0.02228	5.2355	5.8375	.	.	.	.	.	.	.	.	.	.	.
3	0.18497	0.01433	3.0203	3.9074	4.8396	.	.	.	.	.	.	.	.	.	.
4	0.17964	0.01313	1.8314	3.998	2.6416	3.1051	.	.	.	.	.	.	.	.	.
5	0.16982	0.01882	1.4967	3.1511	1.9707	1.0296	4.4945	.	.	.	.	.	.	.	.
6	0.1626	0.02339	-0.6319	3.2159	1.5762	0.3816	2.8898	3.3072	.	.	.	.	.	.	.
7	0.15712	0.02176	-0.1996	2.6659	1.1993	0.6833	1.3686	2.6473	4.0134	.	.	.	.	.	.
8	0.15019	0.02365	-0.2736	2.8358	0.4878	0.4377	0.7262	1.815	2.3769	2.8785	.	.	.	.	.
9	0.14499	0.02087	-0.9649	2.6634	0.3657	0.612	0.8119	1.3348	1.9646	1.933	2.2046	.	.	.	.
10	0.11125	-0.00021	0.7575	0.9919	0.6501	0.5117	0.8424	1.9987	1.0142	1.6999	0.8989	1.6093	.	.	.
11	0.06826	0.008	1.2736	0.4331	0.8051	1.0733	0.6767	1.6782	0.6997	0.9987	0.5665	0.4893	1.8827	.	.
12	0.04475	0.0038	1.1284	0.4637	0.8565	0.8999	0.9022	1.2724	0.7224	0.801	0.5186	0.7095	0.67	1.6291	.
13	0.03163	0.00271	1.2701	0.5075	0.8315	0.9132	0.7195	1.199	0.6065	0.8076	0.5087	0.717	0.4785	0.9448	1.2534

IM147 Phase 2 Regression Coefficients, HC, 1990+ Model Year LDGVs

Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	0.18606	0.00868	.	.	.	.	.	.	.	.	.	3.3615	.	.	.
11	0.10709	0.01506	.	.	.	.	.	.	.	.	.	0.7724	2.9305	.	.
12	0.06909	0.00683	.	.	.	.	.	.	.	.	.	1.0539	0.9218	2.4854	.
13	0.04937	0.00481	.	.	.	.	.	.	.	.	.	1.0329	0.6164	1.4047	1.8847

IM147 Composite Regression Coefficients, HC, 1981 to 1984 Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	0.88112	1.20816	18.7688	.	.	.	.	.	.	.	.	.	.	.	.
2	0.55624	0.30403	2.7624	7.3858	.	.	.	.	.	.	.	.	.	.	.
3	0.53047	0.26019	2.1969	5.8824	3.2855	.	.	.	.	.	.	.	.	.	.
4	0.52156	0.25543	0.9977	5.8612	2.1358	1.8787	.	.	.	.	.	.	.	.	.
5	0.49019	0.25485	-0.044	4.8747	1.5253	0.0287	5.2326	.	.	.	.	.	.	.	.
6	0.48792	0.25374	-1.225	4.9215	1.5106	-0.3233	4.7417	1.1408	.	.	.	.	.	.	.
7	0.46241	0.21664	0.0211	3.9498	1.3363	0.3735	2.1518	0.4819	5.1699	.	.	.	.	.	.
8	0.44686	0.21504	-0.2613	3.9279	0.8207	0.4803	1.1191	0.1717	3.7016	2.687	.	.	.	.	.
9	0.42957	0.18296	-1.3774	3.5298	0.6848	1.0093	1.3393	-0.2624	3.2094	1.7057	2.5925	.	.	.	.
10	0.34155	-0.01373	0.8274	1.0373	1.0349	0.8487	1.8452	0.4581	1.4938	1.5469	1.9606	1.76	.	.	.
11	0.23673	0.02715	1.5626	0.4691	0.6981	1.2432	1.3615	0.6487	1.3509	0.9303	1.6045	0.4984	1.6815	.	.
12	0.14911	0.01514	1.4565	0.3769	0.7648	0.8643	1.4548	0.9108	0.8932	0.9314	0.5447	0.7877	0.503	1.7656	.
13	0.11909	0.02688	1.5445	0.4495	0.8326	0.9259	0.8438	1.1997	0.5083	0.8469	0.6296	0.6889	0.4349	0.9716	1.289

IM147 Phase 2 Regression Coefficients, HC, 1981 to 1984 Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	0.58274	0.19292	.	.	.	.	.	.	.	.	.	3.7065	.	.	.
11	0.38837	0.1664	.	.	.	.	.	.	.	.	.	0.9113	2.7375	.	.
12	0.23224	0.06687	.	.	.	.	.	.	.	.	.	1.1491	0.6568	2.7135	.
13	0.18986	0.08178	.	.	.	.	.	.	.	.	.	0.9726	0.5315	1.5541	1.8213

