Eastern Research Group, Inc.

Evaluation of the Texas Inspection and Maintenance Program in the Dallas/Fort Worth and Houston-Galveston-Brazoria Nonattainment Areas

FINAL REPORT

Prepared for:

Texas Commission on Environmental Quality

Prepared by:

Eastern Research Group, Inc.

November 30, 2009

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Prepared for:

Texas Commission on Environmental Quality
P. O. Box 13087
Austin, TX 78711-3087

Prepared by:

Eastern Research Group, Inc.
3508 Far West Blvd, Suite 210
Austin, Texas 78731

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Table of Contents

Executive Summary ES-1
1.0 Introduction 1-1
1.1 Evaluation Analysis Approach 1-1
1.2 Structure of the Report..... 1-1
2.0 Coverage 2-1
2.1 Parking Lot Survey 2-1
2.2 Participation Rates 2-2
3.0 Inspection 3-1
3.1 Check Major TIMS Fields for Appropriateness 3-1
3.2 Inspection Statistics: Number of Vehicles Inspected by Inspection Type..... 3-11
3.3 Repeat I/M Failure Patterns 3-16
3.4 Emissions Analyzer Data Quality..... 3-20
3.4.1 Analyzer Drift 3-20
3.4.2 Analyzer Dilution Correction Factors..... 3-32
3.4.3 Analyzer Gas Audits..... 3-44
3.4.4 Analyzer Lockouts..... 3-50
3.5 TIMS Emissions Data Checks for Evidence of Station Fraud..... 3-53
3.6 OBD Inspection Analyzer Communication Performance..... 3-63
3.7 TIMS Handling of OBD Codes 3-78
3.8 TIMS OBD Data Checks for Evidence of Station Fraud..... 3-85
4.0 Repair 4-1
4.1 Number and Types of Repairs 4-1
4.2 Emissions Changes Associated with Repairs 4-4
4.3 Overall Success of Repairs to Vehicles Failing OBD 4-15
4.4 Success of Repairs to Specific Emission Control Systems Failing OBD..... 4-16
4.5 Average Repair Costs 4-20
5.0 Esitmates of I/M Benefits 5-1
5.1 Estimate of the Annual I/M Benefit from TIMS Data..... 5-1
5.2 Estimate of the Annual I/M Benefit from Paired I/M and RS Data..... 5-8
5.3 Estimate of the Total I/M Benefit from RS Data..... 5-27
6.0 Measures for Evaluating Station Performance 6-1
6.1 OBD Data Checks for Evidence of Station Fraud 6-2
6.1.1 Comparison of Inspector-Entered VIN to Vehicle-Downloaded OBD VIN 6-2
6.1.2 Comparison of Vehicle-Specific Information Between the First Test and Subsequent Tests..... 6-5
6.2 Tailpipe Inspection Data Checks for Fraud 6-11
6.2.1 Short Time Interval Between Inspections..... 6-12
6.2.2 Changing from ASM to TSI Inspection to Pass..... 6-14
6.2.3 Changing from Vehicle Type from Light Duty to Heavy Duty to Pass Vehicle 6-15
6.2.4 Pass/Fail Outliers 6-16
6.3 Repeated use of Analyzers of Less-Than-Optimal Functionality..... 6-18
6.3.1 High Degree of Drift..... 6-18

6.3.2 Frequently Failing Span Gas Audits 6-19
6.3.3 Failure to Perform All Calibrations 6-20
6.4 Data Entry Issues 6-20
6.4.1 Consistently entering repair type as “Misc” 6-21
6.4.2 Consistently entering repair cost as $0 6-21
6.4.3 VIN Check digit errors 6-22
6.4.4 Anomalous inspection sequences (other than 1P or FP) 6-23
6.5 Anomalous Test Results 6-24
6.5.1 Tailpipe Inspections With CO_2 Greater Than 16% 6-24
6.5.2 Tailpipe Inspections with O_2 Greater than 20.5% 6-25
6.5.3 Tailpipe Inspections with High Dilution Correction Factor Differences 6-25
6.6 Compilation of Percentile Rankings 6-26
7.0 References 7-1

List of Tables

Table 2-1. 2007 Parking Lot Survey Results 2-2
Table 2-2. Count of Unique I/M-Eligible RS Vehicles Registered in I/M Program Areas 2-3
Table 2-3. Count of Unique I/M-Tested Vehicles in I/M Program Areas 2-3
Table 2-4. Time Between RS and I/M Test 2-4
Table 3-1. Distribution of Measured CO_2 Concentrations 3-10
Table 3-2. Distribution of Check Digit Codes on Unique 17-Digit VINs in the I/M Test Records 3-10
Table 3-3. Number of VINs per Plate 3-11
Table 3-4. Emissions Tests per I/M Program Areas 3-11
Table 3-5. Number of Vehicles Receiving at least One Emissions Test 3-12
Table 3-6. Emission Test Pass/Fail Counts 3-12
Table 3-7. Frequency Distribution of Test Sequences for DFW for I/M Cycle Category = 3 3-18
Table 3-8. Frequency Distribution of Test Sequences for HGB for I/M Cycle Category = 3 3-18
Table 3-9. Frequency Distribution of Test Sequences for I/M Cycle Category=1 3-19
Table 3-10. Frequency Distribution of Test Sequences for I/M Cycle Category=2 3-20
Table 3-11. Frequency Distribution of Test Sequences for I/M Cycle Category=4 3-20
Table 3-12. Calibration Span Gas Values and Tolerances 3-22
Table 3-13. Number and Percent of Pre-Calibration Records Occurring Outside Analyzer Tolerance 3-31
Table 3-14. Distribution of Differences Between DCFCO/CO_2 and DCFO2 3-36
Table 3-15. Distribution of Differences Between ERG DCF CO/CO_2 and TIMS DCF CO/CO_2 3-37
Table 3-16. Distribution of Differences Between DCF CO/CO_2 and DCF O_2 by Analyzer Manufacturer, for ASM5051 Inspections 3-37
Table 3-17. Number and Percent of Suspicious O_2 Concentrations by Test Mode 3-38
Table 3-18. Number and Percent of Suspicious O_2 Concentrations (O_2 >20.5%), by Analyzer Manufacturer, for ASM5015 3-38
Table 3-19. Number and Percent of Suspicious CO_2 Concentrations (CO_2 >16.5%), by Analyzer Manufacturer, for ASM 2525 3-39
Table 3-20. Number and Percent of Records in Each Ray by Analyzer Manufacturer, for ASM2525 3-44
Table 3-21. Bottle Gas Concentrations for Low and Mid Span Audits 3-44
Table 3-22. Number of Gas Audits per Analyzer Over a 2.5 Year Period 3-45
Table 3-23. Span Gas Pass/Fail Results from TIMS Compared to Calculated Results 3-50
Table 3-24. I/M Inspections More Than 72 Hours After Successful Calibration or Check 3-52
Table 3-25. Stations with High eVIN Trigger Values 3-55
Table 3-26. Stations with High Readiness Trigger Values 3-56
Table 3-27. Stations with High 96tp Trigger Values 3-58
Table 3-28. Stations with High Emission Trigger Values 3-60
Table 3-29. Stations with Low Emission Trigger Values 3-60
Table 3-30. OBD Communication Rates by Vehicle Model Year 3-64
Table 3-31. OBD Communication Rates by Equipment Manufacturer 3-65

Table 3-32. OBD Communication Rates by Vehicle Make 3-67
Table 3-33. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications 3-69
Table 3-34. Comparison of DLC Communication Status with Overall OBD Test Results . 3-79
Table 3-35. Comparison of OBD Test Result with Overall Test Result 3-80
Table 3-36. Comparison of KOEO MIL Bulb Check Result with Overall OBD Test Result 3-80
Table 3-37. Comparison of Inspector-Entered MIL Illumination Status (Engine Running) with Overall OBD Test Result 3-81
Table 3-38. Comparison of Downloaded MIL Command Status with Overall OBD Test Result 3-81
Table 3-39. Unset Monitors vs. Test Readiness Status for Inspections Prior to October 15, 2008 3-83
Table 3-40. Unset Monitors vs. Test Readiness Status for Inspections After October 15, 2008 3-83
Table 3-41. Comparison of Readiness Status Field with Overall OBD Test Result 3-84
Table 3-42. Rates of OBD-Downloaded and Inspector-Entered VIN Discrepancies, by Model Year 3-86
Table 4-1. Repairs Listed in the TIMS 4-2
Table 4-2. Repairs Performed at RERF Stations 4-3
Table 4-3. Average Emissions Before and After Repairs 4-6
Table 4-4. Average Emissions Before and After Repairs by Inspection Year 4-7
Table 4-5. Average Emissions Before and After Repairs by Model Year Group 4-8
Table 4-6. Average Emissions Before and After Repairs by Repair Slate and Model Year Group 4-9
Table 4-7. System Specific Repair Analysis for Vehicles 4-19
Table 4-8. Comparison of OBD Evaporative Emission Control System Test Results with Gas Cap Test Results 4-19
Table 4-9. TIMS Records with a Repair Cost of $0, by Slate 4-21
Table 4-10. Average Repair Costs 4-23
Table 4-11. Common RERF Repair Slates 4-27
Table 4-12. RERF Repair Slate Average Costs 4-28
Table 5-1. Annual I/M Benefit Using TIMS Data for ASM Emissions 5-4
Table 5-2. Annual I/M Benefit Using TIMS Data for TSI Emissions 5-5
Table 5-3. 2006 Report Annual I/M Benefit Using TIMS Data for ASM Emissions 5-6
Table 5-4. 2006 Report Annual I/M Benefit Using TIMS Data for TSI Emissions 5-7
Table 5-5. Number of Vehicles in Each I/M Sequence Category for the Dataset of RS Events Matched with I/M Tests 5-13
Table 5-6. RS Averages Before and After an I/M Test for HGB and DFW for I/M Sequence Category = FP 5-25
Table 5-7. RS Averages Before and After an I/M Test for HGB and DFW for I/M Sequence Category = 1P 5-25
Table 5-8. Model Year Distributions for RS-Matched-to-I/M Fleet and I/M Tested Fleet .. 5-26
Table 5-9. RS Average Concentrations to Evaluate the Annual I/M Benefit 5-27
Table 5-10. Mean RS Emissions Concentration Levels and Changes in I/M Areas vs. Non-I/M Area 5-34

Table 6-1. Rates of OBD-Downloaded and Inspector-Entered VIN Discrepancies, by Model Year 6-3
Table 6-2. Stations with Highest and Lowest Rates of OBD and Entered VIN Mismatches.. 6-5
Table 6-3. Percentages of Tests with Various OBD Fraud Indicators..... 6-9
Table 6-4. Stations with Highest and Lowest Percents of Electronic Profile and Readiness Profile Mismatches 6-11
Table 6-5. Number of Close-in-Time Retests per Station 6-13
Table 6-6. Percent of Close-In-Time Retest Inspections for 10 Worst Stations..... 6-14
Table 6-7. Percent of Retest Inspections Switched from ASM to TSI for 10 Worst Stations..... 6-15
Table 6-8. Percent of Retest Inspections Switched from Light-Duty to Heavy-Duty, for 10 Worst Stations 6-16
Table 6-9. Stations with Highest Failure Rates, OBD and ASM..... 6-17
Table 6-10. Stations with Lowest Failure Rates, OBD and ASM 6-18
Table 6-11. Percent of Calibrations that Began with an Out-of-Tolerance Analyzer 6-19
Table 6-12. Percent of Span Gas Audits that were Failed 6-19
Table 6-13. Percent of Inspections When Analyzer Should Have Been Locked Out 6-20
Table 6-14. Miscellaneous Repair Percentage (Stations > 500 repairs) 6-21
Table 6-15. Zero-Cost Repair Percentage (Stations > 500 repairs)..... 6-22
Table 6-16. Check Digit Error Percentage (Stations > 100 inspections)..... 6-23
Table 6-17. Anomalous Inspection Sequence Percentage (Stations > 100 repairs) 6-24
Table 6-18. Percent of Inspections with CO_2 Greater Than 16% 6-25
Table 6-19. Percent of Inspections with O_2 Greater Than 16%..... 6-25
Table 6-20. Percent of Inspections with Disagreement Between CO/CO_2 and O_2 DCFs 6-26
Table 6-21. Top 50 Most Suspicious Stations for Errors of Commission..... 6-30
Table 6-22. 50 Mid-Range Stations for Errors of Commission..... 6-32
Table 6-23. Top 50 Stations with Errors of Omission 6-35

List of Figures

Figure 3-1. Distribution of ASM HC5015 Concentrations for All Filtered I/M Tests 3-2
Figure 3-2. Distribution of ASM HC2525 Concentrations for All Filtered I/M Tests 3-3
Figure 3-3. Distribution of ASM CO5015 Concentrations for All Filtered I/M Tests 3-4
Figure 3-4. Distribution of ASM CO2525 Concentrations for All Filtered I/M Tests 3-5
Figure 3-5. Distribution of ASM NO5015 Concentrations for All Filtered I/M Tests 3-6
Figure 3-6. Distribution of ASM NO2525 Concentrations for All Filtered I/M Tests 3-7
Figure 3-7. Distribution of TSI HC Curb Idle Concentrations for All Filtered I/M Tests 3-7
Figure 3-8. Distribution of TSI HC High Speed Concentrations for All Filtered I/M Tests .. 3-8
Figure 3-9. Distribution of TSI CO Curb Idle Concentrations for All Filtered I/M Tests 3-9
Figure 3-10. Distribution of TSI CO High Speed Concentrations for All Filtered I/M Tests . 3-9
Figure 3-11. Count of Emission Test Types by Model Year for DFW 3-13
Figure 3-12. Count of Emission Test Types by Model Year for HGB 3-14
Figure 3-13. Emission Test by Month Year for DFW 3-15
Figure 3-14. Emission Test by Month Year for HGB 3-15
Figure 3-15. Distribution of Difference Between Zero and HC Pre-Calibration Reading ... 3-24
Figure 3-16. Distribution of Difference Between Zero and CO Pre-Calibration Reading ... 3-24
Figure 3-17. Distribution of Difference Between Zero and NO Pre-Calibration Reading ... 3-25
Figure 3-18. Distribution of Difference Between Zero and CO_2 Pre-Calibration Reading .. 3-25
Figure 3-19. Distribution of Difference Between Zero and O_2 Pre-Calibration Reading 3-26
Figure 3-20. Distribution of Difference Between 20.7% and O_2 Pre-Calibration Reading .. 3-26
Figure 3-21. Distribution of Difference Between Low-Span Bottle and HC Pre-Calibration Reading 3-27
Figure 3-22. Distribution of Difference Between Low-Span Bottle and CO Pre-Calibration Reading 3-27
Figure 3-23. Distribution of Difference Between Low-Span Bottle and NO Pre-Calibration Reading 3-28
Figure 3-24. Distribution of Difference Between Low-Span Bottle and CO_2 Pre-Calibration Reading 3-28
Figure 3-25. Distribution of Difference Between Mid-Span Bottle and HC Pre-Calibration Reading 3-29
Figure 3-26. Distribution of Difference Between Mid-Span Bottle and CO Pre-Calibration Reading 3-29
Figure 3-27. Distribution of Difference Between Mid-Span Bottle and NO Pre-Calibration Reading 3-30
Figure 3-28. Distribution of Difference Between Mid-Span Bottle and CO_2 Pre-Calibration Reading 3-30
Figure 3-29. Comparison of ASM2525 DCF CO/CO_2 and DCF O_2 3-34
Figure 3-30. Comparison of ASM5015 DCF CO/CO_2 and DCF O_2 3-35
Figure 3-31. Comparison of Low-Speed Idle TSI DCF CO/CO_2 and DCF O_2 3-35
Figure 3-32. Comparison of High-Speed Idle TSI DCF CO/CO_2 and DCF O2 3-36
Figure 3-33. Distribution of CO_2 Values for ASM 2525 Inspection 3-39
Figure 3-34. High CO_2 Inspection Results Compared to CO_2 Pre-Calibration Reading 3-40
Figure 3-35. Distribution of O_2 Concentrations, by "Ray" 3-42
Figure 3-36. Distribution of CO_2 Concentrations, by "Ray" 3-42

Figure 3-37. Distribution of CO Concentrations, by "Ray" 3-43
Figure 3-38. Percent Difference Between Reading and Bottle Gas, Low-Span CO 3-46
Figure 3-39. Percent Difference Between Reading and Bottle Gas, Low-Span HC 3-46
Figure 3-40. Percent Difference Between Reading and Bottle Gas, Low-Span CO_2 3-47
Figure 3-41. Percent Difference Between Reading and Bottle Gas, Low-Span NOx 3-47
Figure 3-42. Percent Difference Between Reading and Bottle Gas, Mid-Span CO 3-48
Figure 3-43. Percent Difference Between Reading and Bottle Gas, Mid-Span HC 3-48
Figure 3-44. Percent Difference Between Reading and Bottle Gas, Mid-Span CO_2 3-49
Figure 3-45. Percent Difference Between Reading and Bottle Gas, Mid-Span NOx 3-49
Figure 3-46 Change in Rate of DLC Communication Problems over Model Year, by Analyzer Manufacturer 3-66
Figure 3-47. Rates of OBD-Downloaded and Inspector-Entered VIN Discrepancies, by Station and Inspector 3-87
Figure 4-1. Repairs with Cost Greater than $2000 4-22
Figure 4-2. Mean Repair Costs by Model Year and Inspection Year (Unedited Dataset) 4-24
Figure 4-3. Mean Repair Costs by Model Year and Inspection Year (Edited Dataset) 4-25
Figure 4-4. Distribution of Repair Costs by Slate (Unedited Dataset) 4-26
Figure 4-5. Distribution of Repair Costs by Slate (Edited Dataset) 4-26
Figure 4-6. Mean Repair Costs by Model Year and Inspection Year - RERF 4-29
Figure 4-7. Distribution of Repair Costs by Slate - RERF. 4-30
Figure 5-1. Average RS HC Versus Month from the I/M Test RS Readings from the HGB Area 5-10
Figure 5-2. Average RS CO Versus Month from the I/M Test RS Readings from the HGB Area 5-11
Figure 5-3. Average RS NO Versus Month from the I/M Test RS Readings from the HGB Area 5-11
Figure 5-4. Average RS HC Versus Month from the I/M Test RS Readings from the DFW Area 5-12
Figure 5-5. Average RS CO Versus Month from the I/M Test RS Readings from the DFW Area 5-12
Figure 5-6. Average RS NO Versus Month from the I/M Test RS Readings from the DFW Area 5-13
Figure 5-7. Average RS HC vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = 1P 5-15
Figure 5-8. Average RS HC vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = FP 5-15
Figure 5-9. Average RS CO vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = 1P 5-16
Figure 5-10. Average RS CO vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = FP 5-16
Figure 5-11. Average RS NO vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = 1P 5-17
Figure 5-12. Average RS NO vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = FP 5-17
Figure 5-13. Average RS HC by Model Year Group Before and After I/M Test for HGB Vehicles with I/M Sequence Category = FP 5-19

Figure 5-14. Average RS HC by Model Year Group Before and After I/M Test for DFW Vehicles with I/M Sequence Category = FP 5-19
Figure 5-15. Average RS CO by Model Year Group Before and After I/M Test for HGB Vehicles with I/M Sequence Category = FP 5-20
Figure 5-16. Average RS CO by Model Year Group Before and After I/M Test for DFW Vehicles with I/M Sequence Category = FP 5-20
Figure 5-17. Average RS NOx by Model Year Group Before and After I/M Test for HGB Vehicles with I/M Sequence Category = FP 5-21
Figure 5-18. Average RS NOx by Model Year Group Before and After I/M Test for DFW Vehicles with I/M Sequence Category = FP 5-21
Figure 5-19. Average RS HC by Model Year Group Before and After I/M Test for HGB Vehicles with I/M Sequence Category = 1P 5-22
Figure 5-20. Average RS HC by Model Year Group Before and After I/M Test for DFW Vehicles with I/M Sequence Category = 1P 5-22
Figure 5-21. Average RS CO by Model Year Group Before and After I/M Test for HGB Vehicles with I/M Sequence Category = 1P 5-23
Figure 5-22. Average RS CO by Model Year Group Before and After I/M Test for DFW Vehicles with I/M Sequence Category = 1P 5-23
Figure 5-23. Average RS NOx by Model Year Group Before and After I/M Test for HGB Vehicles with I/M Sequence Category = 1P 5-24
Figure 5-24. Average RS NOx by Model Year Group Before and After I/M Test for DFW Vehicles with I/M Sequence Category = 1P 5-24
Figure 5-25. Model Year Distribution of SAN, DFW and HGB Fleets 5-29
Figure 5-26. Mean RS HC Emissions by Area and Model Year 5-30
Figure 5-27. Mean RS CO Emissions by Area and Model Year 5-31
Figure 5-28. Mean RS NO Emissions by Area and Model Year 5-32
Figure 5-29. Percent Difference Between Non-I/M Area and I/M Area RS Concentration Levels 5-33
Figure 6-1. Rates of OBD-Downloaded and Inspector-Entered VIN Discrepancies, by Station and Inspector 6-4
Figure 6-2. Rates of Re-Test Discrepancies in OBD Computer and Readiness Information, by Station and Inspector 6-10
Figure 6-3. Distribution of Results and Percentiles for Errors of Commission 6-27
Figure 6-4. Distribution of Results and Percentiles for Errors of Omission 6-34

Executive Summary

This report documents the evaluation of the Texas I/M program for the 2007 and 2008 biennial period. Eastern Research Group (ERG) performed this evaluation for the Texas Commission on Environmental Quality (TCEQ) using the Texas Information Management System database (TIMS) data from October 1, 2006 through March 31, 2009 and remote sensing (RS) data from July 2006 through August 2009.

This evaluation generally follows the Environmental Protection Agency (EPA) draft guidance on using in-program data for the evaluation of inspection and maintenance (I/M) program performance [Reference 1][1] and EPA guidance on the use of remote sensing (RS) for the evaluation of I/M program performance [Reference 2]. It is focused on program coverage, the inspection process and the repair process. Additionally, program benefits were estimated on both an annual and total emissions basis.

Overall, the results for the Texas I/M program were positive; however, in the course of performing this evaluation several areas were found where improvements could be made. Additionally, some of these suggestions will be helpful for future biennial evaluations and make the results more reflective of program performance. The last section of this Executive Summary provides a concise list of specific recommendations where ERG feels improvements in the program could be made.