IM147 Composite Regression Coefficients, HC, 1985 to 1989 Model Year LDGT1&2s

Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	0.56663	0.7155	17.4831	.	.	.	.	.	.	.	.	.	.	.	.
2	0.41307	0.27941	4.1285	5.3274	.	.	.	.	.	.	.	.	.	.	.
3	0.38375	0.23937	3.4282	3.7248	3.8254	.	.	.	.	.	.	.	.	.	.
4	0.3776	0.23527	2.2862	3.6738	2.7612	1.9754	.	.	.	.	.	.	.	.	.
5	0.35141	0.23018	1.6416	2.7652	1.9068	0.203	5.4202	.	.	.	.	.	.	.	.
6	0.34487	0.2345	0.1878	2.7411	1.8426	-0.4005	4.4017	2.218	.	.	.	.	.	.	.
7	0.3303	0.20554	0.6469	2.1902	1.6331	0.1685	1.7815	1.6532	4.9504	.	.	.	.	.	.
8	0.32267	0.20591	0.7492	2.1797	1.2776	0.2305	0.9713	1.1658	3.8532	2.1259	.	.	.	.	.
9	0.31316	0.18966	-0.0959	2.0508	1.1976	0.5815	1.3116	0.6511	2.8444	1.3636	2.2753	.	.	.	.
10	0.2312	0.04245	1.3359	0.466	1.0324	0.3511	1.787	1.1352	1.8284	1.2853	1.5223	1.5724	.	.	.
11	0.15326	0.03569	1.5184	0.5314	0.3571	0.9645	1.1672	0.9774	1.4614	0.8891	1.4441	0.5349	1.5258	.	.
12	0.09268	0.01207	1.0718	0.5289	0.6221	0.8436	1.2171	0.8383	1.1437	0.7345	0.5506	0.7355	0.6079	1.6637	.
13	0.07251	0.00754	1.221	0.5562	0.7481	0.91	0.8623	0.9975	0.6153	0.7166	0.6573	0.6966	0.5766	0.9448	1.1525

IM147 Phase 2 Regression Coefficients, HC, 1985 to 1989 Model Year LDGT1&2s

Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	0.38232	0.17582	.	.	.	.	.	.	.	.	.	2.907	.	.	.
11	0.2456	0.10791	.	.	.	.	.	.	.	.	.	0.9062	2.4096	.	.
12	0.13522	0.02745	.	.	.	.	.	.	.	.	.	1.0587	0.8344	2.4791	.
13	0.10561	0.01744	.	.	.	.	.	.	.	.	.	0.9906	0.7717	1.4444	1.6076

IM147 Composite Regression Coefficients, HC, 1990+ Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	0.47358	0.21002	25.4779	.	.	.	.	.	.	.	.	.	.	.	.
2	0.30957	0.02101	4.8648	6.3816	.	.	.	.	.	.	.	.	.	.	.
3	0.27326	0.02516	3.888	3.781	5.3959	.	.	.	.	.	.	.	.	.	.
4	0.26274	0.02776	2.459	3.6512	3.7037	2.8503	.	.	.	.	.	.	.	.	.
5	0.24556	0.03553	1.5156	3.0487	2.2656	1.1333	5.1256	.	.	.	.	.	.	.	.
6	0.24105	0.04057	0.2926	3.0167	2.1731	0.3867	4.321	1.949	.	.	.	.	.	.	.
7	0.2245	0.03117	0.9559	2.2238	1.7687	0.8632	1.5799	1.1997	6.1164	.	.	.	.	.	.
8	0.21946	0.03551	0.8458	2.3821	1.239	1.018	0.8595	0.4381	5.2659	1.8798	.	.	.	.	.
9	0.20649	0.02736	-0.2205	2.1038	1.0238	1.4328	1.0755	0.1268	4.644	0.3345	3.178	.	.	.	.
10	0.14857	-0.0053	1.4529	0.2504	0.8221	0.9906	1.4828	0.8031	2.4979	0.7858	1.8619	1.8399	.	.	.
11	0.10014	0.00971	1.233	0.3838	0.75	1.249	0.8911	0.8007	1.2455	0.9788	1.3895	0.6068	1.5933	.	.
12	0.06561	0.00571	1.2678	0.3618	0.9336	1.0717	1.1601	0.6722	1.0448	0.7941	0.6573	0.7481	0.6237	1.5909	.
13	0.04847	0.00362	1.4218	0.4403	0.8949	1.0884	0.7455	0.8543	0.6521	0.8293	0.6849	0.7025	0.5718	0.8249	1.2326

IM147 Phase 2 Regression Coefficients, HC, 1990+ Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	0.25439	-0.00921	.	.	.	.	.	.	.	.	.	3.7379	.	.	.
11	0.16351	0.01393	.	.	.	.	.	.	.	.	.	1.0922	2.61	.	.
12	0.10151	0.00637	.	.	.	.	.	.	.	.	.	1.1242	0.8847	2.4468	.
13	0.07579	0.00269	.	.	.	.	.	.	.	.	.	1.0318	0.7581	1.2923	1.813

IM147 Composite Regression Coefficients, CO, 1981 to 1984 Model Year LDGVs															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	9.26688	12.0712	9.8906	.	.	.	.	.	.	.	.	.	.	.	.
2	7.04988	6.84257	4.2268	3.9173	.	.	.	.	.	.	.	.	.	.	.
3	6.25482	4.82892	1.9633	2.5947	5.6325	.	.	.	.	.	.	.	.	.	.
4	6.14698	4.60366	0.442	2.6858	4.0611	3.6215	.	.	.	.	.	.	.	.	.
5	6.03278	4.6086	0.2948	2.3842	3.4375	2.7805	2.445	.	.	.	.	.	.	.	.
6	5.9907	4.59648	-1.2868	2.4237	3.2458	2.053	2.0363	1.9446	.	.	.	.	.	.	.
7	5.88506	4.42293	-0.6192	1.9614	2.9124	2.029	1.1142	1.6931	2.3067	.	.	.	.	.	.
8	5.69421	4.31936	-0.5108	2.105	2.3926	1.0293	-0.2338	1.1296	1.7768	2.8351	.	.	.	.	.
9	5.48257	3.86232	-1.0847	2.0057	1.7045	1.8524	0.0911	0.1588	1.336	2.8233	1.2436	.	.	.	.
10	3.7416	1.41222	0.3751	1.1819	1.3859	0.4574	0.9912	1.3269	0.633	2.4857	0.6786	0.9644	.	.	.
11	1.73455	0.42403	0.5865	0.7047	0.7755	1.2595	0.9043	1.3168	0.5928	1.196	0.6803	0.6756	1.4246	.	.
12	1.02591	0.1691	0.6384	0.6819	0.7081	1.2496	0.8593	1.0366	0.6866	0.8982	0.631	0.7313	0.7978	1.1668	.
13	0.61707	0.07797	0.7481	0.6453	0.7525	1.1703	0.6936	1.1239	0.5095	0.9175	0.6368	0.7178	0.6804	0.7922	0.7957

IM147 Phase 2 Regression Coefficients, CO, 1981 to 1984 Model Year LDGVs															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	6.2575	4.91001	.	.	.	.	.	.	.	.	.	1.5902	.	.	.
11	2.72138	1.37298	.	.	.	.	.	.	.	.	.	0.9487	2.1612	.	.
12	1.57636	0.56331	.	.	.	.	.	.	.	.	.	1.0279	1.1087	1.7699	.
13	1.04718	0.34246	.	.	.	.	.	.	.	.	.	0.9957	0.9216	1.2234	1.1113

IM147 Composite Regression Coefficients, CO, 1985 to 1989 Model Year LDGVs															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	5.49052	7.60141	8.0871	.	.	.	.	.	.	.	.	.	.	.	.
2	4.401	4.59161	3.6606	3.4406	.	.	.	.	.	.	.	.	.	.	.
3	3.97643	3.43533	2.2184	2.3355	4.6236	.	.	.	.	.	.	.	.	.	.
4	3.89439	3.20531	1.0777	2.3748	3.2459	3.3247	.	.	.	.	.	.	.	.	.
5	3.82466	3.14867	1.1902	2.0936	2.7826	2.4739	2.174	.	.	.	.	.	.	.	.
6	3.78627	3.11501	-0.0293	2.1265	2.6293	1.7113	1.7618	1.9381	.	.	.	.	.	.	.
7	3.67681	2.8626	0.5686	1.7769	2.1844	1.6691	0.7635	1.5267	2.6631	.	.	.	.	.	.
8	3.60692	2.77387	0.6028	1.8114	1.9048	0.9633	0.1406	1.2651	2.1817	1.9243	.	.	.	.	.
9	3.39768	2.39443	0.1046	1.7076	1.3104	1.5167	0.5439	0.4973	1.7435	1.9067	1.2435	.	.	.	.
10	2.23224	0.99522	0.7545	1.0893	0.9857	0.8366	0.9455	1.4527	1.0902	1.9156	0.7336	0.8531	.	.	.
11	1.20706	0.33753	0.8722	0.7157	0.8315	1.123	0.8222	1.2181	0.7424	1.0531	0.6812	0.6913	1.3478	.	.
12	0.73525	0.12498	0.7748	0.6921	0.7973	1.0106	0.9017	0.8915	0.7162	0.8109	0.6412	0.7275	0.7963	1.206	.
13	0.41719	0.02516	0.8609	0.6739	0.7536	1.0237	0.7513	0.9565	0.5631	0.8254	0.6634	0.7132	0.6898	0.7947	0.8025

IM147 Phase 2 Regression Coefficients, CO, 1985 to 1989 Model Year LDGVs															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	3.68774	3.52859	.	.	.	.	.	.	.	.	.	1.3424	.	.	.
11	1.818	1.03471	.	.	.	.	.	.	.	.	.	0.9701	2.065	.	.
12	1.05353	0.3822	.	.	.	.	.	.	.	.	.	1.0173	1.1353	1.7852	.
13	0.60249	0.16835	.	.	.	.	.	.	.	.	.	0.9911	0.9591	1.1922	1.1246