Coverage

The results of two analyses of coverage using out-of-program data revealed a consistent, high rate of participation in the I/M program:

Parking Lot Survey[2] – The 2007 parking lot survey performed by the Texas Department of Transportation (TxDOT) only covered 8 counties and found that 3.3 percent of the sample had expired registration stickers, while 4.4 percent had expired safety stickers. Previous studies conducted by the Texas Transportation Institute [Reference 3] covered all 15 I/M counties and provided additional useful information that was not available in the current TxDOT report.

Participation Rates[3] – The second analysis for coverage estimated program participation by determining the fraction of vehicles seen on the road during RS studies that had recent records in the TIMS. This analysis found that in the DFW and HGB areas greater than 96% of I/M-

[1] Citations for references are given in Section 7.
[2] See Section 2.1 for details.
[3] See Section 2.2 for details.

program-eligible vehicles had been to I/M inspections within 15 months of the date that they were observed on the road during RS. These results are essentially the same as in the 2006 Program Evaluation Report [Reference 4]. This will be referred to as the "2006 Report" in subsequent sections.

Inspection

Appropriateness of Major TIMS Fields[4] –TIMS is used to document the I/M program inspection process. The analysis in this activity checked the major fields in the TIMS using a series of basic data checks to demonstrate the accuracy and completeness of the data in the TIMS. ERG produced frequency distributions of almost all database variables to examine field values for in-range values, out-of-range values, and missing values. The following summarizes the major findings of this analysis:

- Frequency distributions of Acceleration Simulation Mode (ASM), hydrocarbon (HC), carbon monoxide (CO), and nitric oxide (NO) and Two-Speed Idle (TSI) HC and CO were the typical positively skewed distributions seen in a fleet of modern vehicles. Very few out-of-range emission values were found.
- The analysis of the TIMS data indicated that 1.0% of the ASM carbon dioxide (CO_2) measurements and 0.7% of the TSI CO_2 measurements had concentrations greater than the theoretical limit of 16%. These values were comparable to those in the 2006 Report, which were 0.9% and 0.5% respectively.
- The analysis of the validity of vehicle identification numbers (VIN) in the TIMS indicated that 2% of the VINs had either illegal check digits or a check digit that did not agree with the check digit calculation. ERG suspects that VIN errors are caused by transcription errors by I/M inspectors.

Inspection Statistics[5] – Analysis of the TIMS data indicated that during the evaluation period over 16 million ASM, TSI, and On-board Diagnostics (OBD) tests were performed on roughly 8.7 million vehicles. OBD tests are performed on 1996 and newer model year vehicles, ASM tests are performed on 1995 model year and older vehicles, and TSI tests are performed on 1995 and older model year vehicles where ASM tests cannot be performed such as on all-wheel-drive vehicles. Approximately 81% of the tests were OBD tests, about 16% were ASM tests, and about 2% were TSI tests. In 2006 these numbers were: OBD 67%, ASM 30%, and TSI 3%. The DFW and HGB areas had comparable test fail rates. About 4.4% of the OBD tests were fails, about 9% of the ASM tests were fails, and about 5% of the TSI tests were fails. Again, in 2006 these values were: OBD 4.5%, ASM 11% and TSI 6%. It is worth noting that the higher

[4] See Section 3.1 for details.
[5] See Section 3.2 for details.

percentage of OBD tests in this report vs. those seen in the 2006 Report will mean that fleet-wide, fewer vehicles are now initially failing, resulting in fewer repairs. Consequently, any fleet-wide comparisons between the results from this report and the 2006 Report must take this change into account.

Repeat I/M Failure Patterns[6] – ERG examined the TIMS data to determine the relative frequencies of the I/M pass/fail patterns during each vehicle's inspection cycle.

- Approximately 99.98% of the test sequences were found to be made up of a verified initial test, or an initial test that could reasonably be assumed to be a true initial test, and a final test that was certified. This number was 99.3% in the 2006 Report.
- Approximately, 16 to 19 less common sequences accounted for the remaining 0.02% of the tested fleets in DFW and HGB. Many of these remaining sequences seem to be unlikely, and they account for only 198 vehicles of the more than 13 million in the dataset.

Emissions Analyzer Data Quality[7] – The TIMS data were analyzed to determine the quality of the emissions measurements made by the emissions analyzers. Specific analyses were made using instrument calibrations to check for drift, individual inspection results checking for the stoichiometrically correct measured concentrations of CO, CO_2, and oxygen (O_2), gas audit results to validate analyzer accuracy, and comparison of instrument calibrations with inspection results to check for proper lock-out of emissions equipment. The following provides a summary of the results:

- The drift of the emissions analyzers was measured by comparing the pre-calibration measurements of calibration gas with the post-calibration values. With the exception of the zero gas for HC, the analysis showed that more than 85% of the pre-calibrations fell within the tolerance of the analyzer after the analyzer had been given an opportunity to drift for 72 hours between calibrations. This indicates that results for more than 85% of the I/M inspections performed just before the calibration can be expected to be within the instrument tolerance except for very low values of HC. This value was 90% in the 2006 Report.
- The Environmental System Products (ES) analyzers failed to calibrate the O_2 channel 97% of the time by recording oxygen values of less than 3% O_2 in air. All other analyzers measured near theoretical value of 20.7% O_2 in air over 99% of the time. This was also the case in the 2006 Report for the ES analyzers.

[6] See Section 3.3 for details.
[7] See Section 3.4 for details.

- More than 99.9% of calibration records included bottle gas label concentrations that were within the prescribed tolerances. However, the remaining small fraction of records did include some surprisingly high and low bottle gas values. It is possible that the bottle gas concentration was entered incorrectly into the TIMS or that the outlying values represent real bottle gas mixtures that were occasionally used. This result appeared to be better than that in the 2006 Report where there were a small percentage of calibration values in the TIMS (at that time vehicle information database or VID) that were out of range.
- Dilution correction factors based on CO/CO_2 compared with dilution correction factors based on O_2 for all inspections in the evaluation period indicated that 84% of the TSI tests and 88% of the ASM tests produced measured CO, CO_2, and O_2 values that were consistent with the expected stoichiometric relationship for gasoline combustion. These numbers are comparable to those in the 2006 Report. The remaining 12-15% of the dilution correction factor comparisons did not agree, primarily as a consequence of suspicious exhaust gas O_2 concentration recorded by John Bean Snap On (JB) and Sun Snap-On (SE) analyzers. These manufacturers had similar issues in the 2006 Report.
- The Texas state implementation plan (SIP) requires that each analyzer be audited at least twice per year. The TIMS data indicates that 98% of the analyzers in the state were audited at least twice per year and many of them were audited many more times than that. This result is similar to that in the 2006 Report.
- Calibration records, analyzer gas audit records, and vehicle inspection records were used to determine whether analyzer and dynamometer calibrations were taking place as required, and whether uncalibrated analyzers and dynamometers were locked out until passing a calibration. Comparison of ASM and TSI test records with analyzer gas calibration, leak check, and dynamometer coast-down check records appear to indicate that for the majority of analyzers, 72-hour lockouts are independently enforced for each of these three calibrations/checks (i.e., the analyzer/dynamometer system must pass all three tests every 72 hours or it will be locked out). However, 3% of all ASM dynamometer systems had not successfully passed their calibration check within the 72 hour window. This value is double that in the 2006 Report.

TIMS Emissions Checks for Evidence of Station Fraud[8] – The vendor that operates the TIMS for TCEQ provides quarterly reports on 4 triggers, which are station and inspector statistics based on data collected in the TIMS. These trigger metrics were designed to flag fraudulent test activity. For this analysis, ERG examined the 2007 and 2008 station trigger data by flagging those stations that had exceedingly suspicious average trigger values monitor the trigger data being provided in near real-time. The primary objective of this task was to provide a new look at the trigger data by analyzing it differently from the algorithms currently in use.

[8] See Section 3.5 for details.

Because the current trigger system is completely different than that used previously, no comparison with the 2006 Report is meaningful.

OBD Inspection Analyzer Communication Performance [9] – Overall OBD communication rates between vehicle's computers and program analyzers was 99.9%, essentially unchanged from the 2006 Report.

TIMS Handling of OBD Codes[10] – With a few exceptions, OBD inspection logic used in Texas for light-duty gasoline-powered vehicles appeared generally sound and in agreement with EPA policies, although until October 15 2008, Texas used readiness criteria that were slightly different from the federal guidelines as two or fewer unset non-continuous monitors were used as the requirement for vehicles of all model years. After October 15 2008, Texas changed the criteria to match the federal limits of two unset monitors for 1996-2000 vehicles, and one unset monitor for 2001 and newer vehicles. This change addressed a concern cited in the 2006 Report. Additionally, a problem in the 2006 Report of vehicles being incorrectly identified as "Ready" with three or more monitors not set was not seen in this analysis.

Evidence for ODII Test Fraud[11] **–** Data analysis suggests OBD test fraud (by way of clean-scanning) occurs with 1-9% of all OBD tests (including initial tests). Extracting the initial tests from the dataset increases this range to 7-27%. TCEQ is currently using criteria similar to that used in this analysis to identify and prevent OBD test fraud. It is recommended that TCEQ begin looking at software methods that would be able to automatically notify inspectors and stations during an OBD inspection (or shortly thereafter) when an OBD result looks suspicious. ERG believes that such an approach with immediate feedback will serve to reduce OBD test fraud and be cost-effective in the long term.

Repair

Number and Types of Repairs[12] – Analysis of the TIMS data indicates that over 550,000 I/M program induced repairs were made to vehicles during the evaluation period. The I/M program requires reporting the types of repairs in five categories: fuel system, ignition electrical system, emissions system, engine mechanical, and miscellaneous. The fractions of total repairs in these five categories were 16%, 12%, 36%, 2%, and 34%, respectively. The values in the 2006 Report were 17%, 14%, 43%, 2%, and 25%.

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[9] See Section 3.6 for details.
[10] See Section 3.7 for details.
[11] See Section 3.8 for details.
[12] See Section 4.1 for details.

The Department of Public Safety (DPS) collects separate repair information from stations that volunteer to be designated Recognized Emission Repair Facilities (RERF). The repairs reported from RERF stations have much more detailed descriptions than the five categories used in the TIMS. However, the RERF program is voluntary and only about 21,800 repairs were reported to DPS. This figure was 38,000 in the 2006 Report.

A third source of repair information is the Drive a Clean Machine (DACM) program. Texas created the DCAM program under the statutory authority granted in the Low Income and Repair Assistance, Retrofit, and Accelerated Vehicle Retirement Program legislation. This program provides assistance to low income individuals by repairing or retiring vehicles that have failed an emissions test. During the evaluation period, 13,143 of the repairs made at RERFs were performed under the DCAM program. In the 2006 Report this value was 9,649.

Emissions Changes Associated with Repairs[13] – ERG analyzed the Texas TIMS data obtained during the evaluation period to determine the change in emissions of repaired vehicles before and after repair. The apparent emissions concentration changes at this one point in time for each vehicle for ASM HC, CO, and NO were approximately decreases of 66%, 82%, and 66%, respectively, on approximately 340,000 repaired vehicles. In the 2006 Report these values were roughly 66%, 80% and 64% on 448,440 repaired vehicles. Note that almost all of these vehicles would have been fast-pass ASM tests; therefore, the after-repair emissions concentrations are biased high. However, because repair and emissions degradation begin immediately after certification and continues throughout the year until the next-cycle ASM inspection, the net emissions benefit of the repair over the one year annual cycle will be smaller than these percent reductions imply.

OBD Repair Effectiveness[14] **–** Analysis indicates approximately 80% of OBD tests that initially receive a fail for illuminated malfunction indicator light (MIL) with stored diagnostic trouble codes (DTCs) eventually receive a certificate. This value was 83% in the 2006 Report. However, as also seen in the 2006 Report, when evaluating repairs by failure category (evaporative emissions control system, O_2 Sensor, EGR System, air injection system and catalytic converter), unset readiness monitors were seen to potentially "hide" malfunctions in 4% to 40% of "repaired" vehicles.

[13] See Section 4.2 for details.
[14] See Sections 4.3 and 4.4 for details.

Average Repair Costs[15] – The analysis of the TIMS repair cost data with repair costs of zero and greater than $2,000 removed indicate that Texas motorists spent at least $41 million during this evaluation period performing 240,665 repairs so that they would be in compliance with the I/M programs, but it should be noted that TIMS inspectors hand-enter repair costs and, accordingly, these values can have errors. The same overall repair cost was $60 million in the 2006 Report on 348,694 repairs.

As in the 2006 Report, approximately 1/3 of the repair costs in the Texas TIMS were recorded as zero. Again, with zero repair costs and those over $2,000 removed, the mean and median repair costs were $172 and $125, as compared to $171 and $125 in the 2006 Report. The mean and median repair costs on the unedited data were $124 and $45 vs. $142 and $70 in the 2006 Report.

The mean and median repair costs for repairs performed by the RERFs were $589 and $613, while these values were $499 and $516 in the 2006 Report. ERG does not believe the difference in repair costs between all repair stations and the RERF stations are inconsistent. It is expected that the repair costs for RERF stations will be higher than average repair stations since these stations voluntarily participate in the RERF program and, therefore, are more likely to make repairs that are more technically challenging and, therefore, more expensive.

I/M Benefit Emissions Benefits

The Annual I/M Benefit of an I/M program can be measured by the decrease in emissions for the I/M fleet at the time of vehicle repairs. The Annual I/M Benefit was estimated by looking at before and after repair emissions and also by pairing TIMS data with RS data. The Total I/M Benefit was also estimated using the RS Reference Method.

Annual I/M Benefits as Measured by TIMS Data[16] **–** Using the initial and final emissions concentrations of annual inspection sequences as recorded in TIMS data, which is in-program data, ERG calculated the change in emissions concentrations at the time of inspection. About 90% of the I/M sequences were produced by vehicles that simply initially pass. Of course, the emissions reductions from these I/M events were zero. Additionally, about 8% of the ASM I/M sequences were produced by vehicles that initially failed, were repaired, and finally passed. These sequences were associated with emissions reductions at the I/M inspection of 63 to 84%. When all sequences were considered together using the TIMS data, the apparent changes in emissions concentrations at the inspection event were: ASM HC decreased 13 to 28%, ASM CO

[15] See Section 4.5 for details.
[16] See Section 5.1 for details.

decreased 28 to 36%, ASM NO decreased 13 to 16%. Overall these reductions were somewhat smaller than those reported in the 2006 Report; although, it is possible this is due to the I/M program encouraging vehicle owners to properly maintain their vehicle's emission systems. However, additional analyses would be needed to verify that this is indeed the cause for this observation.

Annual I/M Benefits as Measured by the RS Data[17] – The analysis of RS data, which is out-of-program data, provides a different view of the Annual I/M Benefit of the I/M program. The average RS emissions from 30 to 90 days before I/M inspections were compared to the average RS emissions from 1 to 90 days after the I/M inspections. About 95% of the vehicles measured by RS had I/M sequences produced by passing their initial inspections, while 4% had a Fail-Pass I/M test sequence. This is essentially the same as the 94% and 5% seen in the 2006 Report. The emission readings for these two sets of vehicles (initial pass and fail-pass) were also similar, as the initial pass vehicles had emissions increase by roughly 5% vs. 4-7% in the 2006 report, while the fail-pass vehicles had emissions decrease by 4-8% vs. 3-14% in the 2006 Report.

It is important to note the effect of the I/M program on emissions is not simply the drop in emissions during the I/M activities, because during the rest of the annual period emissions increase. Overall, the RS data indicates that initially passing vehicles (95% of the fleet) go through the I/M program, and their emissions increase each year. Finally, when their emissions have increased over the years to a high enough level, the cutpoint is tripped and repairs are done. During all of those previous years the emissions of the initially passing vehicles have been allowed to increase unchecked. More-stringent cutpoints should help reduce the number of vehicles that are allowed to go through the I/M program unchecked as their emissions profile deteriorates. However, more-stringent cutpoints would also cause an increase in the number of vehicles failed when the vehicles have no problem that can be identified. For the future, OBD has the potential to catch vehicles with malfunctioning emission control systems before their emissions move from excellent to questionable, because OBD is designed to sense when an emission control system is not operating properly.

Total I/M Benefits as Measured using the RS Reference Method[18] – The Total I/M Benefit is the difference in fleet emissions between the I/M fleet under consideration and a hypothetical fleet with the same vehicle characteristics and operating conditions but whose vehicles have never been in any I/M program. To perform this analysis, RS data from San

[17] See Section 5.2 for details.
[18] See Section 5.3 for details.

Antonio (SAN) were used as the reference fleet and compared to the DFW and HGB RS fleet measurements. This analysis indicated that the I/M program in the DFW and HGB areas has had a substantial effect on reducing RS emissions concentrations to levels some 30 to 70% below the RS emissions of the SAN fleet. These results cannot be compared to the 2006 Report since such an analysis was not done at that time due to a lack of non-I/M RS data.

Measures for Evaluating Station Performance[19] – This section strives to consolidate the analyses performed that pertain to the evaluation of station performance. There was not a section like this in the 2006 Report, so direct comparisons are cannot be made. Distinctions between errors of commission vs. errors of omission were also identified whenever possible, with the former viewed as more likely attempts at committing a fraudulent test, while the latter could be viewed somewhat more leniently. An example of this is VIN mismatch, where the OBD-downloaded VIN does not correspond to the hand-entered VIN. In the benign case, the discrepancies are basically random. In the highly suspicious case, the exact same OBD-downloaded VIN is found in roughly 1,000 tests, which seems to indicate a clear case of attempted clean-scanning. An example of an error of omission metric is a zero-value repair cost. This may be considered benign because it will not result in falsely passing or failing the I/M test. In all, there were 9 error of commission and 10 error of omission metrics developed and each station was ranked according to their respective overall score in these two categories.

Recommendations

As a result of performing this biennial evaluation of the Texas I/M program, ERG has developed a list of recommendations Texas should consider implementing. As in the 2006 Report, the purpose of most of these recommendations is to improve the program, but some also are intended to improve future biennial I/M program evaluations. It is important to note that several of the recommendations made in the 2006 Report were implemented and led to improved overall program performance. For each recommendation, ERG has provided an importance rating of High **(***)**, Medium **(**)**, or Low **(*)**. These ratings are provided to assist TCEQ in prioritizing efforts to improve the I/M program.

OBD Recommendations

ERG expects that the future of vehicle testing at I/M inspection stations in Texas will continue to be dominated by OBD testing, as it replaces TSI and ASM tailpipe emissions testing. In the 2006 Report 70% of all inspections were OBD test, with 30% of the fleet receiving a

[19] See Section 6 for details.

tailpipe test. Those numbers are now 81% for OBD and 19% for tailpipe testing. Because this trend will continue, any OBD problems identified in this evaluation are viewed as more critical to the overall success of the program.

Recommendation 1 (***): Investigate requiring a "set" status for certain monitors to prevent hiding malfunctions. Our analysis found that in 4% to 40% of instances when a vehicle received an initial fail for a certain monitored component, the retest OBD result, which follows a repair, could be hidden by an "unset" readiness status for that monitor. This opens up the possibility that malfunctioning emissions control components could remain unrepaired even though the follow-up OBD test received a "pass." ERG recommends TCEQ investigate implementing a software change that would require certain monitors to have a "set" readiness status on an OBD retest that follows certain types of initial failures. This issue will likely gain importance as strategies are developed to perform program evaluations on OBD fleets, because without this assurance it is not possible to verify that a major emission control component, such as the catalyst, has actually been repaired.

Recommendation 2 (***): Improve response to trigger flags. Based on our analysis of the TIMS triggers implemented by TCEQ and Gordon-Darby, it is clear the new triggers can identify suspicious testing activity. The new triggers have been greatly simplified and clearly allow one to quickly review irregular testing activity at a test station. However, it also appears that more resources may be needed to address the problems the triggers identify. This finding is supported by ERG's own analysis of the TIMS data, and the ERG work could be used to develop additional triggers if so desired. However, if resources will not permit an increased level of response to the existing triggers, adding more triggers to the system is not recommended.

Recommendation 3 (**): Consider Real-time Monitoring of OBD Triggers. It is recommended that TCEQ begin looking at software methods that would be able to automatically notify inspectors and stations during an OBD inspection (or shortly thereafter) when the results from an OBD test look suspicious.

Recommendation 4 (***): Station Performance Metrics. Section 6 of this report contains a number of new analyses and ideas for monitoring station performance and detecting fraudulent test activity. Given the large number of ideas presented in this section, it is impractical to single out which ones may be most useful for TCEQ to implement at this time. However, ERG feels strongly that some of these ideas would probably be useful for TCEQ to consider in the future. Some of the ideas are related to tailpipe ASM or TSI testing; however,

this recommendation was place under the OBD Recommendations sub-heading because OBD testing is likely going to be the dominant test-type for the Texas program in the coming years.

ASM and TSI Recommendations

Even though OBD testing will eventually replace tailpipe emissions testing in Texas, tailpipe testing will probably be used on the 1995 and older vehicles for some time. Therefore, efforts need to continue to provide quality tailpipe tests and accurate TIMS records of them.

Recommendation 1 (***): Improve response to trigger flags. The same Recommendation and associated caveats for the OBD vehicles regarding triggers outlined above also apply to ASM and TSI tests.

Recommendation 2 (*): Reject calibration bottle concentration values that are outside the specified range. Our analysis of analyzer gas calibration data indicated that about 0.1% of the bottle gas label concentrations were outside of the acceptable tolerances. This is not a large problem; however, not enforcing tolerances on bottle gas label concentrations may leave open a possibility for fraud. ERG recommends that the software be modified to reject any calibration gas bottle values that are out of range of the bottle gas label concentration specifications. Thus, the software would not allow a calibration to proceed unless reasonable bottle gas values were entered.

Recommendation 3 (**): Address O_2 Measurement Issues. In this report and the 2006 Report issues with measuring O_2 concentrations accurately were uncovered for John-Bean, Sun Snap-On, and Environmental System Products analyzers.

Recommendation 4 (**): ASM Dynamometer Calibration Checks. It was found that 3% of all ASM dynamometer systems had not successfully passed their calibration check within the 72 hour window. Although this is a small number, it is double the number seen to fail in the 2006 Report; therefore, it is recommended that this issue be investigated further to determine the cause.

RS Recommendations

In the past, initial measurements of tailpipe emissions at the annual I/M inspection could be used to track fleet emissions. However, as tailpipe emissions measurements are being replaced by OBD testing, vehicle emissions levels are no longer routinely measured and recorded. That leaves RS as the only major source of data to monitor the emissions of the fleet in the future.