IM147 Composite Regression Coefficients, CO, 1990+ Model Year LDGVs

Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	5.62882	3.05114	14.1209	.	.	.	.	.	.	.	.	.	.	.	.
2	4.16263	1.40373	4.1999	5.0129	.	.	.	.	.	.	.	.	.	.	.
3	3.84928	0.90295	2.0243	3.5083	5.1234	.	.	.	.	.	.	.	.	.	.
4	3.79569	0.82093	0.6865	3.4697	3.4217	3.8707	.	.	.	.	.	.	.	.	.
5	3.74039	0.84809	0.9263	3.0501	3.0759	2.3548	2.4069	.	.	.	.	.	.	.	.
6	3.69164	0.84097	-0.418	2.9879	2.7724	1.4797	1.8325	2.8737	.	.	.	.	.	.	.
7	3.60802	0.72362	0.2888	2.5963	2.3389	1.3716	0.6475	2.02	3.1605	.	.	.	.	.	.
8	3.54512	0.73218	0.2011	2.6803	1.8672	0.4836	0.045	1.5147	2.5268	2.1618	.	.	.	.	.
9	3.3191	0.63591	-0.5877	2.5841	0.9946	0.913	0.3031	0.7605	2.0338	1.805	1.5015	.	.	.	.
10	2.33281	0.12368	0.8627	1.4067	0.7931	0.6929	0.5996	1.5372	1.2939	1.5496	0.7195	1.0174	.	.	.
11	1.14597	0.07195	0.8829	0.8553	0.8561	0.9971	0.6084	1.1998	0.5295	1.0312	0.6292	0.6836	1.427	.	.
12	0.64589	0.00678	0.7856	0.7476	0.8086	0.9368	0.7324	0.9804	0.6531	0.845	0.6498	0.7248	0.9011	1.0253	.
13	0.27203	-0.00513	0.7617	0.705	0.758	0.9566	0.6629	0.9463	0.5609	0.8841	0.6674	0.7136	0.7093	0.7561	0.774

IM147 Phase 2 Regression Coefficients, CO, 1990+ Model Year LDGVs

Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	3.72459	0.96776	.	.	.	.	.	.	.	.	.	1.7779	.	.	.
11	1.68958	0.30741	.	.	.	.	.	.	.	.	.	0.9902	2.121	.	.
12	0.94832	0.12176	.	.	.	.	.	.	.	.	.	1.03	1.2943	1.4878	.
13	0.43524	0.06182	.	.	.	.	.	.	.	.	.	1.0022	0.9992	1.0874	1.1022

IM147 Composite Regression Coefficients, CO, 1981 to 1984 Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	20.6965	24.9732	12.6811	.	.	.	.	.	.	.	.	.	.	.	.
2	13.3411	10.3032	4.0622	5.6571	.	.	.	.	.	.	.	.	.	.	.
3	12.3126	7.36435	1.776	4.3308	5.1971	.	.	.	.	.	.	.	.	.	.
4	12.1042	7.02622	-0.397	4.4381	3.5035	4.2351	.	.	.	.	.	.	.	.	.
5	12.0527	7.19205	-0.6418	4.2762	3.1383	3.695	1.3538	.	.	.	.	.	.	.	.
6	11.9685	7.20231	-2.5005	4.3477	2.8907	2.6546	0.8444	2.2266	.	.	.	.	.	.	.
7	11.807	7.08736	-1.7293	3.8076	2.5075	2.4323	-0.0037	2.0744	2.3528	.	.	.	.	.	.
8	11.6947	7.05512	-1.7922	3.9213	2.0893	1.8624	-1.1465	1.7128	2.0753	1.8569	.	.	.	.	.
9	11.3043	5.98779	-2.4399	3.5771	1.7377	3.1169	-0.5576	0.104	1.5691	1.7959	1.5672	.	.	.	.
10	8.49974	1.34387	-0.3377	1.8447	1.4618	1.2526	0.9093	1.3174	0.3783	1.7289	0.802	1.1466	.	.	.
11	3.6701	0.53011	0.3752	0.7417	0.797	1.456	0.6948	1.4668	0.637	1.0858	0.6348	0.6777	1.4646	.	.
12	1.98174	0.11753	0.7506	0.7285	0.5843	1.3695	0.8424	1.1166	0.6193	0.7984	0.5657	0.7829	0.8215	1.1544	.
13	1.09985	0.14803	0.816	0.6551	0.7798	1.2115	0.771	1.1356	0.4689	0.9171	0.5556	0.7201	0.6845	0.805	0.7714

IM147 Phase 2 Regression Coefficients, CO, 1981 to 1984 Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	13.6489	6.89656	.	.	.	.	.	.	.	.	.	2.104	.	.	.
11	5.65353	2.37259	.	.	.	.	.	.	.	.	.	0.9678	2.1519	.	.
12	3.07187	0.82239	.	.	.	.	.	.	.	.	.	1.0966	1.1263	1.7013	.
13	2.05416	0.91591	.	.	.	.	.	.	.	.	.	0.9926	0.9263	1.2294	1.0552