Because of this trend, it is important to address any RS problems seen in this evaluation as soon as possible, even if they appear to be relatively minor right now.

Recommendation 1 (***): Collect RS data in San Antonio. This report was able to use RS data from San Antonio to analyze the DFW/HGB RS fleet data using the Reference Method; however, this was a pleasant and unexpected surprise. If possible, efforts should continue to obtain RS data from San Antonio for future evaluations whenever possible.

Recommendation 2 (**): Perform regular evaluations of RS measurements. As in most jurisdictions that routinely collect RS data, Texas archives the data for future use but it does not regularly examine the data. During this biennial evaluation, which made extensive use of the archived RS data, ERG identified problems with the data that could have been avoided. For the future it is recommended that RS data be regularly examined (perhaps every six months) using a cursory analysis to ensure that the important aspects of the RS data are being properly recorded.

Recommendation 3 (*): Encourage RS measurement vendors to improve license plate character recognition software. The license plates of the vehicles that are measured by RS are required to match RS readings with the registration and then the TIMS records to perform any sort of analysis. RS vendors use video cameras to obtain digital images of license plates, which are then post-processed using character recognition software. However, the software remains under development, and RS operators frequently use banks of people with video displays to read plate images and manually enter results into a computer file. The current limitation on RS accuracy and RS cost may well be with the license plate reading rather than with the measurement of tailpipe emissions concentrations. As opportunity permits, Texas should continue to encourage RS vendors to find or develop better license plate character recognition software.

Recommendation 4 (**): Increase the fraction of RS records with known county of registration. ERG's examination of the RS data indicated that most of the RS records had the assigned county of registration at the time of the RS measurement as "Unknown." This makes the RS value less useful because without a county of registration in the RS dataset it cannot be determined if the vehicle was registered in an I/M area. It is not known why these records have unknown counties of registration.

Recommendation 5 (*): Enter the state and the license plate in RS datasets for out-of-state vehicles measured by RS. In the RS data, out-of-state license plates are commonly designated as OS, but the state or the license number is not recorded. In our analyses using the RS data, ERG observed that a large fraction of the vehicles that were measured by RS in I/M

areas were out-of-state vehicles. This observation raises emissions source and enforcement issues. Inclusion of the state information for out-of-state vehicles would allow the RS data to be designated as coming from I/M or non-I/M jurisdictions. The state and plate information for out-of-state vehicles would also allow vehicles that are permanently driving in the I/M area while registered in another state to be identified.

Vehicle Tracking Recommendations

Whether vehicles are inspected or measured by TSI, ASM, OBD, or RS, these sources of data on individual vehicles can be used effectively only if vehicles are identified and tracked accurately in all of the databases. A major part of the effort in this biennial evaluation was spent trying to properly identify TIMS and registration data for individual vehicles. Because transcription errors of VINs and plates were common in these databases, in the end ERG could provide only approximately correct vehicle histories that were needed for the analyses. The following two recommendations are the most important vehicle tracking recommendations resulting from this biennial evaluation.

Recommendation 1 (***): Develop a system to ensure error-free VINs and plates in the TIMS and in the registration database. Almost 2% of the VINs in the TIMS had some sort of transcription error. It is not known what percent of plates in the TIMS were incorrect, but many were observed by looking at TIMS records for the same VIN. ERG also saw VIN errors in the registration database. ERG did not see errors in the plates in the registration database. All of these combined errors make looking up vehicle TIMS histories and matching RS measurements (which have their own plate transcription errors) with registration records and TIMS histories unnecessarily difficult. Ideally, VIN transcription errors would be totally eliminated from the registration database and from the TIMS. VIN transcription errors will occur at every point where VINs are hand-entered. Therefore, the most effective time to eliminate the errors is to prevent them from ever occurring by using software at every point of original entry. Prevention should be possible since all 1981+ VINs have a check digit. Once the VINs are error-free, keeping the plates error-free will be possible.

Recommendation 2 (***): Develop an historical vehicle registration database. Gordon-Darby added a field to the TIMS to help track vehicles and this is an improvement. Although it may be beyond the reach of TCEQ, upgrading the registration database to allow collection and querying historical information on individual vehicles is still a goal worth pursuing. Ideally, each registration transaction would create a new record in the registration database.

Repair Tracking Recommendations

Whether malfunctioning vehicle emission control systems are detected by TSI, ASM, or OBD, Texas needs to improve the system of recording the repairs that are made to vehicles. The repairs, not the inspections, keep vehicle emission control systems operating properly and, in turn, maintain low vehicle emissions.

Recommendation 3 (***): Use a more detailed, but short, list of repairs for I/M inspectors to choose from. The TIMS gives inspectors five general repair categories to use to report I/M-induced repairs and these categories appear too broad to be useful. It is recommended that Texas develop an improved system for reporting I/M-induced vehicle repairs that contains more detail, providing inspectors a list of the 5 to 10 most emissions-influential repairs for the technology of the vehicle that the inspector is working on. These repair types have already been determined by an analysis of British Columbia I/M program repair and ASM emissions data. Other information on the myriad of other repairs that might have been performed is not needed because they have minor influences on emissions. This approach would make a convenient, short list of repairs for inspectors that would make the inspector's task simpler, while recording the valuable repair information that is most important for the I/M program. This is also a critical element in making program evaluation projections, as without reliable repair data, be it an OBD or non-OBD vehicle, it is not possible to link emission reductions to repair.

1.0 Introduction

EPA requires that states with I/M programs submit an evaluation of their programs every two years to their EPA Regional office. TCEQ conducted the most recent biennial evaluation in 2006, and, in consultation with ERG, has chosen a set of evaluation elements that will comprehensively, yet simply, document the performance of the Texas I/M programs for the most recent two years and adhere to the program evaluation requirements outlined by EPA.

1.1 Evaluation Analysis Approach

The Clean Air Act requires that states evaluate their I/M programs every two years. The Sierra Method was used to evaluate the previous version of the Texas I/M program in 2000 [Reference 5] and later ERG used updated EPA guidance [References 1 and 2] as a framework for a more recent evaluation performed in 2006 [Reference 4].

This report follows the same general approach as the 2006 Report, as it focuses on analyzing and evaluating data to assess program coverage, the vehicle inspection process, the vehicle repair process, program air quality benefits, and station performance. These areas were chosen to provide the most useful information at reasonable cost, as well as provide an objective assessment on the overall status of the I/M program, with the intent of identifying both areas that may be improved upon and those that are performing well.

1.2 Structure of the Report

As previously stated, this report follows the same outline as the 2006 Report; however, there are some differences. A brief history of the Texas I/M program was provided in the 2006 Report and will not be discussed here. The 2006 Report also contained a section on Enforcement that was based on the analysis of registration information, as well as an analysis of covert and overt audit data performed on both stations and equipment. This topic is not covered in this report either.

Section 2 investigates program coverage first by examining the results of a recent parking lot survey of windshield registration stickers and by comparing vehicle license plates read during RS measurements with the vehicles seen in the I/M program TIMS database.

Section 3 investigates the inspection process in various ways using the TIMS data for the evaluation period. For example, TIMS data fields were checked for appropriate ranges, the various types of inspections and failure patterns were counted, the emissions analyzer calibration and audit results were checked, and trigger data were analyzed to look for evidence of fraud.

In Section 4 the TIMS data and RERF data were analyzed to determine the number and type of repairs performed, average repair cost, and emissions reductions associated with specific repairs.

Section 5 provides emission benefits estimates based on TIMS and RS data. Some of the analyses done in this section were not part of the original work plan, but were performed at no additional cost.

Finally, Section 6 is a fairly detailed analysis of station performance based on TIMS data. It covers errors of commission, such as “clean-piping” or VIN mismatches, as well as errors of omission that can range from data entry issues to anomalous test results. There was not a section in the 2006 Report devoted to this, although there were analyses pertaining to this topic in that report. However, it was felt to be worthwhile to attempt to consolidate this information in this report to present a more focused picture of station performance and how it may be monitored.

2.0 Coverage

An important component of an program I/M is the level of fleet coverage, or the vehicle compliance rate, achieved by the program. In this section, coverage is evaluated using two different sources of out-of-program data. In Section 3.1, the results of a parking lot survey are described that provide an estimate of fleet compliance with the I/M program. Section 3.2 covers the evaluation of fleet coverage by estimating the fraction of vehicles observed on the road during remote sensing that also have I/M program TIMS records.

2.1 Parking Lot Survey

The Vehicle Title and Registration Division (VTR) of the Texas Department of Transportation (TxDOT) has conducted annual parking lot surveys through contracts to university research facilities since 2001, although no survey was performed in 2002. Prior to 2001, VTR conducted the surveys from 1994 through 2000. The goals of these surveys have been twofold. First, there is an ongoing need to assess the state's sticker-based I/M and safety inspection programs because TX is not required to have a registration-based program as long as the safety and I/M inspection compliance is shown to be greater than the registration compliance. The other goal is to review the state's registration revenue collection by measuring registration compliance rates and estimate any potential revenue loss.

Data Collection

The registration and safety-I/M data collected in the Texas State 2007 annual parking lot survey for each county was scaled based on the overall population in a given county. This was done to provide a more accurate picture of the registration results for each county as well as for the statewide projections. The same eight counties used in past TxDOT survey were used in this analysis: Bexar, Dallas, El Paso, Harris, Hidalgo, Potter/Randall, Tarrant and Travis. Of these counties, Dallas, El Paso, Harris, Travis, and Tarrant have operating I/M programs. Parking lots selected for the survey had a minimum of 100 spaces, and data was collected using handheld barcode scanners. The use of barcode scanners allowed a visual comparison of the VIN and license plate with the data scanned from the registration barcode and any discrepancies to be noted.

Summary of Results

The results of the 2007 survey are provided in Table 2-1 along with those from the 2006 survey for comparison. It can be seen that nearly 17,000 vehicles were surveyed and the vast majority (nearly 98 percent in 2007) were registered in TX. Those vehicles with expired

registrations comprised 3.3 percent of the sample, which is below the survey historical average of 4.7 percent. However, the safety-I/M sticker expiration rate was higher at 4.4 percent.

Table 2-1. 2007 Parking Lot Survey Results

Survey Vehicle Field Data (Less Duplicates)	2006	2007
Number of Vehicles Surveryed	16,841	16,684
Number of Tx Registered Vehicles	16,013	16,342
Percent of Tx Registered Vehicles	95.1	97.9
Percent of Out-of-State Vehicles	2	1.2
Percent of Foreign Vehicles	3	0.8
Percent Expired Registration Sticker	3	3.3
Percent Expired Inspection Sticker	3.9	4.4
Average Number of Months Late	3.9	3

Recommendations for Future Surveys

If it is possible, it would be helpful to extend the survey to include additional counties with I/M programs. This would reduce the need to assume that the compliance rates observed in those counties surveyed are representative of those counties omitted from the survey. Increasing the sample size from 15,500 to 21,000 as described in the current report, would be helpful, but it should be noted that the previous report used by the TCEQ for the purpose of verifying I/M compliance contained approximately 72,000 records and covered all 15 I/M counties. Also the prior report [Reference 3] had very valuable information for assessing I/M program compliance that was not available in the current report. This information included data to determine the percent of valid license plates, percent of current registration, percent of current inspection, percent of both current registration and inspection and percent of valid emissions tests.

2.2 Participation Rates

Estimates of the participation rate of vehicles subject to I/M in the DFW area and in the HGB area were made through a comparison of RS data and TIMS data. RS is a sample of vehicles that were driven on the road. If these vehicles were eligible for I/M, they should have been participating in the I/M program. TIMS data were analyzed to determine the fraction of vehicles that are participating in the I/M program that were seen on the road by RS and are eligible for I/M.

ERG first created a dataset of I/M-eligible and I/M-county registered vehicles seen on the road with at least one RS measurement. This dataset does not include out of state vehicles nor non-I/M county Texas vehicles, but does consist of all I/M eligible model years. That is, vehicles younger than 2 years and older than 24 years at the time of the RS measurement are excluded

from the analysis. Table 2-2 shows the counts of unique vehicles measured by RS registered in the DFW and HGB program areas. RS measurements were collected from July 2006 through August 2008, which covers approximately the first 80% of the evaluation period.

Table 2-2. Count of Unique I/M-Eligible RS Vehicles Registered in I/M Program Areas

Registered at time of RS	Unique RS Vehicles
DFW	1,210,269
HGB	991,980
Total	2,202,249

Next, the number of unique I/M tested vehicles that received certifications in each of the I/M Program Areas was determined. Table 2-3 shows the counts for the DFW and HGB program areas.

Table 2-3. Count of Unique I/M-Tested Vehicles in I/M Program Areas

I/M Area where Test Performed	Unique I/M-Tested Vehicles
DFW	4,521,958
HGB	3,887,298
Total	8,409,256

The I/M tests were then matched to RS measurements by GroupID, which is a best estimate of the correct VIN[20]. If an I/M test occurred any time between October 1, 2006 and March 31, 2009 and was found to link up with an RS measurement taken any time between July 2006 and August 2008, this was judged to be a matched pair. Of the 1,210,269 RS measurements in DFW, there were 1,182,753 matched pairs for a 97.73% participation rate. Of the 991,980 RS measurements in HGB, there were 960,354 matched pairs for a 96.81% participation rate.

A further refinement to the participation rate was to look at a distribution of time differences between the matched pairs of RS to certifying I/M tests. For these calculations I/M tests both before and after RS measurement events were considered. If the time difference is more than a year, then that vehicle may no longer be participating in the I/M program. However, if the time difference is between 12-15 months, these vehicles may actually be participating in the I/M program. They may have returned late for their I/M test or they may have needed several repairs to satisfy I/M requirements. The final test can occur a few months after the initial

[20] The Group ID is a variable created to correct VIN transcription errors and account for changes in the vehicle license plate. Each vehicle record will have its own Group ID, just as each record should have its own VIN.

I/M test. Table 2-4 shows the distribution of time differences between matching pairs in each I/M program area.

Table 2-4. Time Between RS and I/M Test

I/M Program Area	Time difference between RS and I/M Test	Count	Percent
DFW	<12 months	1,169,404	97.16
	12 -15 months	20,232	1.71
	> 15 months	13,349	1.13
	Total	1,202,985	100.00
HGB	<12 months	937,303	97.60
	12 -15 months	13,108	1.36
	> 15 months	9,942	1.04
	Total	960,353	100.00

3.0 Inspection

3.1 Check Major TIMS Fields for Appropriateness

The goal of this check was to analyze the ranges and values produced in the major variables that make up the TIMS. This analysis is an indication of the ability of the TIMS database system to accurately record the activities of the I/M program. When TIMS variables have values that are out of range or are missing for an unexplained reason, this suggests that I/M program activities are not being properly monitored. [Section 4.2.1.5 of Reference 1]

Since the in-program data is the primary basis of the I/M program evaluation, a series of basic data checks were used to demonstrate the accuracy and completeness of the data in the database.

1) The beginning and ending dates of the data under consideration include:

   - I/M Test Records: October 1, 2006 – March 31, 2009.
   - RS Measurements: July 2006 – August 2008.

2) A frequency distribution was conducted of almost all database variables to demonstrate the accuracy and completeness of data entry. These frequency distributions included only filtered data, so many missing values and nonsensical values were removed during the filtering process. Throughout this report, additional details about the accuracy and completeness of individual fields are noted.

The following is a list of some findings after checking the various TIMS fields:

- 88% of the ASM tests had missing Dilution Pass/Fail Flags while for TSI tests only 0.12% had missing Dilution Pass/Fail Flags. Also, the Dilution Limit was set to 0 on 32% of the ASM tests while virtually none of the TSI tests had the Dilution Limit set to 0.
- Duration of tail pipe test times is missing on 32% of ASM tests and on 29% of TSI tests.
- The GAS_CAP_PF_FL and GAS_CAP_PF_FL1 fields appear to be the same quantity, but the values do not always agree exactly
- RPM bypass is used on 13% of the TSI tests.

3) A distribution of the emissions measurements is a special case of the above. Ideally, no observations with missing values should be present. Figures 3-1 through 3-10 show the distributions of the emissions measurements for HC, CO, and NO for ASM tests and HC and CO for TSI tests in both program areas. The distributions are all positively skewed (that is, most observations are at low emissions concentrations), and there is no evidence of large numbers of

observations at very high concentration values. The shapes of the distributions look typical for a fleet of modern in-use vehicles. Overall, the figures indicate that no gross errors are being made in measuring and recording tailpipe emissions. Also, all observations should have a CO_2 concentration between about 6% and 16%, since a combustion process must be present. Table 3-1 shows the distribution of CO_2 measurements that fall within range.

Figure 3-1. Distribution of ASM HC5015 Concentrations for All Filtered I/M Tests

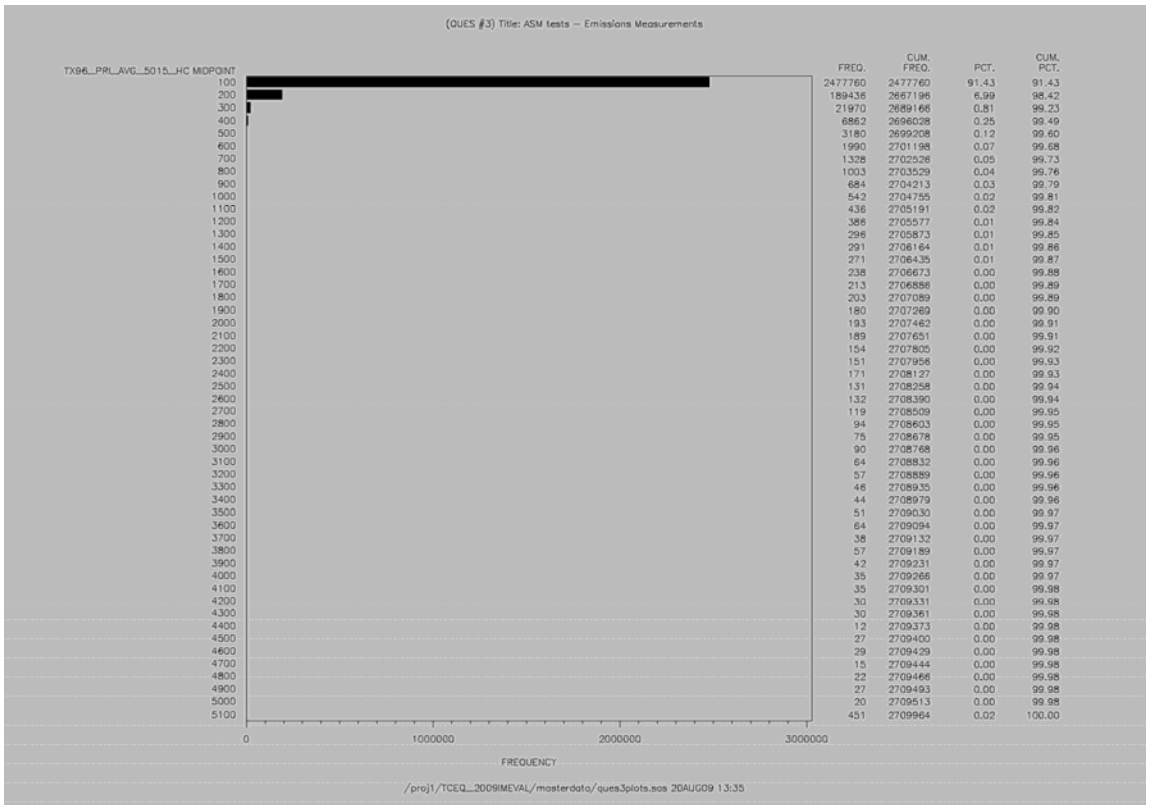
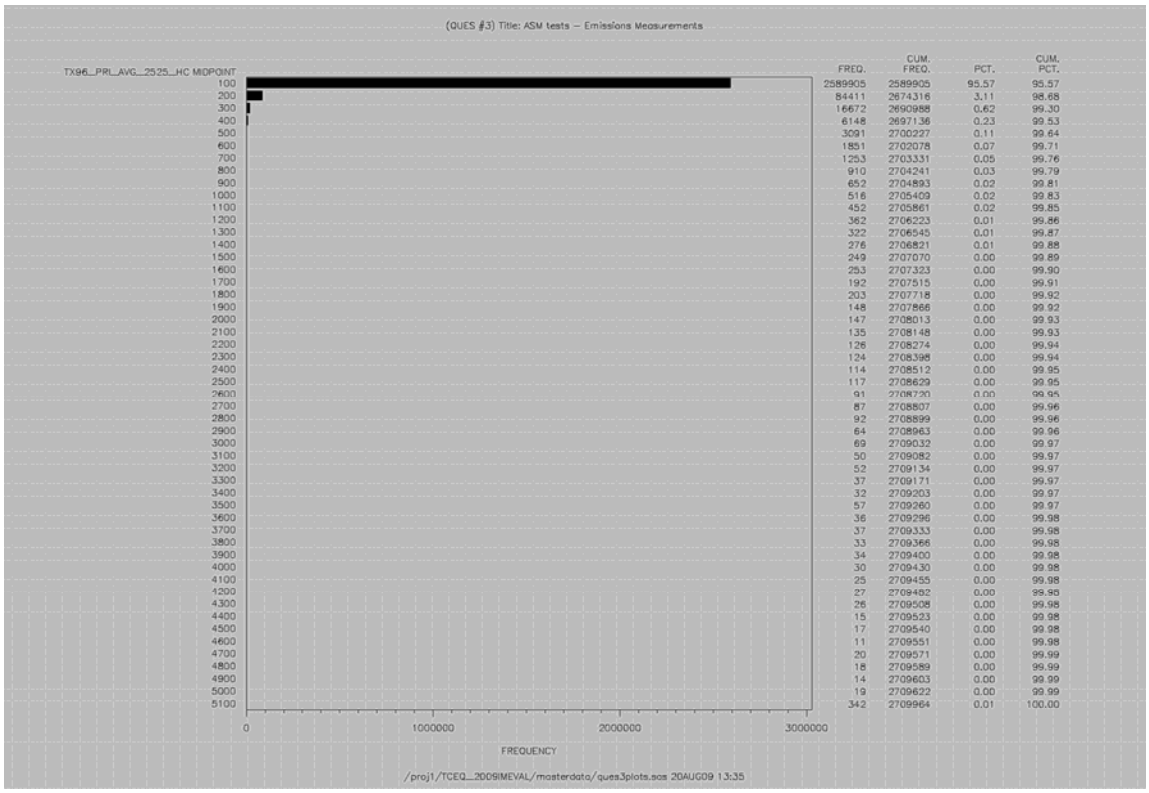
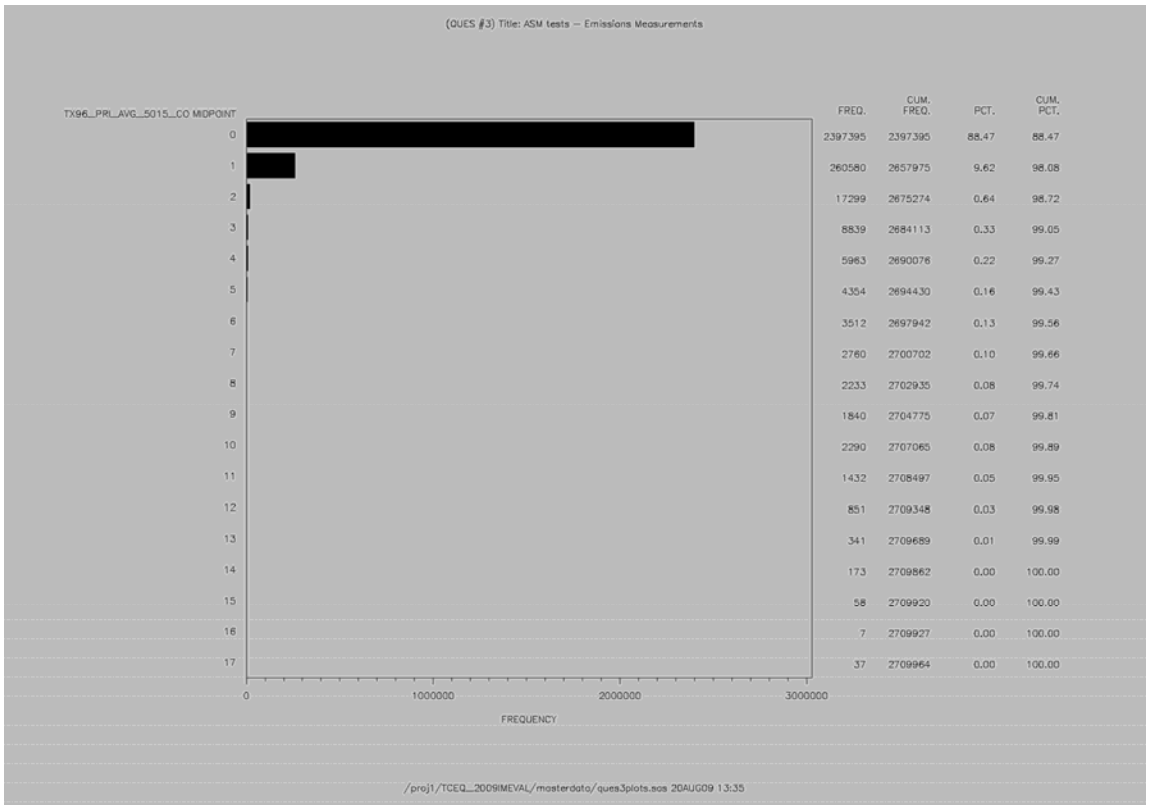