IM147 Composite Regression Coefficients, CO, 1985 to 1989 Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	13.8694	15.2236	13.6321	.	.	.	.	.	.	.	.	.	.	.	.
2	10.0033	6.93139	4.8288	5.0651	.	.	.	.	.	.	.	.	.	.	.
3	9.29649	5.09279	2.976	3.6934	4.9723	.	.	.	.	.	.	.	.	.	.
4	9.17411	4.84963	0.9452	3.7766	3.4685	3.917	.	.	.	.	.	.	.	.	.
5	9.01802	4.90791	0.7536	3.4092	2.7376	2.824	2.7994	.	.	.	.	.	.	.	.
6	8.92955	4.9686	-1.1289	3.4762	2.4874	1.4985	2.1637	2.6928	.	.	.	.	.	.	.
7	8.7691	4.69542	-0.4087	2.9985	1.953	1.7862	1.1736	2.1621	2.7068	.	.	.	.	.	.
8	8.59122	4.73532	-0.4517	3.0442	1.581	1.1186	-0.1135	1.556	1.9648	2.6236	.	.	.	.	.
9	8.26766	4.22168	-1.1718	2.6961	1.313	1.7854	0.4833	0.3603	1.3881	2.3245	1.6872	.	.	.	.
10	5.78009	1.23495	0.4919	1.2003	1.0982	0.5089	1.1372	1.5991	0.9224	2.0207	0.7215	1.1196	.	.	.
11	2.63622	0.43578	0.5368	0.7202	0.7365	1.367	0.8528	1.2188	0.6956	1.0567	0.6954	0.6738	1.4299	.	.
12	1.54921	0.09091	0.7468	0.6822	0.6828	1.1699	0.8768	0.9935	0.681	0.7599	0.6257	0.7538	0.8813	1.0928	.
13	0.75374	0.02099	0.8847	0.6423	0.7554	1.0555	0.785	1.0367	0.5445	0.8676	0.6146	0.7165	0.7117	0.7729	0.7783

IM147 Phase 2 Regression Coefficients, CO, 1985 to 1989 Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	9.24585	4.98289	.	.	.	.	.	.	.	.	.	1.9147	.	.	.
11	3.97568	1.51254	.	.	.	.	.	.	.	.	.	0.971	2.1233	.	.
12	2.25662	0.44549	.	.	.	.	.	.	.	.	.	1.0591	1.2223	1.6066	.
13	1.25401	0.30824	.	.	.	.	.	.	.	.	.	0.9967	0.9833	1.1632	1.0721

IM147 Composite Regression Coefficients, CO, 1990+ Model Year LDGT1&2s

Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	9.73928	4.40577	20.8542	.	.	.	.	.	.	.	.	.	.	.	.
2	7.10153	1.61757	4.8974	5.5895	.	.	.	.	.	.	.	.	.	.	.
3	6.61337	0.75824	3.3147	3.753	6.1468	.	.	.	.	.	.	.	.	.	.
4	6.57544	0.66445	2.1461	3.7345	4.9221	3.2434	.	.	.	.	.	.	.	.	.
5	6.35077	0.80324	2.4477	3.0432	3.6244	1.7761	4.4519	.	.	.	.	.	.	.	.
6	6.24116	0.84043	-0.0626	2.9872	3.2967	0.1221	3.6344	4.0729	.	.	.	.	.	.	.
7	6.18035	0.75951	0.6396	2.7006	2.7887	0.0988	2.4575	3.3995	2.5426	.	.	.	.	.	.
8	6.06991	0.85508	0.764	2.6575	2.3907	-0.3028	1.2626	2.5809	1.552	3.1236	.	.	.	.	.
9	5.74238	0.60774	-0.3973	2.3462	1.9317	0.2824	1.9415	0.7603	1	2.6996	2.1846	.	.	.	.
10	4.16315	-0.20486	1.0893	1.1803	0.9905	-0.2445	1.6449	1.896	0.6331	2.2387	1.0143	1.2424	.	.	.
11	1.8405	0.03592	0.7004	0.7222	1.0138	1.2204	0.7689	1.0977	0.5132	1.0686	0.7013	0.668	1.485	.	.
12	0.9886	0.02438	0.744	0.73	0.7776	1.1099	0.7872	0.5787	0.6457	0.7582	0.7113	0.7368	0.8642	1.1738	.
13	0.31426	-0.00518	0.7938	0.7228	0.7626	0.8887	0.727	0.7973	0.607	0.8159	0.6716	0.7166	0.7099	0.7665	0.7696

IM147 Phase 2 Regression Coefficients, CO, 1990+ Model Year LDGT1&2s

Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	6.66055	0.6872	.	.	.	.	.	.	.	.	.	2.3246	.	.	.
11	2.67155	0.3375	.	.	.	.	.	.	.	.	.	0.9971	2.1714	.	.
12	1.38252	0.11966	.	.	.	.	.	.	.	.	.	1.0512	1.1996	1.6648	.
13	0.44345	0.05096	.	.	.	.	.	.	.	.	.	1.0135	0.9835	1.0996	1.0715