Figure 3-2. Distribution of ASM HC2525 Concentrations for All Filtered I/M Tests



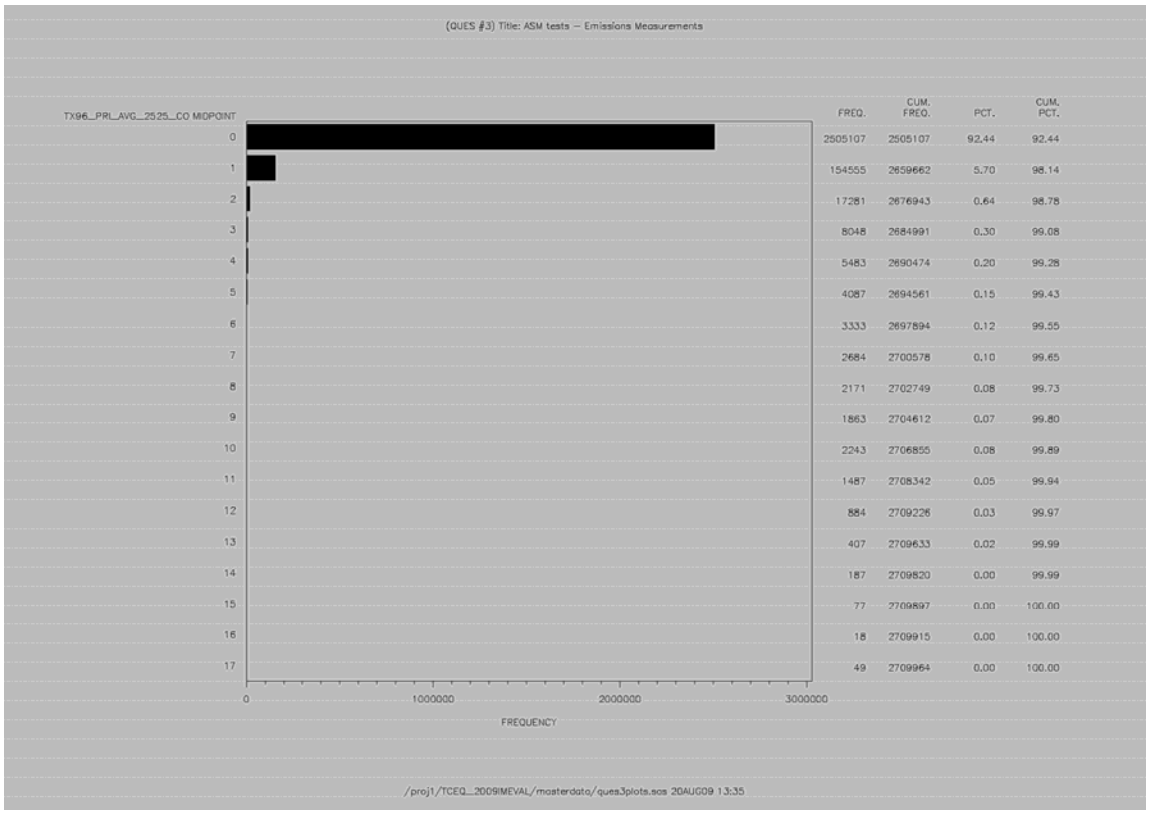
TX96_PRI_AVG_2525_HC MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
100	2589905	2589905	95.57	95.57
200	84411	2674316	3.11	98.68
300	16672	2690988	0.62	99.30
400	6148	2697136	0.23	99.53
500	3091	2700227	0.11	99.64
600	1851	2702078	0.07	99.71
700	1253	2703331	0.05	99.76
800	910	2704241	0.03	99.79
900	652	2704893	0.02	99.81
1000	516	2705409	0.02	99.83
1100	452	2705861	0.02	99.85
1200	362	2706223	0.01	99.86
1300	322	2706545	0.01	99.87
1400	276	2706821	0.01	99.88
1500	249	2707070	0.00	99.89
1600	253	2707323	0.00	99.90
1700	192	2707515	0.00	99.91
1800	203	2707718	0.00	99.92
1900	148	2707866	0.00	99.92
2000	147	2708013	0.00	99.93
2100	135	2708148	0.00	99.93
2200	126	2708274	0.00	99.94
2300	124	2708398	0.00	99.94
2400	114	2708512	0.00	99.95
2500	117	2708629	0.00	99.95
2600	91	2708720	0.00	99.95
2700	87	2708807	0.00	99.96
2800	92	2708899	0.00	99.96
2900	64	2708963	0.00	99.96
3000	69	2709032	0.00	99.97
3100	50	2709082	0.00	99.97
3200	52	2709134	0.00	99.97
3300	37	2709171	0.00	99.97
3400	32	2709203	0.00	99.97
3500	57	2709260	0.00	99.97
3600	36	2709296	0.00	99.98
3700	37	2709333	0.00	99.98
3800	33	2709366	0.00	99.98
3900	34	2709400	0.00	99.98
4000	30	2709430	0.00	99.98
4100	25	2709455	0.00	99.98
4200	27	2709482	0.00	99.98
4300	26	2709508	0.00	99.98
4400	15	2709523	0.00	99.98
4500	17	2709540	0.00	99.98
4600	11	2709551	0.00	99.98
4700	20	2709571	0.00	99.99
4800	18	2709589	0.00	99.99
4900	14	2709603	0.00	99.99
5000	19	2709622	0.00	99.99
5100	342	2709964	0.01	100.00

Figure 3-3. Distribution of ASM CO5015 Concentrations for All Filtered I/M Tests



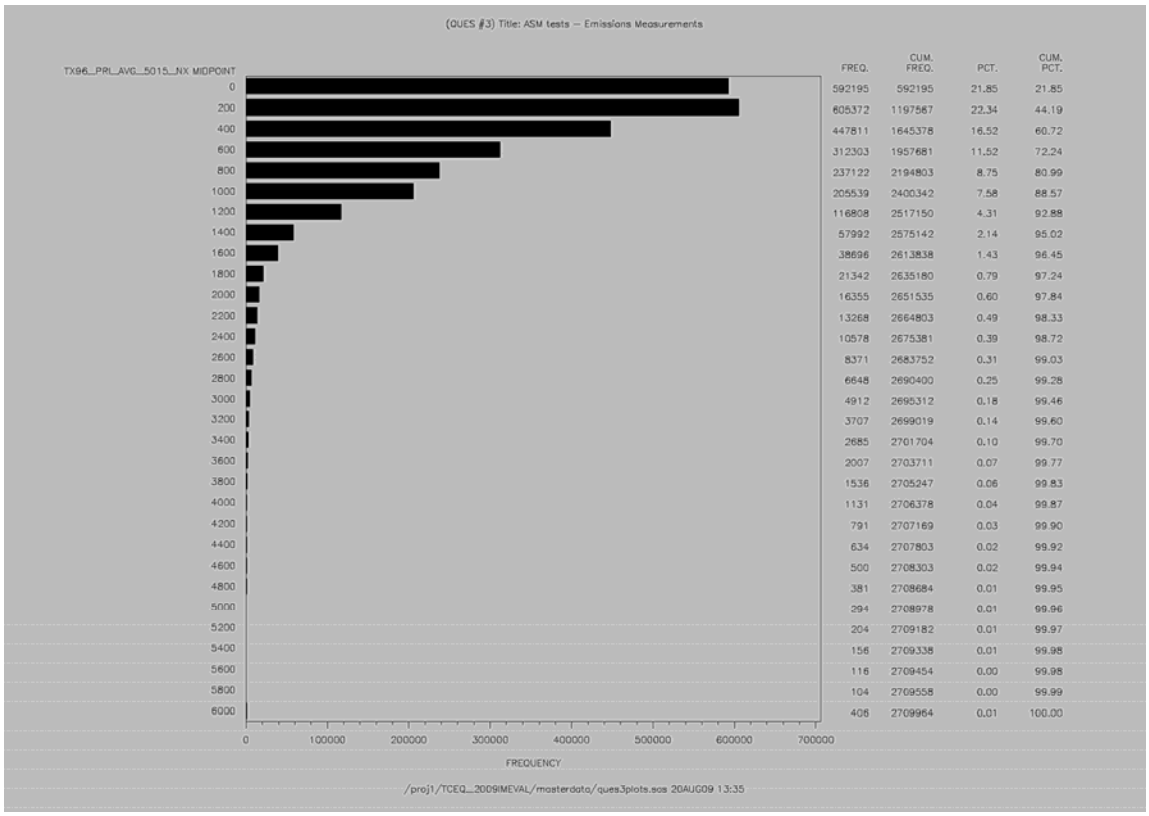
MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
0	2397395	2397395	88.47	88.47
1	260580	2657975	9.62	98.08
2	17299	2675274	0.64	98.72
3	8839	2684113	0.33	99.05
4	5963	2690076	0.22	99.27
5	4354	2694430	0.16	99.43
6	3512	2697942	0.13	99.56
7	2760	2700702	0.10	99.66
8	2233	2702935	0.08	99.74
9	1840	2704775	0.07	99.81
10	2290	2707065	0.08	99.89
11	1432	2708497	0.05	99.95
12	851	2709348	0.03	99.98
13	341	2709689	0.01	99.99
14	173	2709862	0.00	100.00
15	58	2709920	0.00	100.00
16	7	2709927	0.00	100.00
17	37	2709964	0.00	100.00

Figure 3-4. Distribution of ASM CO2525 Concentrations for All Filtered I/M Tests



FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
2505107	2505107	92.44	92.44
154555	2659662	5.70	98.14
17281	2676943	0.64	98.78
8048	2684991	0.30	99.08
5483	2690474	0.20	99.28
4087	2694561	0.15	99.43
3333	2697894	0.12	99.55
2684	2700578	0.10	99.65
2171	2702749	0.08	99.73
1863	2704612	0.07	99.80
2243	2706855	0.08	99.89
1487	2708342	0.05	99.94
884	2709226	0.03	99.97
407	2709633	0.02	99.99
187	2709820	0.00	99.99
77	2709897	0.00	100.00
18	2709915	0.00	100.00
49	2709964	0.00	100.00

Figure 3-5. Distribution of ASM NO5015 Concentrations for All Filtered I/M Tests



MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
0	592195	592195	21.85	21.85
200	605372	1197567	22.34	44.19
400	447811	1645378	16.52	60.72
600	312303	1957681	11.52	72.24
800	237122	2194803	8.75	80.99
1000	205539	2400342	7.58	88.57
1200	116808	2517150	4.31	92.88
1400	57992	2575142	2.14	95.02
1600	38696	2613838	1.43	96.45
1800	21342	2635180	0.79	97.24
2000	16355	2651535	0.60	97.84
2200	13268	2664803	0.49	98.33
2400	10578	2675381	0.39	98.72
2600	8371	2683752	0.31	99.03
2800	6648	2690400	0.25	99.28
3000	4912	2695312	0.18	99.46
3200	3707	2699019	0.14	99.60
3400	2685	2701704	0.10	99.70
3600	2007	2703711	0.07	99.77
3800	1536	2705247	0.06	99.83
4000	1131	2706378	0.04	99.87
4200	791	2707169	0.03	99.90
4400	634	2707803	0.02	99.92
4600	500	2708303	0.02	99.94
4800	381	2708684	0.01	99.95
5000	294	2708978	0.01	99.96
5200	204	2709182	0.01	99.97
5400	156	2709338	0.01	99.98
5600	116	2709454	0.00	99.98
5800	104	2709558	0.00	99.99
6000	406	2709964	0.01	100.00

Figure 3-6. Distribution of ASM NO2525 Concentrations for All Filtered I/M Tests

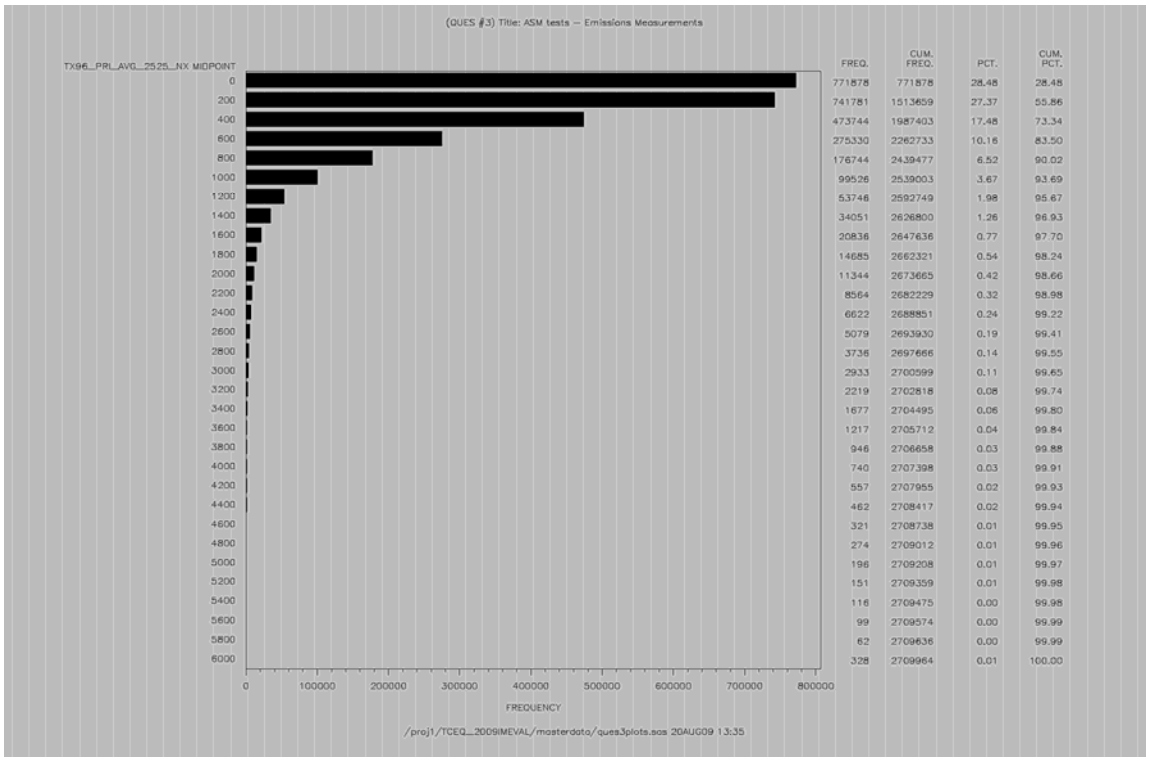


Figure 3-7. Distribution of TSI HC Curb Idle Concentrations for All Filtered I/M Tests

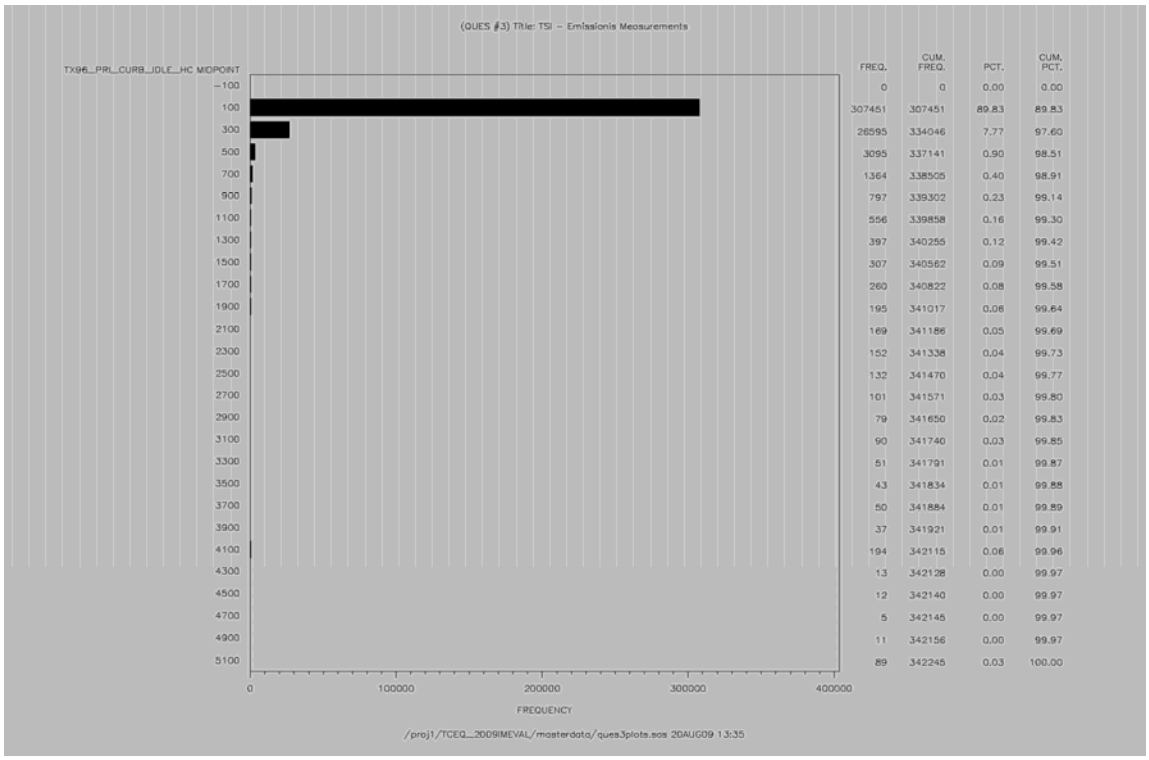


Figure 3-8. Distribution of TSI HC High Speed Concentrations for All Filtered I/M Tests

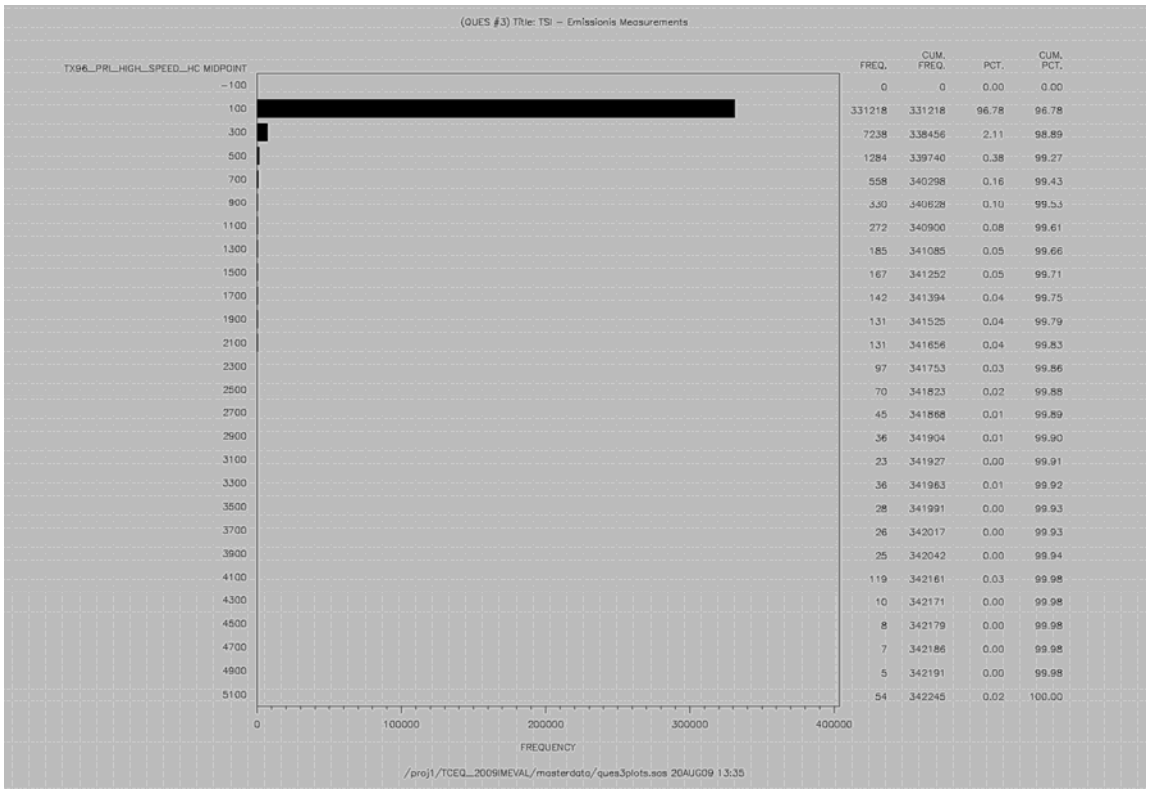


Figure 3-9. Distribution of TSI CO Curb Idle Concentrations for All Filtered I/M Tests

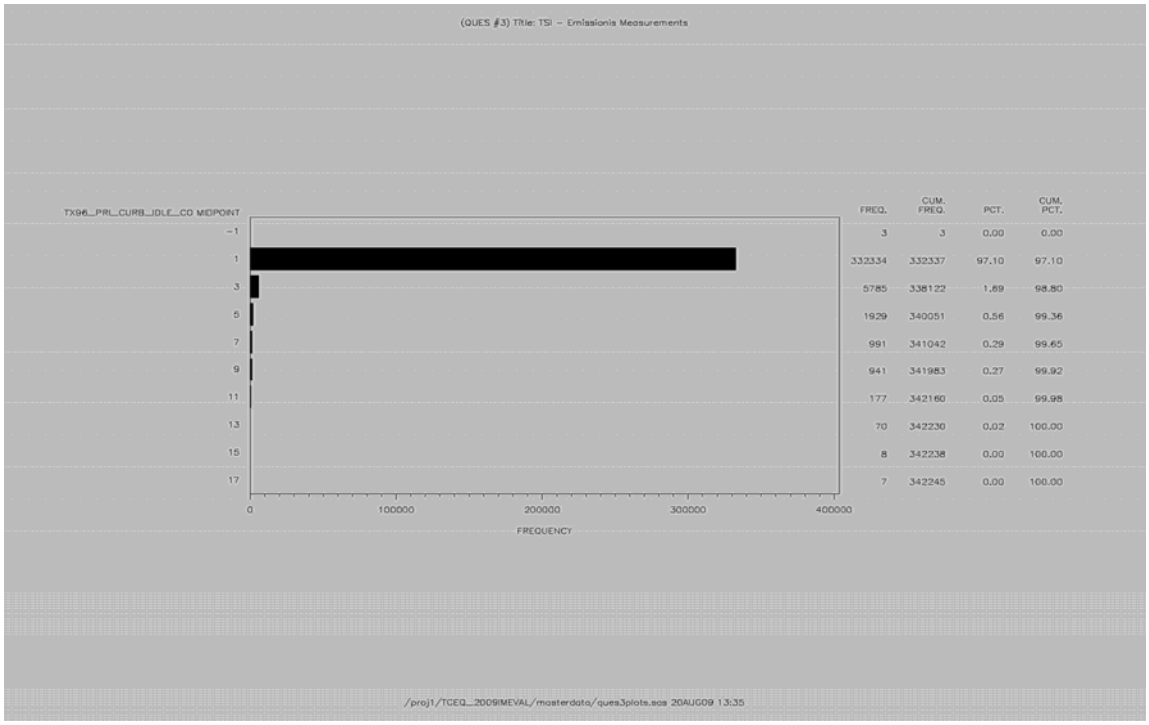


Figure 3-10. Distribution of TSI CO High Speed Concentrations for All Filtered I/M Tests

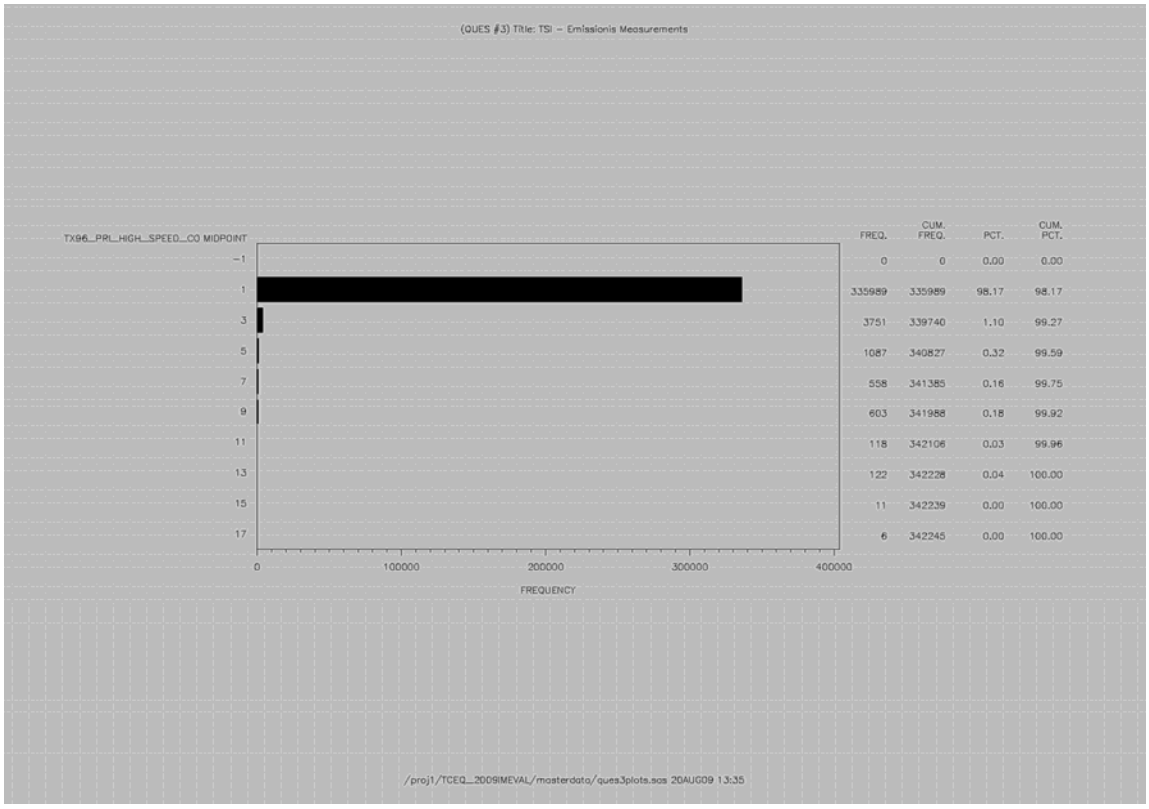


Table 3-1. Distribution of Measured CO_2 Concentrations

Emission Test Type	Test Mode	Frequency	Fraction of CO_2 Readings		
			$CO_2 < 6\%$	$6\% < CO_2 < 16\%$	$CO_2 > 16\%$
ASM	5015	2,709,964	0.0038	0.9864	0.0099
	2525	2,709,964	0.0032	0.9859	0.0109
TSI	Curb Idle	342,245	0.0048	0.9880	0.0072
	Fast Idle	342,245	0.0043	0.9884	0.0073

4) The fraction of observations with both the license plate and the VIN missing was determined. 99.75% of the observations have neither VIN nor Plate missing. A small percentage (0.25%) of the observations have VIN present, but a missing Plate. These are the only two combinations present.

5) The validity of each 17-digit VIN was checked. Following the simplest method, the check digit in 17-digit (1981+) VINs was checked. Table 3-2 shows the counts of the various Check Digit results. Older unique VINs that have fewer than 17 digits do not have check digits, and were not examined.

The frequency distribution of the VIN characters for the BADCKs showed about the same number of counts for all illegal check digit characters – except for B, S, and Z. These three illegal check digit characters, which are easily confused with 8, 5, and 2, had elevated counts relative to the other illegal check digit characters. It was concluded that the illegal check digit characters may be caused by VIN transcription errors. Similarly, illegal VIN characters I, O, and Q are easily confused with legal VIN characters 1 and 0. So, this is another case where VIN transcription errors may be the cause.

The table shows that a large number of the 17-digit VINs that did not have BADCKs or CHARs had check digits that did not agree with the calculated check digit. Again, this must be caused by VIN transcription errors at some point in the VIN entry process. Altogether, almost 2% of the VINs had some sort of transcription error. These errors make looking up vehicle TIMS histories and matching RS measurements with registration records and TIMS histories, activities that had to be done repeatedly in this project, prone to errors. It is believed that VIN transcription errors need to be totally eliminated from the DPS registration database and from the TIMS. The most effective point of eliminating the errors is to prevent them from ever occurring by using software at the point of original entry.

Table 3-2. Distribution of Check Digit Codes on Unique 17-Digit VINs in the I/M Test Records

Check Digit Code	Description of Code	Frequency	Percent
BADCK	Illegal Check Digit (should be 0 to 9 or X)	9,960	0.12
CHAR	Either I, O, or Q is in the VIN string	103	0.00

ERROR	Check Digit does not agree with check digit calculation	113,286	1.35
OK	Check Digit agrees with check digit calculation	8,273,479	98.53
Total		8,396,528	100.00

6) Each license plate should usually be associated with only a single VIN. In Table 3-3 below, 98.37% of the plates have a single VIN. Beyond this, some suspect plates begin to be found. For example, 1.5% of the plates have two VINs. However, this may not be a problem because in some situations, such as for dealer plates and for vanity plates, plates can be legitimately moved to another vehicle.

Table 3-3. Number of VINs per Plate

VIN Count	Frequency	Percent
1	8,168,279	99.01
2	77,159	0.94
3	1,959	0.02
4	488	0.01
5	288	0.00
>5	1,440	0.02
Total	8,249,613	100.00

3.2 Inspection Statistics: Number of Vehicles Inspected by Inspection Type

The goal of this element was to estimate the I/M participation rate of I/M eligible vehicles in each I/M program area. The TIMS data were used to make a simple count of various types of inspections performed (TSI, ASM, OBD) and the number of vehicles that received these inspections. This is an indication of the extent to which the Texas I/M program fleet was receiving the attention of the I/M program. Counts include only emissions inspections.

Inspection Statistics

Table 3-4 shows the number of ASM, OBD, and TSI tests in each I/M program area performed during the evaluation period (October 1, 2006 to March 31, 2009).

Table 3-4. Emissions Tests per I/M Program Areas

I/M Program Area	Emission Test Type	Counts	Percent
DFW	ASM	1,499,161	17.2
	OBD	7,030,002	80.6
	TSI	189,556	2.2
	Total	8,718,719	100.0
HGB	ASM	1,210,803	16.2
	OBD	6,120,727	81.8
	TSI	152,689	2.0

	Total	7,484,219	100.0

Table 3-5 shows the number of vehicles receiving at least one I/M test during the evaluation period.

Table 3-5. Number of Vehicles Receiving at least One Emissions Test

I/M Program Area	Emission Test Type	Counts	Percent
DFW	ASM	890,354	18.8
	OBD	3,697,910	78.1
	TSI	146,209	3.1
	Total	4,734,473	100.0
HGB	ASM	720,832	17.8
	OBD	3,217,590	79.4
	TSI	115,935	2.8
	Total	4,054,357	100.0

Table 3-6 shows the number of passes and fails and the fail fraction along with the number of emissions tests (including ASM, OBD, and TSI) performed in each I/M Program Area.

Table 3-6. Emission Test Pass/Fail Counts

I/M Program Area	Emission Test Type	Pass/Fail Status	Counts	Fail Fraction
DFW	ASM	Fail	130,097	0.087
		Pass	1,369,064	
	OBD	Fail	285,929	0.041
		Pass	6,742,823	
	TSI	Fail	10,085	0.053
		Pass	179,471	
HGB	ASM	Fail	107,655	0.089
		Pass	1,103,148	
	OBD	Fail	286,043	0.047
		Pass	5,833,658	
	TSI	Fail	7,424	0.049
		Pass	145,265	

ERG also looked at the emission test types within I/M cycles to determine whether emission test types changed mid-cycle. For about 99.74% of the I/M cycles the same emissions test type was performed throughout the duration of the cycle.

Figures 3-11 and 3-12 show the distributions of numbers of vehicles by model year for each emission test type for the DFW and HGB I/M areas, respectively. There is a noticeable transition between the 1995 and 1996 model year vehicles. This sudden change occurs because

OBD tests are conducted on 1996 and newer model year vehicles while ASM tests are conducted on 1995 and older model vehicles. TSI tests are performed on vehicles such as those with all-wheel drive that cannot be tested on a dynamometer. The figures show that the TIMS contains a small number of apparent OBD inspections on pre-1996 vehicles, which do not have OBD capability. The reason for these observations is not known, but whatever the reason, the magnitude of this issue is very minor in such a large dataset.

Figure 3-11. Count of Emission Test Types by Model Year for DFW

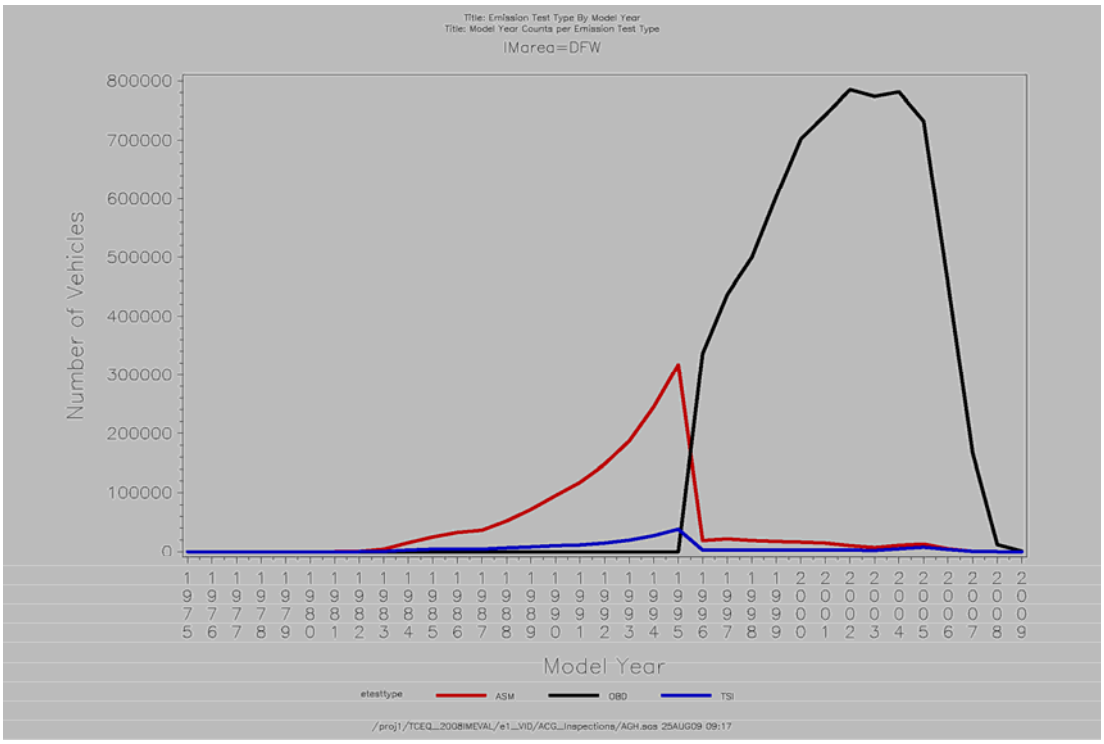
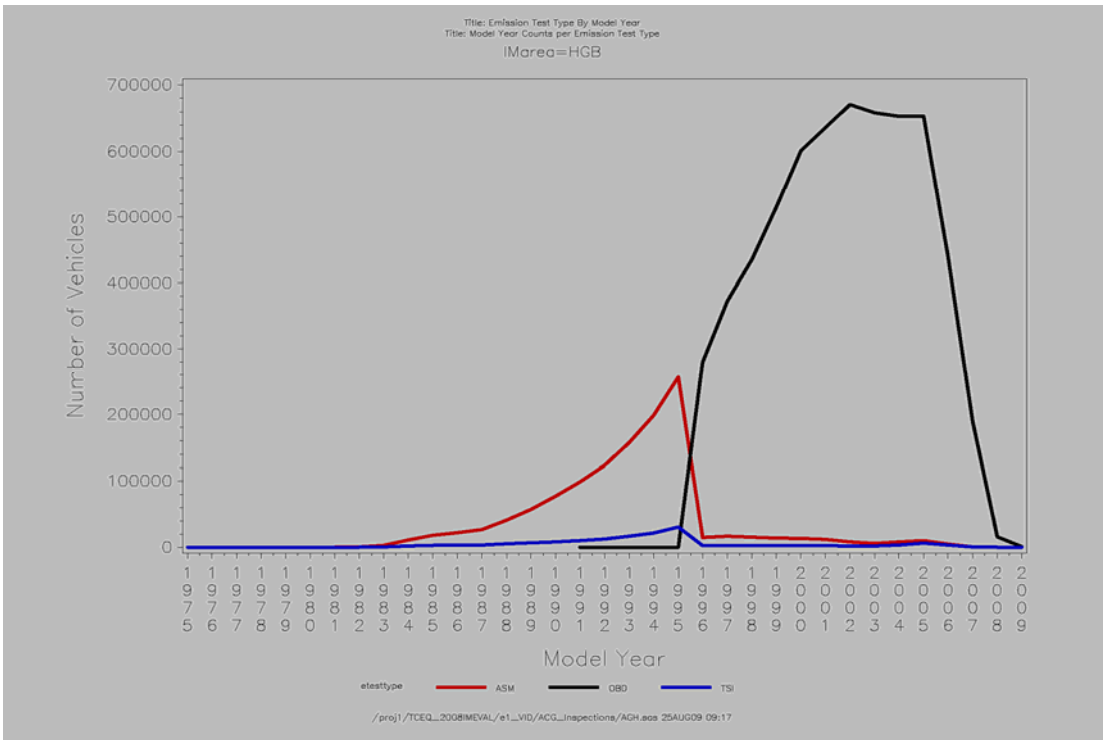


Figure 3-12. Count of Emission Test Types by Model Year for HGB



Figures 3-13 and 3-14 show the number of vehicles tested by month and by year for the DFW and HGB I/M program areas, respectively. The number of tests conducted each month is not the same from month to month in both I/M areas for all years. There tends to be a peak in March and a low in November. In both Figures 3-13 and 3-14, the counts of vehicles tested begins in October 2006, which is the beginning of the evaluation period. The figures show a gradually increasing trend in number of inspections for 2007, 2008, and 2009 as the fleet grows.

Figure 3-13. Emission Test by Month Year for DFW

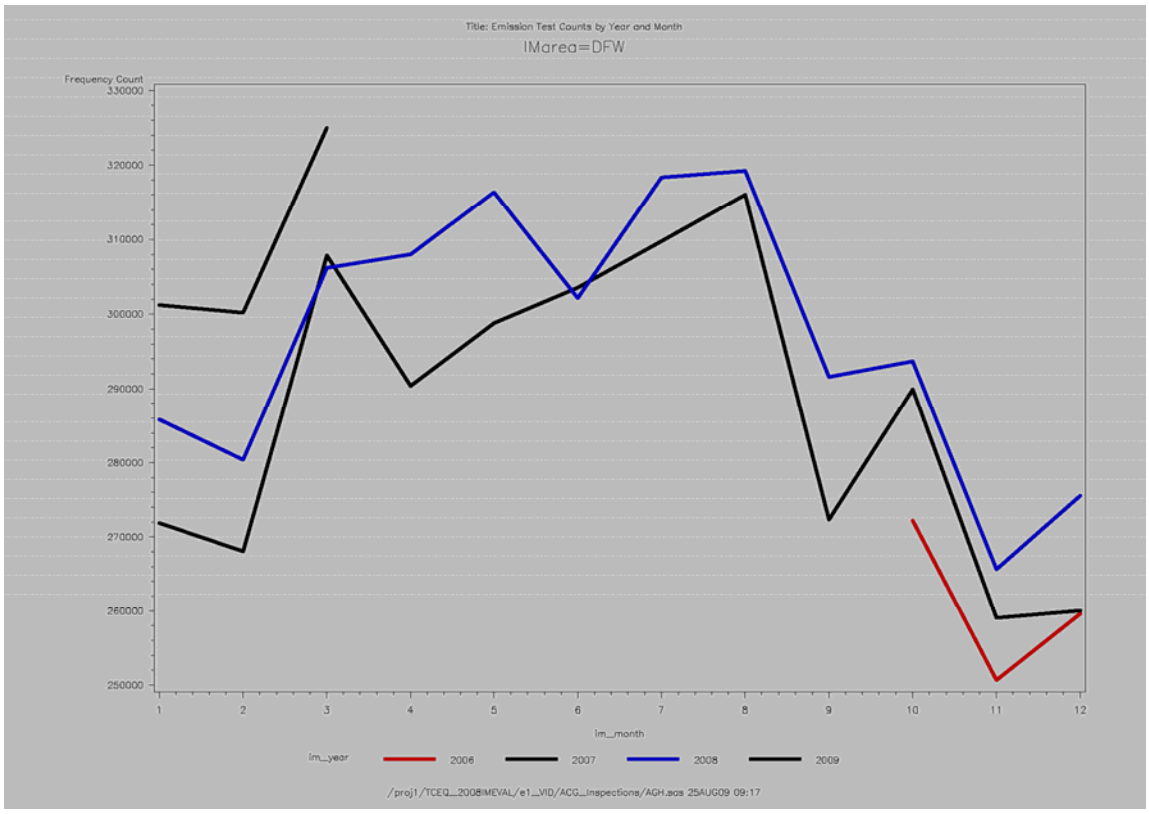
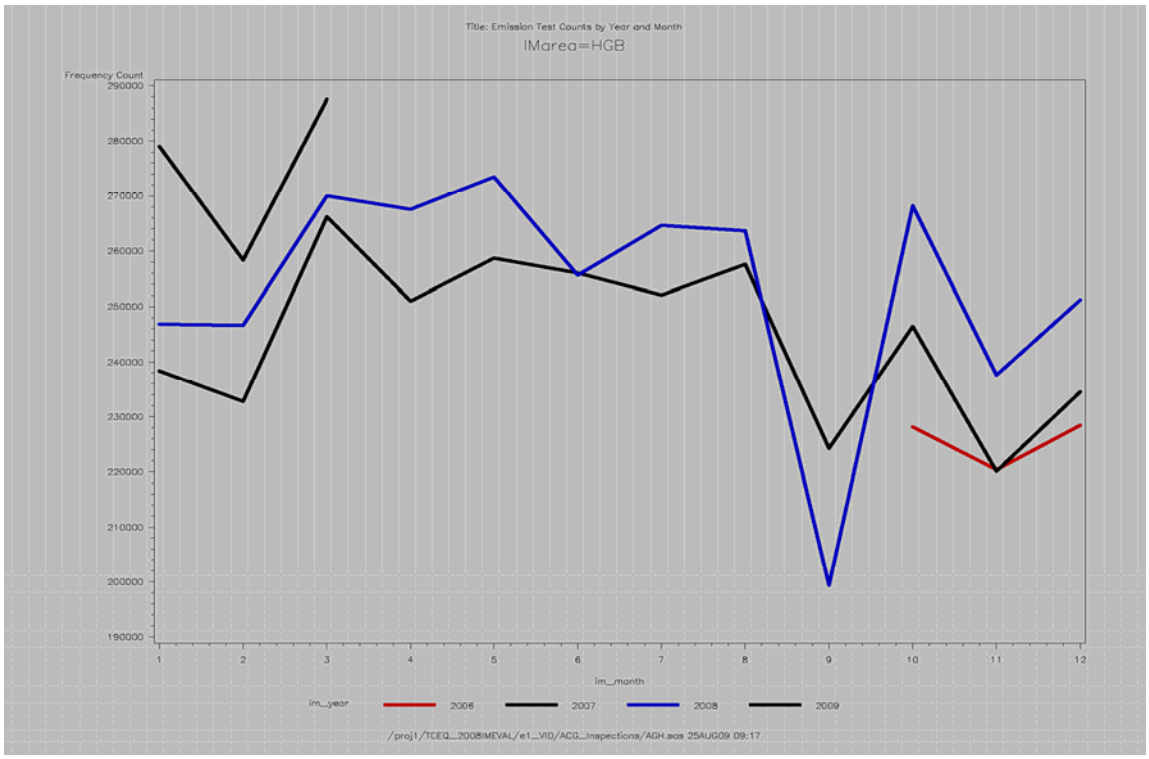


Figure 3-14. Emission Test by Month Year for HGB



3.3 Repeat I/M Failure Patterns

ERG examined the TIMS to determine the patterns of repeated I/M failures. This illustrates the extent and properties of repairs related to the I/M program.