IM147 Composite Regression Coefficients, NOx, 1981 to 1984 Model Year LDGVs

Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	0.88044	1.59831	13.9728	.	.	.	.	.	.	.	.	.	.	.	.
2	0.59034	0.7521	2.1278	4.9985	.	.	.	.	.	.	.	.	.	.	.
3	0.51405	0.55542	3.7485	3.858	6.0898	.	.	.	.	.	.	.	.	.	.
4	0.50608	0.53292	2.7857	3.7645	4.5611	4.8088	.	.	.	.	.	.	.	.	.
5	0.50038	0.52308	1.8882	3.3032	4.5487	3.9151	2.5841	.	.	.	.	.	.	.	.
6	0.49859	0.52116	-0.3119	3.3238	4.2688	3.1951	2.2305	2.3146	.	.	.	.	.	.	.
7	0.49285	0.51053	-0.1924	2.7423	4.4598	3.4302	0.6798	2.3994	2.7573	.	.	.	.	.	.
8	0.48391	0.49064	1.4802	2.7878	3.397	1.4246	-0.3484	1.2872	2.5791	2.9951	.	.	.	.	.
9	0.47485	0.4697	-1.3966	2.5877	3.4995	2.3294	-0.6719	-0.3573	2.0316	3.1392	1.9234	.	.	.	.
10	0.37891	0.23247	-0.0452	1.4342	2.2214	1.053	0.9414	1.3514	1.0033	2.6483	0.9386	1.2695	.	.	.
11	0.14698	0.05673	-0.0821	0.7178	0.8421	1.2211	1.0057	1.0475	0.6909	1.1895	0.5227	0.5818	1.6693	.	.
12	0.07162	0.02088	0.7266	0.73	0.768	0.8443	0.7672	0.6798	0.9669	0.7172	0.6657	0.7324	0.8746	1.0786	.
13	0.03296	0.00952	0.787	0.6373	0.9244	0.8663	0.7351	0.9267	0.6821	0.8366	0.5995	0.7084	0.7058	0.78	0.727

IM147 Phase 2 Regression Coefficients, NOx, 1981 to 1984 Model Year LDGVs

Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	0.62103	0.59564	.	.	.	.	.	.	.	.	.	2.552	.	.	.
11	0.21366	0.09595	.	.	.	.	.	.	.	.	.	0.8422	2.4327	.	.
12	0.09688	0.03109	.	.	.	.	.	.	.	.	.	1.0585	1.2349	1.5221	.
13	0.04004	0.01479	.	.	.	.	.	.	.	.	.	1.0012	0.9719	1.1811	0.9455

IM147 Composite Regression Coefficients, NOx, 1985 to 1989 Model Year LDGVs

Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	0.82399	1.36994	15.7886	.	.	.	.	.	.	.	.	.	.	.	.
2	0.54872	0.63552	3.0508	4.8202	.	.	.	.	.	.	.	.	.	.	.
3	0.48658	0.47811	3.9352	3.6357	5.939	.	.	.	.	.	.	.	.	.	.
4	0.47851	0.45047	3.6666	3.574	4.4109	4.4067	.	.	.	.	.	.	.	.	.
5	0.4678	0.4385	2.8415	2.9352	4.2742	3.2726	3.7315	.	.	.	.	.	.	.	.
6	0.46329	0.43505	-0.4665	2.9614	3.7155	2.6799	3.15	3.4084	.	.	.	.	.	.	.
7	0.45461	0.41619	-0.264	2.3408	3.9823	2.8116	1.3651	3.362	3.107	.	.	.	.	.	.
8	0.44117	0.3979	1.217	2.3973	2.7583	0.5364	0.1617	2.3482	2.8522	3.5198	.	.	.	.	.
9	0.43081	0.37005	-1.4203	2.2127	2.8121	1.3416	0.1059	0.4735	2.1588	3.7445	1.8009	.	.	.	.
10	0.34425	0.18854	0.3021	1.1817	1.6413	-0.2737	1.1837	2.0573	0.9764	3.1089	0.9139	1.2679	.	.	.
11	0.14249	0.05287	0.1216	0.6682	0.847	0.7423	1.0007	0.9561	0.7554	1.2453	0.5471	0.6313	1.6215	.	.
12	0.0723	0.01942	0.5926	0.7123	0.7055	0.7234	0.8115	0.6916	0.9342	0.7406	0.6586	0.7456	0.858	1.0946	.
13	0.02756	0.0071	0.618	0.6593	0.861	0.7847	0.7209	0.9137	0.6397	0.851	0.6173	0.7113	0.7061	0.7731	0.7423

IM147 Phase 2 Regression Coefficients, NOx, 1985 to 1989 Model Year LDGVs

Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	0.55293	0.44977	.	.	.	.	.	.	.	.	.	2.5168	.	.	.
11	0.20408	0.08145	.	.	.	.	.	.	.	.	.	0.9155	2.339	.	.
12	0.0984	0.02592	.	.	.	.	.	.	.	.	.	1.0681	1.2046	1.5383	.
13	0.03496	0.00939	.	.	.	.	.	.	.	.	.	0.9989	0.9746	1.1521	0.9785