The dataset for this analysis was created by snipping out a piece of the historical TIMS from October 2006 to March 2009. This process also extracts the I/M inspection histories of some individual vehicles. To distinguish and handle partial and complete individual vehicle histories, ERG developed four I/M cycle categories:

1) Initial test (first time GroupID is encountered) occurred during the first three months of the dataset, but unsure whether it is a true initial test (i.e., the true initial test may have occurred prior to October 1, 2003) AND the Final test is a Certified[21] test.

2) Initial test (first time GroupID is encountered) occurred during the first three months of the dataset, but unsure whether it is a true Initial test AND the Final test is NOT a Certified test.

3) Initial test (either definition applies) occurs after the first three months of the dataset and assumed to be a true Initial test AND the Final test is a Certified test.

4) Initial test (either definition applies) occurs after the first three months of the dataset and assumed to be a true Initial test AND the Final test is NOT a Certified test.

Every vehicle that participates in the I/M program produces a brief history when it is inspected, repaired, and retested. Ideally, vehicles should be tested and pass if they are in proper working condition and if they are not, it is expected they would fail, be repaired, tested, and passed immediately. If all vehicles in the inspected fleet had only one of these two possibilities, one could conclude that the accuracy of the I/M measurements and the efficacy of the repairs made to Texas vehicles were ideal. The actual test-repair sequences of real I/M programs were determined by an analysis of the TIMS data and, in general, produced many more possibilities besides the ideal two scenarios. For example, a sequence that is fail, fail, fail, pass can indicate that either the motorist is "shopping around" for a passing result, that the repairs done to the vehicle were inadequate, or that the emissions test was inaccurate.

Each vehicle was tested at an I/M station on one or more occasions. The TIMS does contain a variable that gives the type of test (Initial or Retest) and a variable that gives the result

[21] In this report, the term Certified test is used to designate an I/M inspection in which the vehicle was issued a certificate, that is, a windshield sticker, for having completed and met the I/M program inspection requirements.

of the emissions test (Pass or Fail). For the purposes of determining failure patterns, ERG did not consider whether the test was designated by the TIMS as an initial or retest. In the I/M sequences that were built, it was considered the first test after the last certifying test as an initial test, and any test after the initial up to an including the certifying test is a retest. Failures were designated with an “F” and passes with a “P”.

For each unique GroupID, the designators were concatenated in chronological order to create a sequence that describes the failure pattern that each vehicle experienced during an I/M testing cycle. For example, for a vehicle that initially failed and then passed on a re-test, the test sequence would be “FP”. The frequency distribution of the resulting test sequences for completed I/M cycles (I/M Cycle Category = 3) is shown in Tables 3-7 and 3-8 for DFW and HGB, respectively.

Table 3-7. Frequency Distribution of Test Sequences for DFW for I/M Cycle Category = 3

Test Sequence	Vehicle Frequency	% of Vehicles
P	7,176,311	95.402
FP	316,317	4.205
PP	14,561	0.194
FFP	12,911	0.172
FFFP	657	0.009
FF	481	0.006
PFP	452	0.006
FPP	167	0.002
FFF	111	0.001
PPP	74	0.001
FFFFP	53	0.001
16 Other Test Sequences	92	0.001
Total	**7,522,187**	**100.000**

Table 3-8. Frequency Distribution of Test Sequences for HGB for I/M Cycle Category = 3

Test Sequence	Vehicle Frequency	% of Vehicles
P	6,090,256	94.979
FP	291,949	4.553
PP	16,862	0.263
FFP	11,311	0.176
FFFP	558	0.009
PFP	504	0.008
FF	226	0.004
FPP	202	0.003
PPP	154	0.002
FFF	85	0.001
19 Other Test Sequences	106	0.002
Total	**6,412,213**	**100.000**

In Table 3-7, the distribution shows that the top five most frequently found sequences accounted for 99.98% of the vehicles tested in DFW. In Table 3-8, the distribution shows that the top five most frequently found sequences accounted for 99.98% of the vehicles tested in HGB. However, some of these sequences raise questions, such as, why are between 0.20-0.27% of the vehicles tested a second time after they pass initial in both I/M program areas? One explanation is that a vehicle goes to one station and passes its emissions test, but fails its safety test. Rather than returning to the same station, the vehicle goes to another station, but needs to be completely tested again even though it failed just the safety portion at its previous test.

Approximately, 16 to 19 less common sequences accounted for the remaining 0.03% of the tested fleets in DFW and HGB. Many of these remaining sequences seem to be unlikely, and these sequences account for only 198 vehicles of the more than 13 million in the dataset. It is suspected that these sequences represent data entry problems instead of real situations. While better inspection database systems could reduce the occurrence of these unlikely test sequences, the problem is very minor.

Tables 3-7 and 3-8 showed the results for the third I/M cycle category separated into the HGB and DFW fleets. Tables 3-9 through 3-11 show the first, second, and fourth I/M cycle categories for the combined fleet.

The test sequences for the first I/M cycle category in Table 3-9 look very similar to the sequences in Tables 3-7 and 3-8. Many of these cycles are probably complete and certified cycles with the true initial tests occurring in the dataset, but uncertainty remains without examining the TIMS data prior to October 1, 2006. The test sequences for the second and fourth I/M Cycle Categories in Tables 3-10 and 3-11 consist of many more sequences that end in a Fail. As expected, these are not certified cycles. Approximately 87% of the sequences are either a single Fail or Fail-Fail. The remaining percentage of single, uncertified passes may be due to grouping errors.

Table 3-9. Frequency Distribution of Test Sequences for I/M Cycle Category=1

Test Sequence	Vehicle Frequency	% of Vehicles
P	1,320,126	94.74
FP	66,075	4.74
PP	3,363	0.24
FFP	3,334	0.24
FFFP	197	0.01
PFP	122	0.01
14 Other Test Sequences	187	0.02
Total	**1,393,404**	**100.00**

Table 3-10. Frequency Distribution of Test Sequences for I/M Cycle Category=2

Test Sequence	Vehicle Frequency	% of Vehicles
F	4,577	82.62
P	538	9.71
FF	374	6.75
FFF	20	0.36
PF	11	0.20
PP	8	0.14
FP	6	0.11
PFF	3	0.05
3 Other Test Sequences	3	0.06
Total	**5,540**	**100.00**

Table 3-11. Frequency Distribution of Test Sequences for I/M Cycle Category=4

Test Sequence	Vehicle Frequency	% of Vehicles
F	75,604	83.62
P	10,056	11.12
FF	4,099	4.53
FFF	235	0.26
PF	163	0.18
FP	136	0.15
PP	81	0.09
FFFF	15	0.02
7 Other Test Sequences	21	0.03
Total	**90,410**	**100.00**

3.4 Emissions Analyzer Data Quality

The goal of this task was to demonstrate the accuracy of the emissions inspection methods. The following four I/M analyzer checks were made using Texas TIMS data: Drift, Dilution Correction Factors, Gas Audits, and Lockouts.

3.4.1 Analyzer Drift

Texas I/M program emissions analyzers are calibrated every 72 hours. The calibration is done using the analyzer to measure a bottled calibration gas mixture with a concentration that is known within a specified precision. Before a calibration is performed, a pre-calibration measurement on the calibration gas is made and recorded in the TIMS for HC, CO, NO, O_2, and CO_2 gases. The difference between the pre-calibration analyzer reading and the labeled concentration of the gas mixture is a direct measure of instrument drift. If the analyzer has not drifted since the last calibration, its readings for the calibration gas will be close to the bottle label value, and little calibration adjustment will be necessary. This fact can be used to develop an indicator of analyzer calibration stability. Analyzers that consistently drift little from

calibration to calibration can be expected to produce more accurate measures of vehicle emissions than those that drift greatly. If the difference between the bottle label value and the pre-calibration analyzer reading is very large, then it is presumed that some of the emissions measurements made during the previous 72 hours were less accurate than desirable.

Calibration Procedures and Specifications

In each 72 hour calibration, the analyzer first records pre-calibration readings for HC, CO, CO_2, and NO for zero, low-span, and mid-span bottle gases, and for O_2 with ambient air. The analyzer is then calibrated on the mid-span gases to within 1% of the bottle gas values. Next, the analyzer is tested on the low-span gases, and must fall within 2% of the bottle gas value. If the analyzer cannot be brought within specifications during the calibration, the instrument is automatically prohibited from performing any portion of an I/M test until it is successfully adjusted.

Table 3-12 shows the specified bottle gas values for the low-span and mid-span portions of the calibration. The bottled gases are permitted a 5% blend tolerance, which is also shown in the table. Finally, the table shows the specified accuracy of the analyzer for I/M inspections for each pollutant and gas level. These tolerances for I/M inspections are less stringent than the 1% mid-span and 2% low-span tolerances that are used for calibrations. The I/M inspection tolerances are applicable to this analysis of pre-calibration readings since the concern here is with whether analyzer drift affected I/M inspection results just prior to calibration. As an example from the table, the low-span HC bottle gas concentration is specified to be 200 ppm, but may range between 190 and 210 ppm. If a bottle gas labeled to contain 195 ppm HC were used for a calibration, the analyzer would be required to read between 189 and 201 ppm in order to meet the specification.

Table 3-12. Calibration Span Gas Values and Tolerances

Gas	Specified Bottle Gas Concentration	Bottle Gas Blend Tolerance	Analyzer Tolerance for I/M Inspections
Zero Gas			
HC (ppm)	<1	Not applicable for zero gases	±4
CO (%)	<0.01		±0.02
NOx (ppm)	<1		±25
CO_2 (%)	<4.0		±0.3
O2 (%)	20.7		±1.04
Low-Span Bottle Gas			
HC (ppm)	200	±10	±6
CO (%)	0.5	±0.025	±0.02
NOx (ppm)	300	±15	±25
CO_2 (%)	6.0	±0.3	±0.3
Mid-Span Bottle Gas			
HC (ppm)	3200	±160	±160
CO (%)	8.0	±0.4	±0.24
NOx (ppm)	3000	±150	±120
CO_2 (%)	12.0	±0.6	±0.36

The actual concentrations of the bottle gases used in each calibration are recorded in the TIMS. More than 99.9% of calibration records include bottle gas label concentrations within the tolerances listed in Table 3-12. However, the remaining small fraction of records includes some surprisingly high and low bottle gas values, such as 62 records with zero percent or ppm for each of the low-span and mid-span concentrations. It is possible that the bottle gas concentration was entered incorrectly into the TIMS, or that the outlying values represent real bottle gas mixtures that were occasionally used. In either case, the calibration results are called into question when the analyzer reading is compared to out-of-specification bottle gas label values. To eliminate this issue in future calibration records, ERG recommends that TCEQ restrict the inspector-entered bottle gas values to a range that corresponds to the specifications. Thus, the TIMS software would not allow a calibration to proceed unless reasonable bottle gas values were entered.

Results

812,462 span test calibration records from the TIMS between 1 October 2006 and 31 March 2009 were available for this analysis. 1 record with missing station ID and analyzer ID information was deleted, leaving 812,461 records in the dataset.

The calibration dataset included records for the entire state, rather than just the Dallas/Fort Worth and Houston/Galveston/Brazoria areas of interest. It was found that

calibration records from analyzers located outside the DFW or HGB (i.e. in areas using only TSI inspections rather than ASM inspections) contained only missing information for all NO results, or only zero values for all NO results, for all calibrations by that analyzer. These 158,540 out-of-area records were deleted, leaving 653,921 records in the dataset.

Finally, an additional 8,406 records where the pre-calibration reading for each gas and level was zero were deleted, leaving 645,515 records in the dataset. Although these records contain no span gas calibration readings, each does include a pass or fail result for the span gas calibration. Some of these records do contain dynamometer calibration information, and some contain a pass or fail result for the leak check, so these might only be records for calibration events that did not include a span gas calibration. However, if that is the case, the analyzer software should not allow a pass/fail result to be recorded for the span gas audit.

Figures 3-15 through 3-28 each show the distribution of the difference between the analyzer reading and the labeled value of the bottle gas, for one gas type/concentration level combination. For the zero level readings, the difference between zero and the recorded concentration is shown. The calibration records for O_2 have been divided into two separate groups for Figures 3-19 and 3-20. The pre-calibration value of O_2 should be 20.7%, corresponding to the O_2 content of ambient air. It was found that analyzers with manufacturer codes of SE, JB, and Worldwide (WW) measured near 20.7% O_2 in more than 99% of calibrations, while analyzers with the manufacturer code ES measured less than 3% O_2 in more than 97% of calibrations. It may be that ES analyzers are designed to measure O_2 from bottle gas (perhaps the CO/HC bottle that contains zero O_2) during calibrations, instead of ambient air as specified. Since the tolerance for the analyzer is tighter at 0% O_2 than at 20.7% O_2, the two sets of readings are plotted separately.

All of the distributions show a clear peak at zero, indicating that many analyzers drift very little between 72 hour calibrations. For many of the figures, almost the entire range of readings fall within the tolerance for that gas type/concentration level.

Figure 3-15. Distribution of Difference Between Zero and HC Pre-Calibration Reading

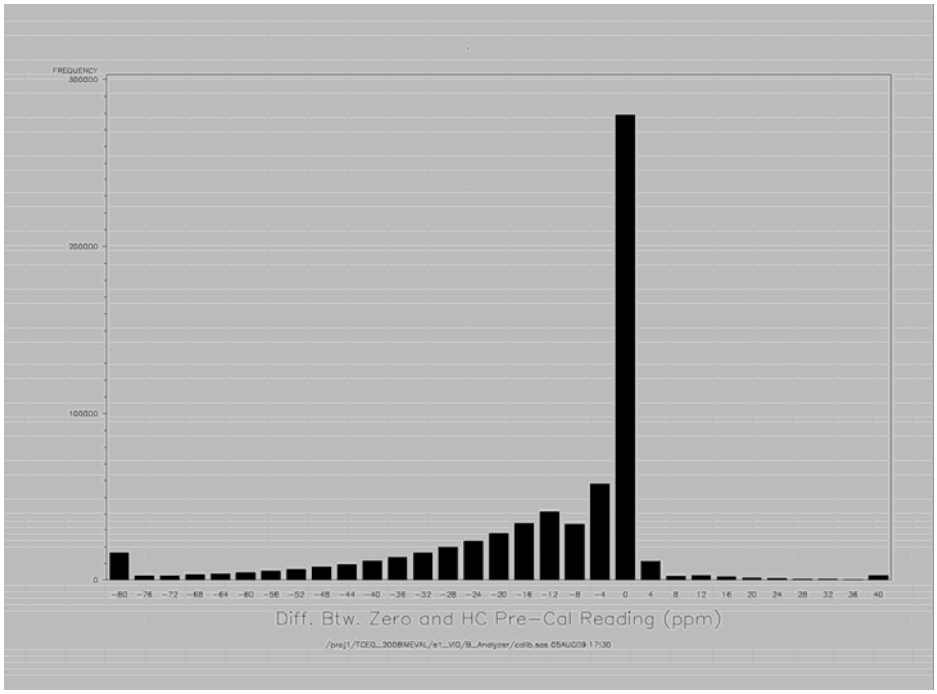


Figure 3-16. Distribution of Difference Between Zero and CO Pre-Calibration Reading

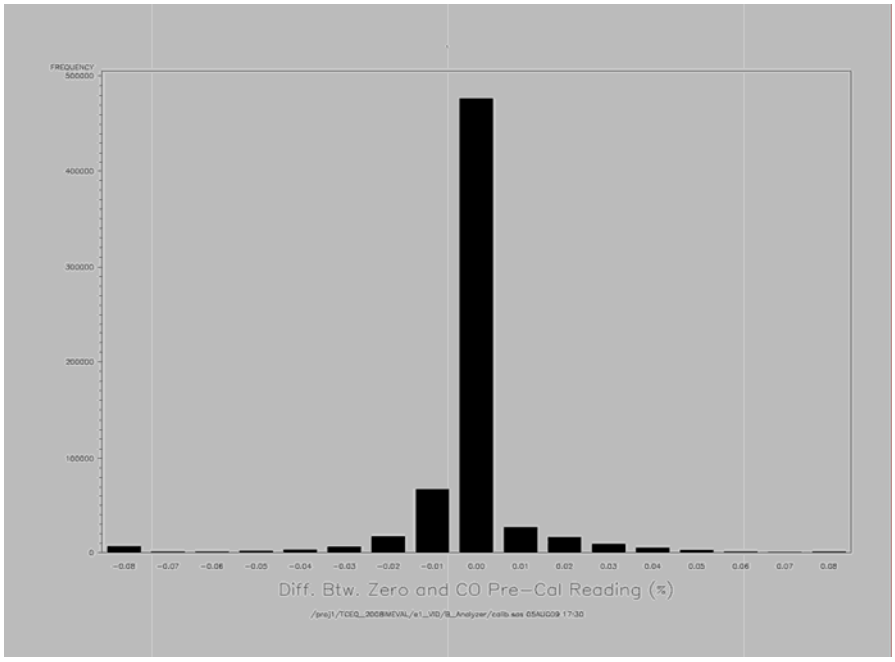


Figure 3-17. Distribution of Difference Between Zero and NO Pre-Calibration Reading

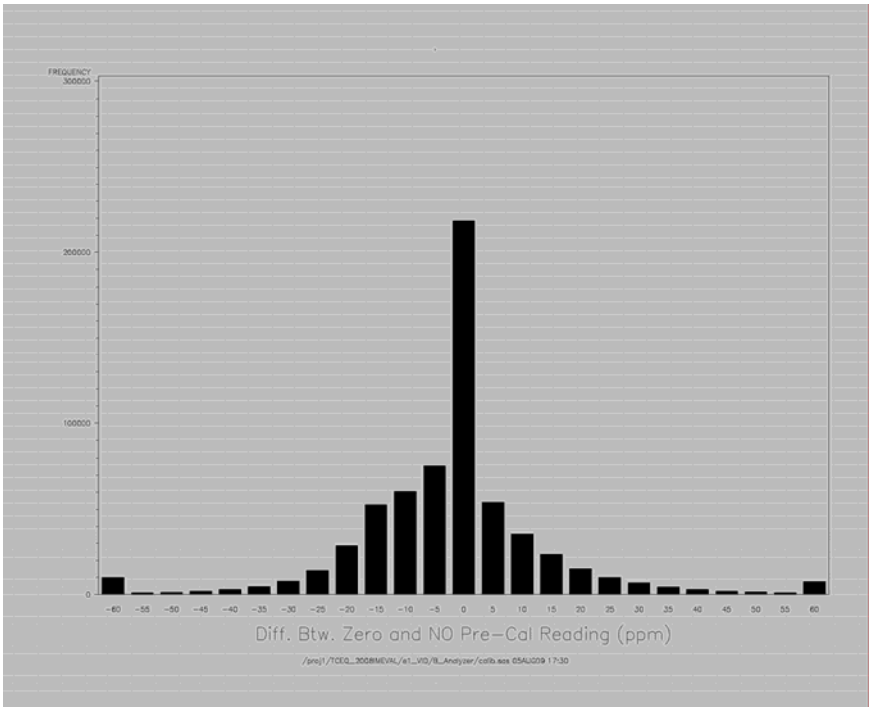


Figure 3-18. Distribution of Difference Between Zero and CO_2 Pre-Calibration Reading