IM147 Composite Regression Coefficients, NOx, 1990+ Model Year LDGVs															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	0.89663	0.69852	36.5998	.	.	.	.	.	.	.	.	.	.	.	.
2	0.51211	0.21316	5.1177	5.8472	.	.	.	.	.	.	.	.	.	.	.
3	0.44799	0.14368	6.3447	3.9439	7.1091	.	.	.	.	.	.	.	.	.	.
4	0.43718	0.11969	6.3263	3.8611	5.0794	5.5583	.	.	.	.	.	.	.	.	.
5	0.4116	0.11863	4.7571	2.675	4.7186	3.5952	6.8937	.	.	.	.	.	.	.	.
6	0.40287	0.11926	-0.6486	2.7059	3.7194	3.0461	5.7291	5.5197	.	.	.	.	.	.	.
7	0.39547	0.10825	-0.2279	2.0893	3.9596	3.32	3.74	5.0681	3.3616	.	.	.	.	.	.
8	0.37094	0.1121	1.8629	2.1003	2.1825	-0.0057	2.3861	3.5505	2.7425	5.2427	.	.	.	.	.
9	0.35919	0.09426	-1.8075	1.8994	2.0777	0.874	2.2073	1.6337	1.7328	5.4475	2.1483	.	.	.	.
10	0.27047	0.01275	1.1983	0.563	1.2164	-0.4082	2.2643	2.633	0.4833	3.3654	1.0148	1.6932	.	.	.
11	0.10736	0.01556	0.0524	0.6952	0.8359	0.782	0.8861	1.0436	0.6559	1.1881	0.5165	0.6625	1.6616	.	.
12	0.05405	0.00619	0.3724	0.7374	0.6968	0.7144	0.8282	0.6987	0.8659	0.7865	0.6759	0.7436	0.8588	1.0792	.
13	0.01741	0.0018	0.4251	0.6831	0.8395	0.7796	0.6819	0.8662	0.6071	0.851	0.6547	0.7112	0.7099	0.7711	0.7451

IM147 Phase 2 Regression Coefficients, NOx, 1990+ Model Year LDGVs															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	0.42584	0.03497	.	.	.	.	.	.	.	.	.	3.2431	.	.	.
11	0.1545	0.02122	.	.	.	.	.	.	.	.	.	0.9719	2.3734	.	.
12	0.07551	0.00841	.	.	.	.	.	.	.	.	.	1.0818	1.2015	1.5197	.
13	0.02608	0.00273	.	.	.	.	.	.	.	.	.	0.9985	0.9742	1.1431	0.9962

IM147 Composite Regression Coefficients, NOx, 1981 to 1984 Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	1.77318	2.6756	22.2252	.	.	.	.	.	.	.	.	.	.	.	.
2	0.97763	0.81534	-1.0649	7.1138	.	.	.	.	.	.	.	.	.	.	.
3	0.8015	0.50589	2.4042	5.4388	7.4103	.	.	.	.	.	.	.	.	.	.
4	0.79236	0.48531	2.0196	5.3843	5.8747	4.4401	.	.	.	.	.	.	.	.	.
5	0.79068	0.48066	1.6893	5.1366	5.8394	4.1067	1.2009	.	.	.	.	.	.	.	.
6	0.78557	0.47575	-1.2448	5.1715	5.4814	2.6816	0.7411	3.3124	.	.	.	.	.	.	.
7	0.78143	0.476	-1.1956	4.6879	5.5481	3.0216	-0.6373	3.5383	2.1759	.	.	.	.	.	.
8	0.77522	0.46777	0.2093	4.7642	4.7945	1.4012	-1.6688	2.4918	2.0835	2.1312	.	.	.	.	.
9	0.75704	0.44065	-3.2536	4.3906	4.8993	2.5761	-2.1246	0.0658	1.5079	2.4101	2.4034	.	.	.	.
10	0.61652	0.14763	0.0597	2.7629	3.084	0.6688	-0.1034	2.211	0.8412	2.4747	0.7692	1.4734	.	.	.
11	0.23012	0.06297	-0.4836	0.9276	1.153	1.1834	0.6381	0.989	0.5432	1.561	0.4098	0.5401	1.7176	.	.
12	0.12238	0.03037	0.2166	0.7951	0.7934	0.968	0.7041	0.5695	0.9014	0.7627	0.6746	0.7513	0.9025	1.04	.
13	0.06163	0.01533	0.4239	0.6053	0.9275	1.0363	0.721	0.9598	0.6409	0.8842	0.6341	0.711	0.7041	0.7617	0.7441

IM147 Phase 2 Regression Coefficients, NOx, 1981 to 1984 Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	1.14059	0.66921	.	.	.	.	.	.	.	.	.	3.6705	.	.	.
11	0.36161	0.1254	.	.	.	.	.	.	.	.	.	0.7893	2.5732	.	.
12	0.16442	0.03582	.	.	.	.	.	.	.	.	.	1.0922	1.2588	1.5043	.
13	0.0767	0.01903	.	.	.	.	.	.	.	.	.	1.0131	0.9198	1.2264	0.9462