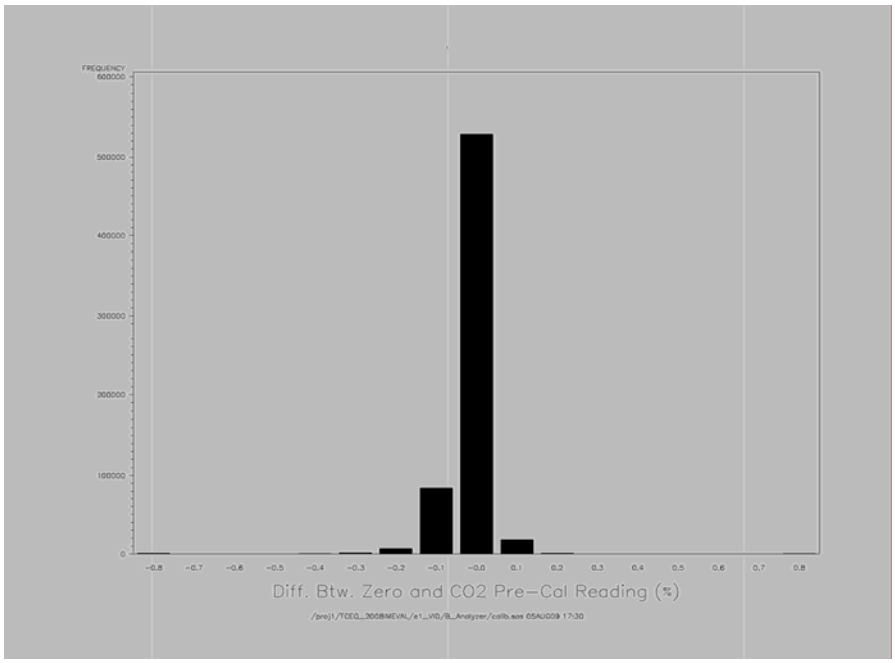


Figure 3-19. Distribution of Difference Between Zero and O_2 Pre-Calibration Reading

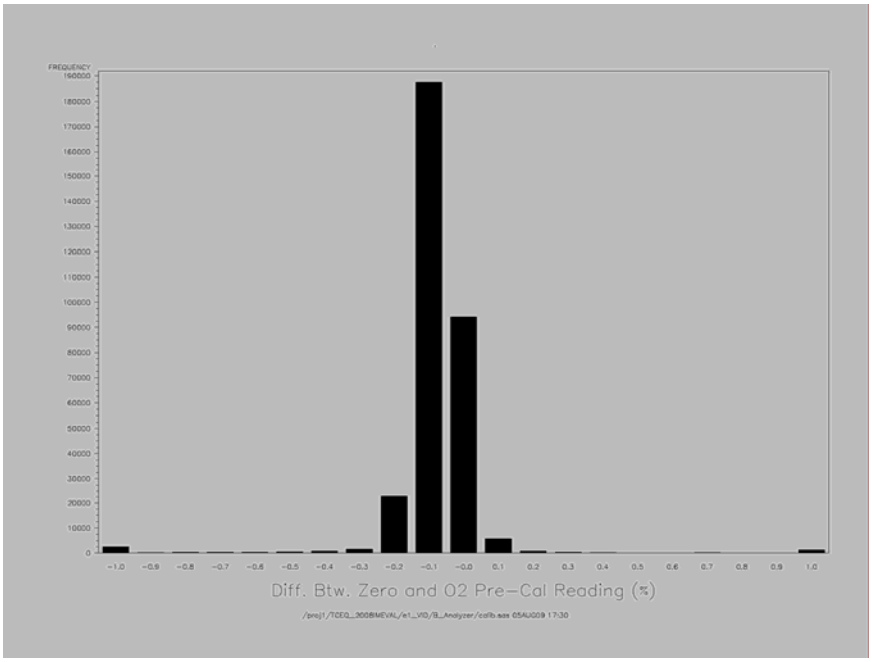


Figure 3-20. Distribution of Difference Between 20.7% and O_2 Pre-Calibration Reading

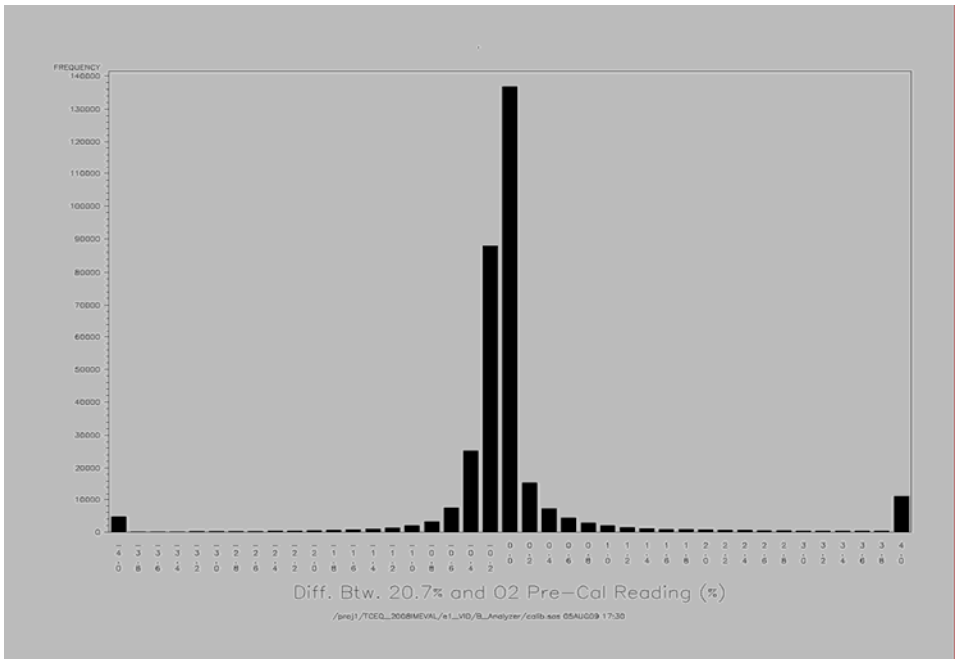


Figure 3-21. Distribution of Difference Between Low-Span Bottle and HC Pre-Calibration Reading

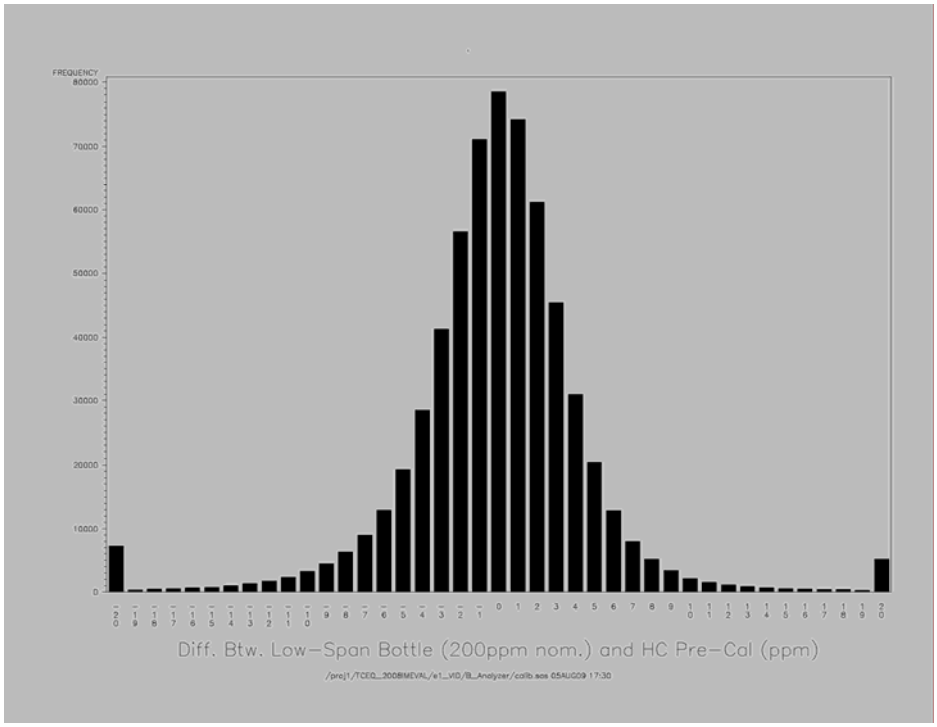


Figure 3-22. Distribution of Difference Between Low-Span Bottle and CO Pre-Calibration Reading

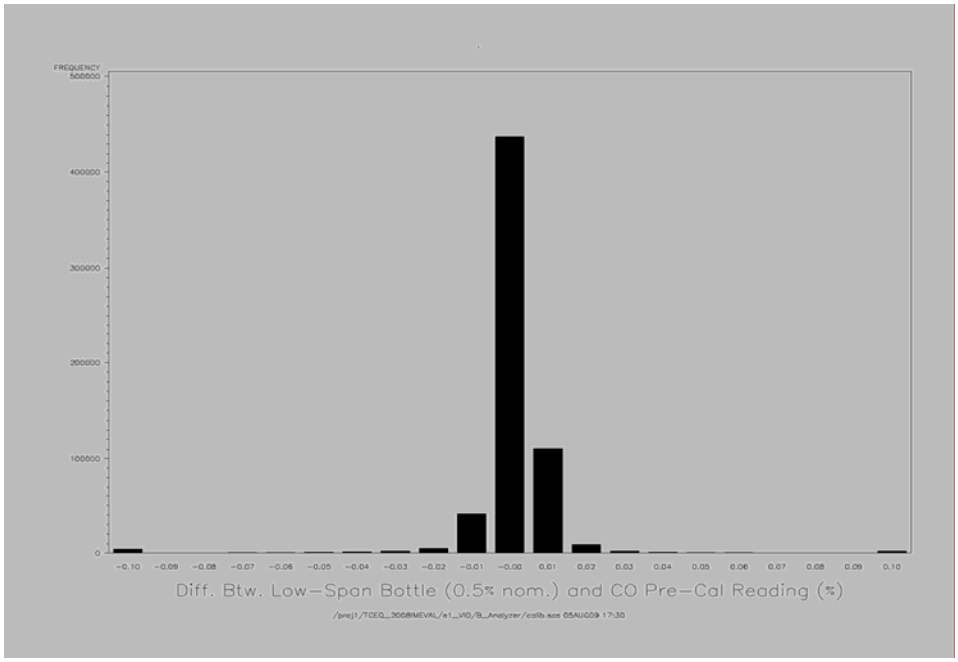


Figure 3-23. Distribution of Difference Between Low-Span Bottle and NO Pre-Calibration Reading

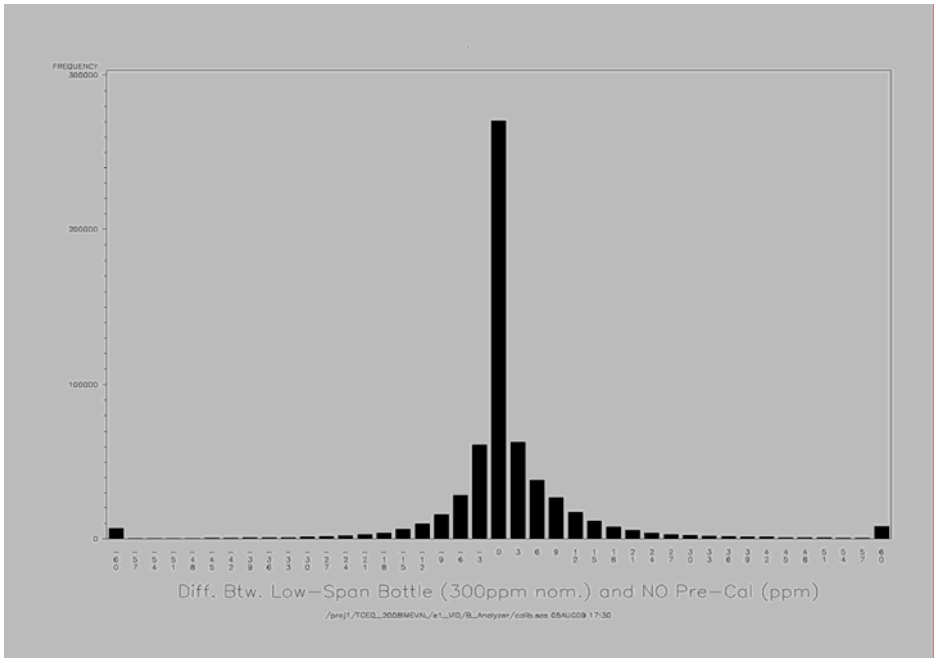


Figure 3-24. Distribution of Difference Between Low-Span Bottle and CO_2 Pre-Calibration Reading

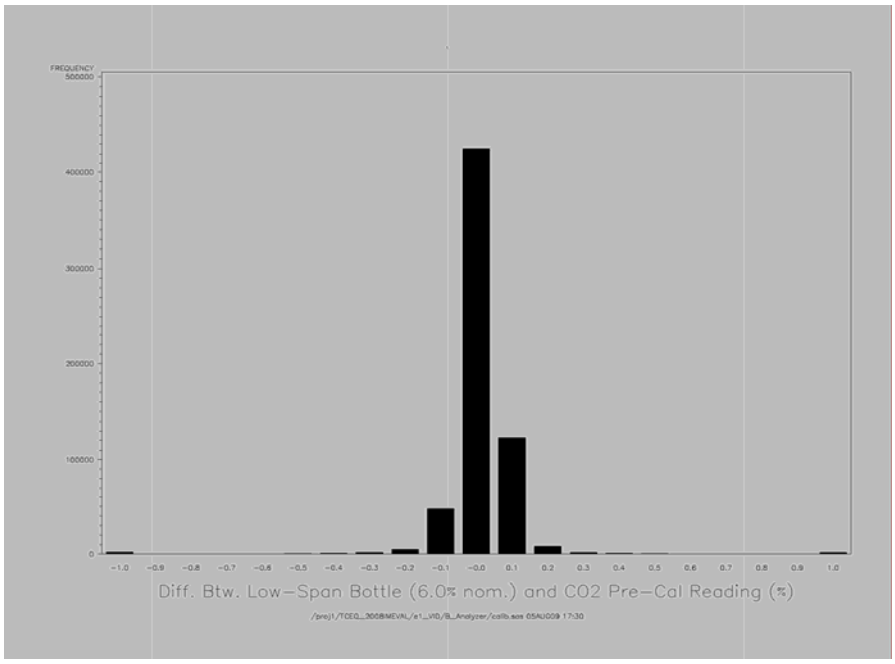


Figure 3-25. Distribution of Difference Between Mid-Span Bottle and HC Pre-Calibration Reading

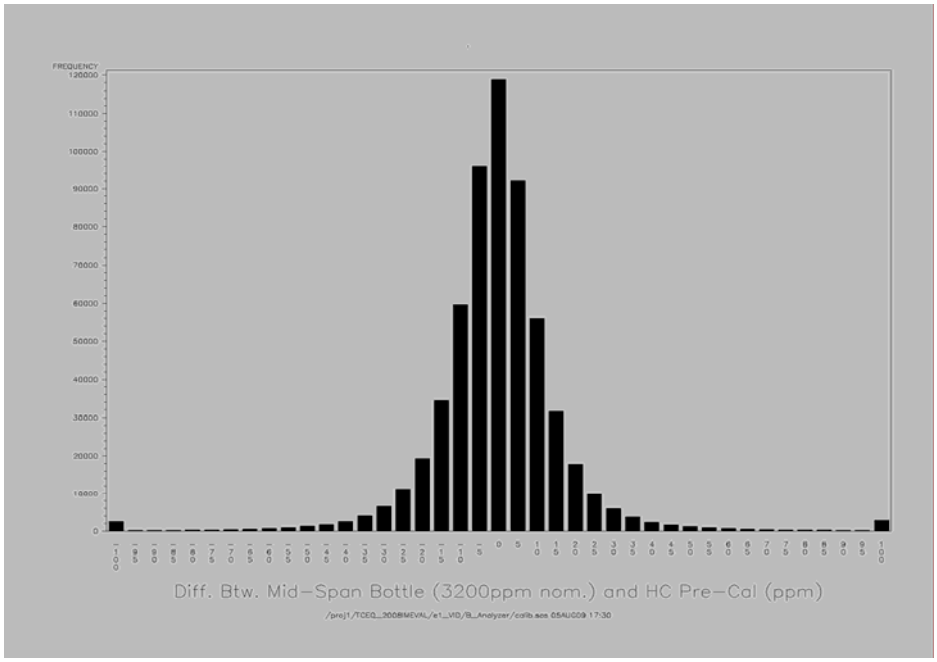


Figure 3-26. Distribution of Difference Between Mid-Span Bottle and CO Pre-Calibration Reading

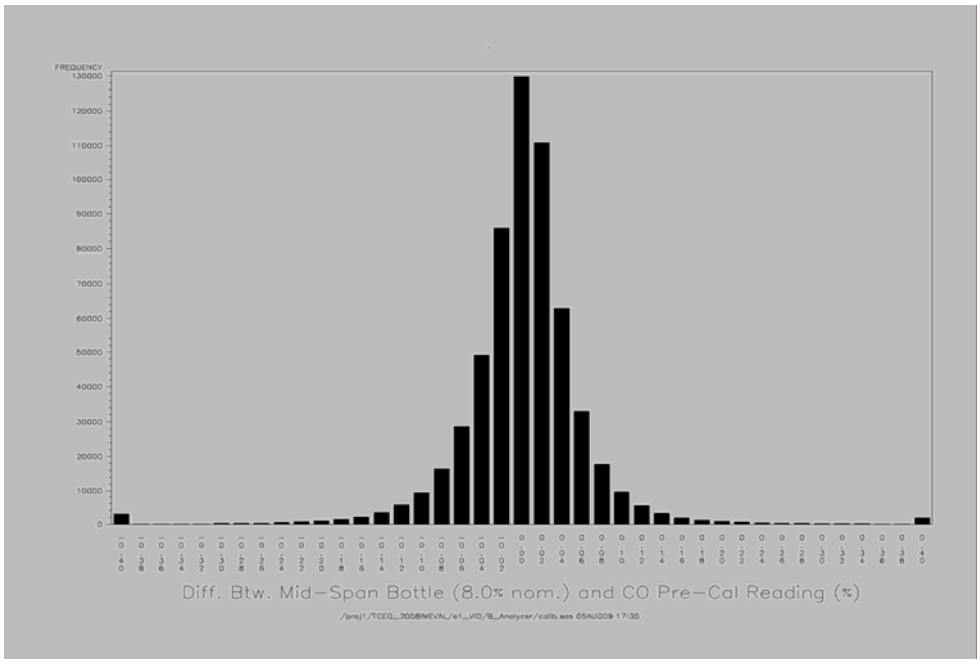


Figure 3-27. Distribution of Difference Between Mid-Span Bottle and NO Pre-Calibration Reading

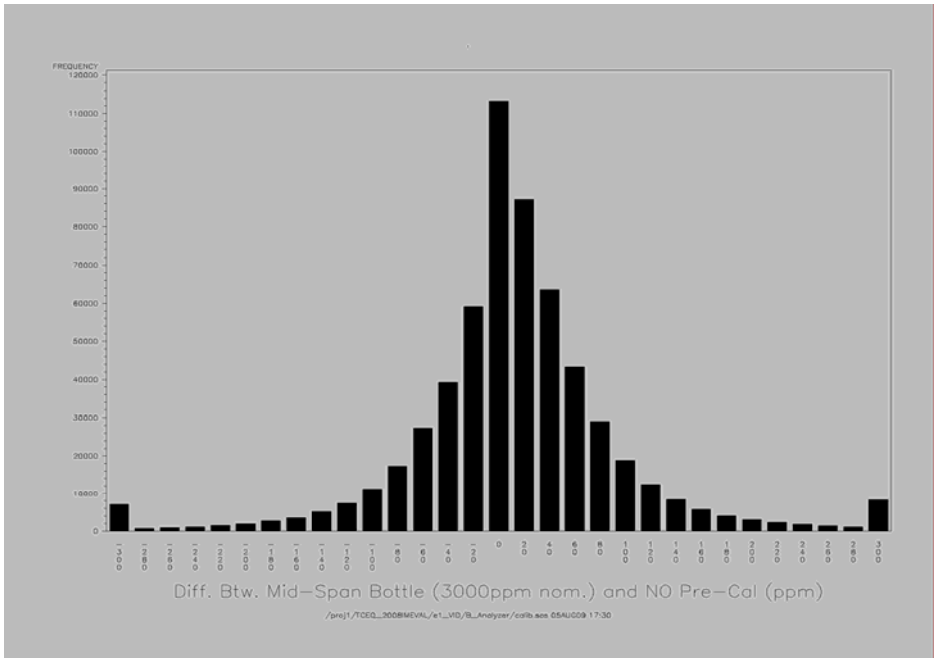


Figure 3-28. Distribution of Difference Between Mid-Span Bottle and CO_2 Pre-Calibration Reading

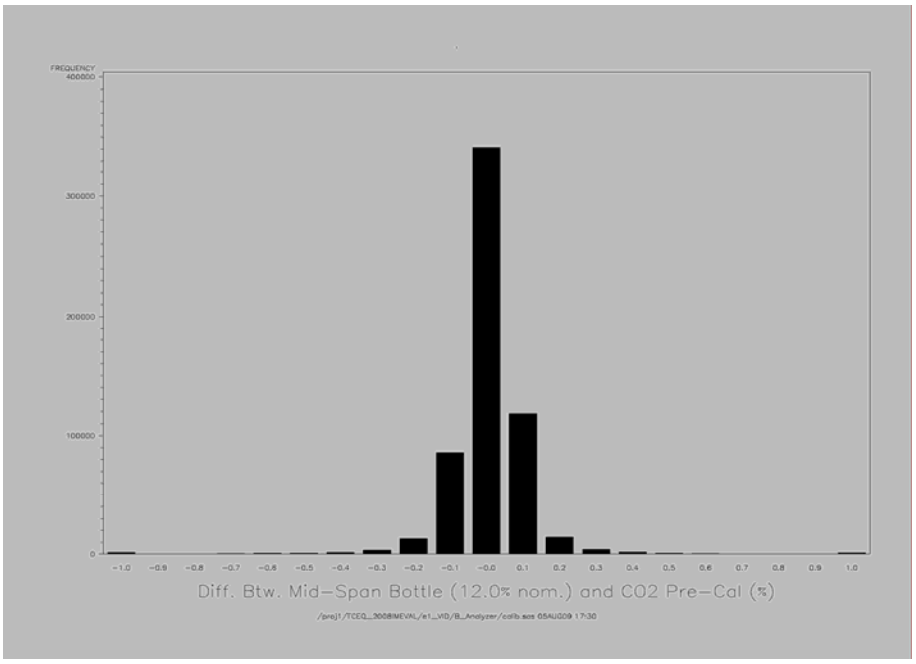


Table 3-13 shows the specified value and tolerance for each gas type/concentration level, the total number of pre-calibration records available at that level, the percent of records whose values fell within the tolerance bounds, and finally, the amount of difference from the specified value that would include 90% of calibration records (the 90th percentile).