IM147 Composite Regression Coefficients, NOx, 1985 to 1989 Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	1.53131	2.39066	19.1208	.	.	.	.	.	.	.	.	.	.	.	.
2	0.92778	0.80006	0.4734	6.3569	.	.	.	.	.	.	.	.	.	.	.
3	0.77287	0.47484	3.3615	4.7621	7.647	.	.	.	.	.	.	.	.	.	.
4	0.76394	0.4522	3.2324	4.7126	6.0512	4.47	.	.	.	.	.	.	.	.	.
5	0.75562	0.45153	2.6897	4.0983	5.8865	3.8567	2.922	.	.	.	.	.	.	.	.
6	0.74955	0.4519	-0.8381	4.1043	5.3452	2.7511	2.4874	3.6682	.	.	.	.	.	.	.
7	0.73604	0.43783	-0.7677	3.3026	5.526	3.2994	-0.0163	3.9319	3.8903	.	.	.	.	.	.
8	0.7273	0.42932	0.645	3.3545	4.6163	1.3597	-1.1299	2.8509	3.7622	2.6237	.	.	.	.	.
9	0.71142	0.3944	-2.8606	3.0614	4.7403	2.5337	-1.5906	0.297	3.1385	2.9429	2.1918	.	.	.	.
10	0.57504	0.1145	0.0543	1.5894	2.8092	0.5252	-0.1017	2.3307	1.9505	2.91	0.9769	1.4561	.	.	.
11	0.20555	0.04751	-0.4329	0.7123	1.0233	1.0206	0.7147	0.8005	0.794	1.4455	0.4808	0.581	1.7381	.	.
12	0.10175	0.02366	0.1643	0.7009	0.8486	0.8031	0.8477	0.5172	0.9143	0.6589	0.6773	0.7512	0.9067	1.0646	.
13	0.03924	0.00888	0.4472	0.6194	0.9382	0.8668	0.7417	0.8886	0.6209	0.8399	0.6328	0.7177	0.7075	0.7819	0.7267

IM147 Phase 2 Regression Coefficients, NOx, 1985 to 1989 Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	0.98114	0.5121	.	.	.	.	.	.	.	.	.	3.2652	.	.	.
11	0.30966	0.08548	.	.	.	.	.	.	.	.	.	0.8541	2.5226	.	.
12	0.14176	0.02736	.	.	.	.	.	.	.	.	.	1.0831	1.255	1.5035	.
13	0.05908	0.01277	.	.	.	.	.	.	.	.	.	1.0114	0.9489	1.2046	0.9338

IM147 Composite Regression Coefficients, NOx, 1990+ Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
1	1.36435	1.26328	30.4323	.	.	.	.	.	.	.	.	.	.	.	.
2	0.68737	0.31269	2.0387	6.3658	.	.	.	.	.	.	.	.	.	.	.
3	0.58509	0.20124	3.9934	4.6556	6.8806	.	.	.	.	.	.	.	.	.	.
4	0.57465	0.17965	3.7451	4.6093	5.1071	4.9635	.	.	.	.	.	.	.	.	.
5	0.55221	0.18602	3.4381	3.6003	4.9732	3.6629	4.6002	.	.	.	.	.	.	.	.
6	0.54739	0.18882	0.7345	3.6265	4.3279	2.904	4.0176	3.3696	.	.	.	.	.	.	.
7	0.53147	0.17374	0.3162	2.8086	4.4764	3.2446	1.3899	3.6794	4.5038	.	.	.	.	.	.
8	0.51648	0.17351	2.2319	2.8117	3.2493	0.9649	0.0529	2.1267	4.2544	3.5644	.	.	.	.	.
9	0.50787	0.15312	-0.8203	2.6144	3.3792	1.6807	-0.2677	0.5626	3.5367	3.7081	1.6418	.	.	.	.
10	0.38986	0.0063	2.2347	0.9043	1.9881	0.5994	0.2319	1.5179	2.0767	2.4937	0.9883	1.6465	.	.	.
11	0.15532	0.01862	0.1437	0.6939	0.8694	1.0785	0.4364	0.5763	0.9011	1.13	0.5564	0.6361	1.7324	.	.
12	0.07617	0.00781	0.56	0.7	0.8067	0.8177	0.6048	0.4635	1.0357	0.6848	0.7114	0.7365	0.8807	1.0943	.
13	0.02687	0.00135	0.4313	0.6749	0.8709	0.7942	0.6777	0.8278	0.6267	0.8496	0.6436	0.7137	0.7073	0.7794	0.743

IM147 Phase 2 Regression Coefficients, NOx, 1990+ Model Year LDGT1&2s															
Mode	RMS	Reg	Regression Coefficients												
Number	Error	Constant	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
10	0.61055	0.04466	.	.	.	.	.	.	.	.	.	3.3215	.	.	.
11	0.22151	0.02607	.	.	.	.	.	.	.	.	.	0.9281	2.4391	.	.
12	0.10478	0.01138	.	.	.	.	.	.	.	.	.	1.053	1.2349	1.5211	.
13	0.03748	0.00291	.	.	.	.	.	.	.	.	.	1.001	0.9715	1.167	0.9652