Note that the total record counts vary by concentration level in Table 3-13. About 646,000 records were available at the zero level, but only 623,000 records at the low-span level. The reduction results from calibrations where the zero pre-calibration values were recorded, but not the low-span values. For a similar reason, there are only 591,000 records available at the mid-span level. It is important to record the pre-calibration readings so that analyzer drift can be tracked, but it appears that not all portions of the pre-calibration data are recorded at every calibration event.

For almost all gas type/concentration level combinations, more than 85% of records fell within the tolerance of the analyzer. The exception is the zero level HC, where only 50% of records were within tolerance (the wide distribution can be seen in Figure 4-15 as well). This indicates that results for more than 85% of I/M inspections performed just before the calibration can be expected to be within instrument tolerance (except for very low values of HC).

Table 3-13. Number and Percent of Pre-Calibration Records Occurring Outside Analyzer Tolerance

Gas	Specification	Total Number of Pre-Cal Records	Within Tolerance		90th Percentile
			N	%	
Zero Gas					
HC (ppm)	0±4	645,515	325,113	50.4	43
CO (%)	0.00±0.02	645,515	605,925	93.9	0.02
NOx (ppm)	0±25	645,515	580,671	90.0	26
CO_2 (%)	0.0±0.3	645,515	641,246	99.3	0.1
O_2 (%)	0.0±0.1	320,476	287,428	89.7	0.2
O_2 (%)	20.7±1.04	325,039	293,311	90.2	1
Low-Span Gas					
HC (ppm)	200±6	622,816	553,357	88.8	7
CO (%)	0.50±0.02	622,808	589,480	94.6	0.01
NOx (ppm)	300±25	610,374	574,409	94.1	17
CO_2 (%)	6.0±0.3	622,830	613,443	98.5	0.1
Mid-Span Gas					
HC (ppm)	3200±160	591,124	588,077	99.5	24
CO (%)	8.00±0.24	591,181	582,065	98.5	0.09
NOx (ppm)	3000±150	590,469	520,905	88.2	133
CO_2 (%)	12.00±0.36	591,180	580,550	98.2	0.1

3.4.2 Analyzer Dilution Correction Factors

For every ASM emissions test, a dilution correction factor based on the measured CO and CO_2 concentration is calculated. Dilution correction factors (DCFs) can also be calculated based on the measured O_2 concentration. The dilution correction factors from these two separate sources of tailpipe emissions should be within agreement with a relatively small tolerance. With those emissions tests where the DCFs are not in substantial agreement, there is question about the accuracy of the emissions test. The analysis does not indicate which emission is in error but indicates that something is wrong with the CO, CO_2, or O_2 measurements. Unless all three of these pollutants are in agreement with respect to their corresponding dilution correction factors, the HC, CO, and NOx measurements reported by the instrument are in question. [Section 4.2.1.3 of Reference 1]

The measurement of exhaust emissions concentrations can be confounded by the dilution of the exhaust gas by non-optimal probe placement, leaking exhaust systems, cylinder misfires, and excess oxygen from air pumps. The Texas I/M program analyzers quantify the degree of dilution for each ASM or TSI inspection using measured CO and CO_2 concentrations to calculate a DCF. For this analysis, the CO/CO_2 DCFs were recalculated for the ASM and TSI inspections in the TIMS.

The CO/CO_2 DCFs are the official dilution correction factors; however, DCFs can also be calculated using the O_2 concentration measured at each emissions test. A comparison of CO/CO_2 DCFs with O_2 DCFs is just another way to check the emissions instruments. Therefore, ERG also calculated DCFs based on the measured O_2 concentration. The dilution corrections reported in the TIMS, the CO/CO_2 dilution corrections calculated by ERG, and the O_2 dilution corrections calculated by ERG should be in agreement with a relatively small tolerance. This analysis does not necessarily indicate which emission is in error, but does indicate that something is wrong with the CO, CO_2, or O_2 measurements. Unless all three of these pollutants are in agreement with respect to their corresponding dilution correction factors, the resulting HC, CO, and NOx measurements reported by the instrument are in question.

Background

Assuming stoichiometric combustion of gasoline, an exhaust dilution correction factor can be estimated using a carbon mass-balance and the measurements of CO and CO_2. These constituents are measured in the non-dispersive infrared bench of the analyzer. The equations are based on the average composition of gasoline. First, define the variable x:

$$x = \frac{CO_2}{CO_2 + CO}$$

where CO_2 and CO values are in percent. Then the dilution factor, DCFCO/CO_2, is as follows:

$$DCF_{CO\,/\,CO2} = 100\frac{x/(4.64 + 1.88x)}{CO_2}$$

If a fuel other than gasoline were used, the 4.64 constant would be different. However, only gasoline-fueled vehicles will be considered in this analysis.

In addition, many emissions analyzers also measure exhaust gas oxygen concentration with an electrochemical cell. Assuming an ambient air oxygen concentration of 20.9%, the exhaust oxygen measurement can also be used to estimate dilution in the exhaust. A dilution correction factor based on the measured oxygen concentration is:

$$dcf_{O_2} = \frac{20.9}{20.9 - O_2}$$

This relationship assumes that the tailpipe oxygen concentration for stoichiometric combustion and no air in-leakage is 0.0% O_2. Field measurements indicate that new vehicles with no exhaust system leaks and operating at stoichiometric air/fuel ratio have 0.0% tailpipe oxygen concentrations.

If CO, CO_2, and O_2 are measured correctly, the independent DCFs (CO/CO_2 and O_2) for each vehicle inspection should agree well with each other. Previous studies have indicated that the difference between the two DCFs should be no larger than about ±0.14 [Reference 1].

Results

For this analysis, vehicle inspection records from the TIMS for vehicles tested in the Dallas/Fort Worth and the Houston/Galveston/Brazoria areas were used. Results for 3,476,011 inspections of gasoline-fueled vehicles that received either the ASM or the two-speed idle (TSI) test were available. 252,234 records were dropped due to flags that indicated the inspection had been aborted, timed out, or ended due to a dilution condition, leaving 3,223,777 records in the dataset for this analysis.

It was found that the TIMS variable indicating which inspection type was performed (ASM or TSI) was not always accurate. In a small number of cases, it indicated that an ASM inspection was performed, but the emissions concentration data in the record was for a TSI inspection, or vice-versa. Therefore the inspection type was determined by whether a record

contained a non-zero, non-missing value for CO_2 for the ASM2525, ASM5015, low-idle TSI, or high-idle TSI. The presence of CO_2 indicates that combustion was taking place and being recorded. This resulted in a dataset with 2,867,514 records for the ASM2525 test condition, 2,867,820 records for the ASM5015 test condition, 355,494 records for the low-idle TSI inspection, and 355,133 records for the high-idle TSI inspection.

The CO/CO_2-based DCF and the O_2-based DCF were calculated for each inspection record, and then plotted against each other. Figure 3-29 shows a plot of the ASM2525 DCF based on CO/CO_2 versus the ASM2525 DCF based on O_2 for each ASM2525 test. Similar plots for ASM5015, low-idle TSI, and high-idle TSI results are shown in Figures 3-30, 3-31, and 3-32. In each plot, most of the points fall near the 1:1 line as expected, and the degree of scatter around the 1:1 line is relatively low. However, in addition to the points clustered on the 1:1 line, the four plots also show a smaller horizontal ray (DCF $CO/CO_2 \approx 1$ while $DCFO_2$ increases) and a vertical ray (DCF $O_2 \approx 1$ while DCF CO/CO_2 increases). This is especially noticeable in Figures 3-31 and 3-32, for the TSI records. Points at a distance from the 1:1 line may represent analyzer sensors for CO, CO_2, or O_2 that are broken or out of calibration, data entry errors, or other anomalies. Some of the reasons for these out-of-line points will be discussed in further detail in the sub-sections below.

Figure 3-29. Comparison of ASM2525 DCF CO/CO_2 and DCF O_2

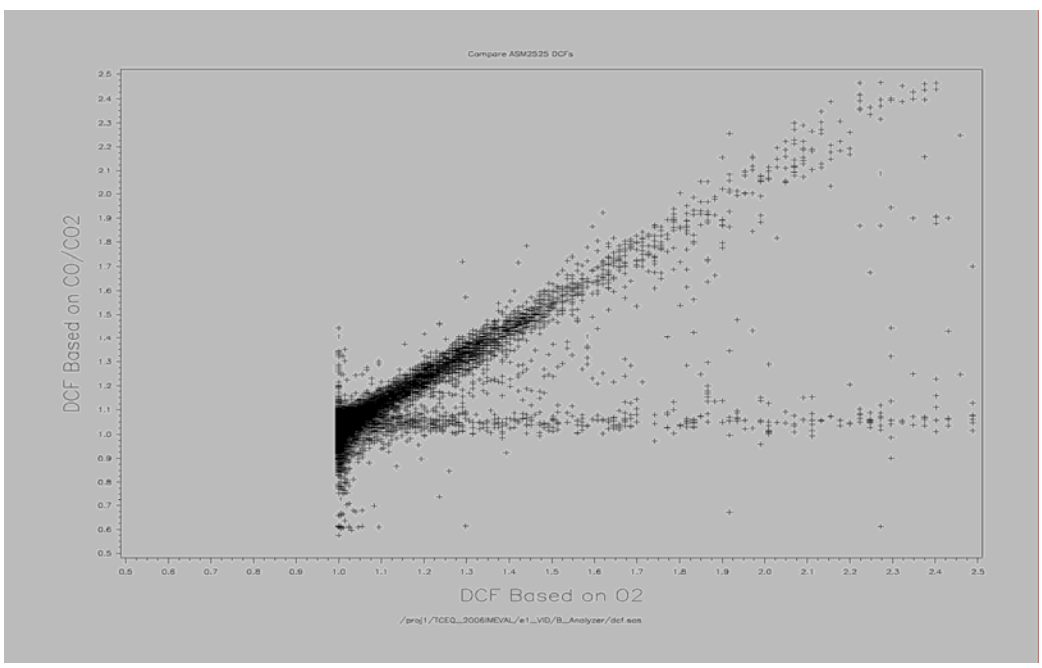


Figure 3-30. Comparison of ASM5015 DCF CO/CO_2 and DCF O_2

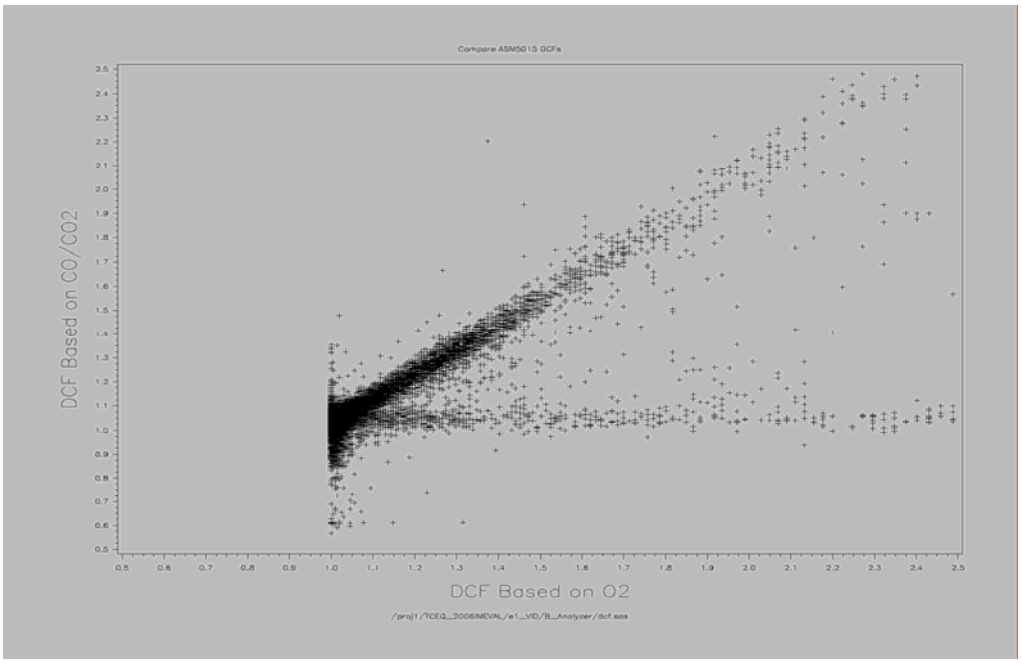


Figure 3-31. Comparison of Low-Speed Idle TSI DCF CO/CO_2 and DCF O_2

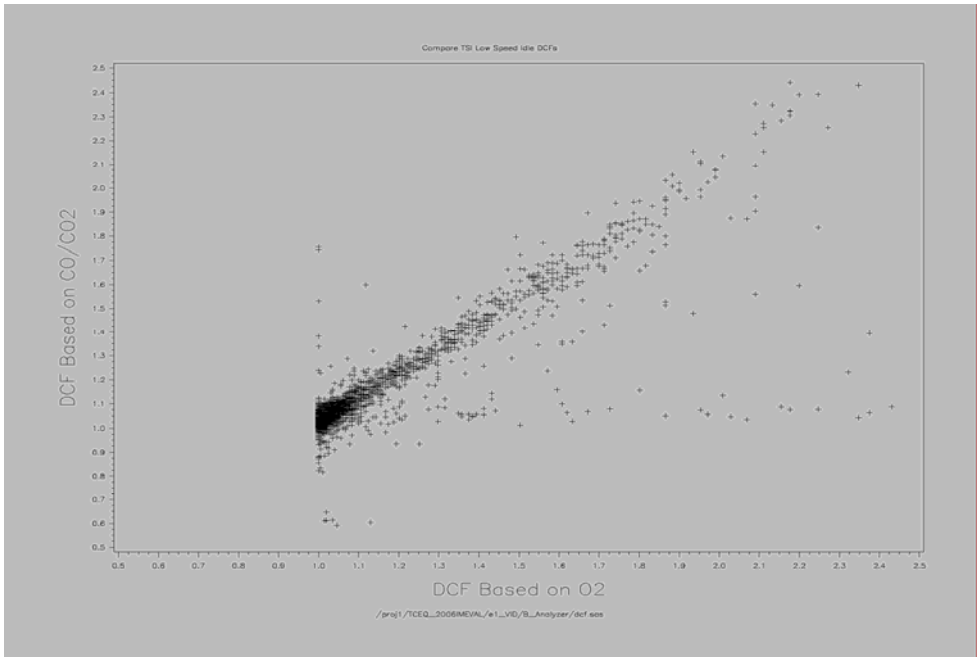
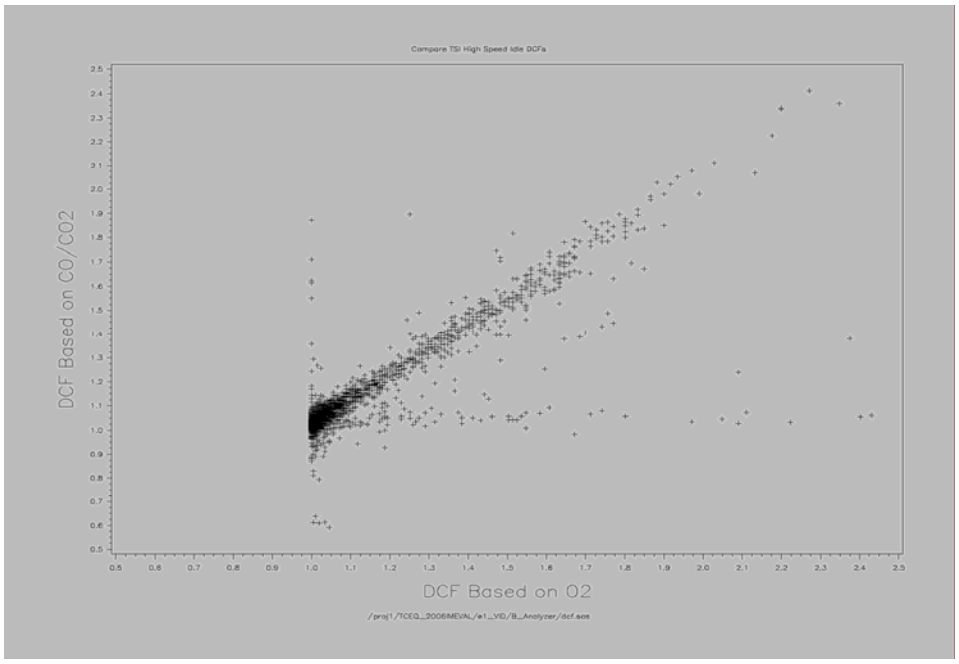


Figure 3-32. Comparison of High-Speed Idle TSI DCF CO/CO_2 and DCF O2



The information presented graphically in Figures 3-29 through 3-32 is quantified in Table 3-14. For each inspection record, the difference between the CO/CO_2-based DCF and the O_2-based DCF was calculated. The table shows the number and percentage of records that fall into six levels of DCF difference, for each type of inspection. As noted above, previous studies have found that this difference should be no more than about ±0.14. It can be seen from Table 3-14 that for the ASM inspection, more than 85% of records have a difference of less than 0.14. For the TSI inspection records, slightly less than 85% have a difference of less than 0.14.

Table 3-14. Distribution of Differences Between DCFCO/CO_2 and DCFO2

Test Type	<0.01	0.01-0.14	0.14-0.3	0.3-1.0	1-10	>10	Total
ASM2525	377,036 13.2%	2,143,460 74.8%	30,908 1.1%	27,171 1.0%	58,349 2.0%	230,590 8.0%	2,867,514 100%
ASM5015	427,583 14.9%	2,086,951 72.8%	30,600 1.1%	28,921 1.0%	60,920 2.1%	232,845 8.1%	2,867,820 100%
TSI Low	41,804 11.8%	255,571 71.9%	7,354 2.1%	4,738 1.3%	10,124 2.9%	35,903 10.1%	355,494 100%
TSI High	40,101 11.3%	259,296 73.0%	5,306 1.5%	4,346 1.2%	9,960 2.8%	36,124 10.2%	355,133 100%

The TIMS contains a DCF based on CO/CO_2 for the ASM2525 and ASM5015 test cycles. The TIMS DCF CO/CO_2 was compared to the DCF CO/CO_2 calculated by ERG.

Results are shown in Table 3-15. It was expected that agreement would be extremely close, since the same two emissions concentrations (CO and CO_2) were used for the TIMS calculation and the ERG calculation. It can be seen from Table 3-15 that agreement was very good; more than 99% of records had a difference of less than 0.14.

Table 3-15. Distribution of Differences Between ERG DCF CO/CO_2 and TIMS DCF CO/CO_2

Test Type	<0.01	0.01-0.14	0.14-0.3	0.3-1.0	1-10	>10	Total
ASM2525	2,605,069 90.8%	241,154 8.4%	7,294 0.3%	4,992 0.2%	4,808 0.2%	4,503 0.2%	2,867,820 100%
ASM5015	2,640,514 92.1%	208,288 7.3%	6,893 0.2%	4,452 0.2%	3,525 0.1%	3,842 0.1%	2,867,514 100%

The TIMS record for each inspection contains an identification number for the analyzer used to perform the inspection. The first two characters of the analyzer identification number indicate the manufacturer of the analyzer. The distribution of differences between the DCF CO/CO_2 and the DCF O_2 (both calculated by ERG, not from the TIMS) were compared by analyzer manufacturer, and some substantial differences were found, as shown in Table 3-16. The ES and WW analyzers both provide about 95% of records with DCF differences of less than 0.14, but the JB and SE analyzers have only 33% and 32% of differences that are less than 0.14. One of the reasons for these large differences was found to be related to problems with the O_2 sensor, which will be discussed in more detail below.

Table 3-16. Distribution of Differences Between DCF CO/CO_2 and DCF O_2 by Analyzer Manufacturer, for ASM5051 Inspections

Analyzer Mfg. ID	<0.01	0.01-0.14	0.14-0.3	0.3-1.0	1-10	>10	Total
ES	315,095 19.8%	1,194,894 75.0%	13,535 0.9%	10,584 0.7%	17,659 1.1%	40,445 2.5%	1,592,212 100.0%
JB	102 0.9%	3,496 32.1%	265 2.4%	451 4.1%	1,234 11.3%	5,357 49.1%	10,905 100.0%
SE	4,869 1.4%	101,394 30.0%	5,709 1.7%	10,481 3.1%	38,397 11.4%	176,846 52.4%	337,696 100.0%
WW	107,517 11.6%	787,167 84.9%	11,091 1.2%	7,405 0.8%	3,630 0.4%	10,197 1.1%	927,007 100.0%

O_2 Emissions Concentration Anomalies

One factor that was found to cause problems with the DCF calculations was inaccuracy in the reported O_2 emissions concentrations. The tailpipe oxygen concentration for stoichiometric combustion and no air in-leakage would be 0.0% O_2, while the ambient air concentration of O_2 is

assumed to be 20.9%. The percent of otherwise-valid inspection records that included O_2 concentrations greater than 20.5% is shown in Table 3-17, for each test condition. From the table, 7% of ASM and 8% of TSI records included suspicious O_2 concentrations, with tailpipe exhaust O_2 concentrations very close to or equal to ambient O_2 concentrations. These will cause the O_2-based DCF to have a very high (or undefined, when O_2 equaled exactly 20.9%) value.

Table 3-17. Number and Percent of Suspicious O_2 Concentrations by Test Mode

Test Type	O_2 >20.5%	O_2 <20.5%	Total
ASM2525	189,719 6.6%	2,677,796 93.4%	2,867,515 100.0%
ASM5015	191,015 6.7%	2,676,806 93.3%	2,867,821 100.0%
TSI Low	28,948 8.1%	326,571 91.9%	355,519 100.0%
TSI High	29,344 8.3%	325,814 91.7%	355,158 100.0%

It was also found that the rate of suspicious O_2 concentrations was much higher for two of the analyzer manufacturers than for the other two, as shown in Table 3-18. The ES and WW analyzers were responsible for 88% of inspection records, but only 22% of suspicious O_2 concentrations.

Table 3-18. Number and Percent of Suspicious O_2 Concentrations (O_2 >20.5%), by Analyzer Manufacturer, for ASM5015

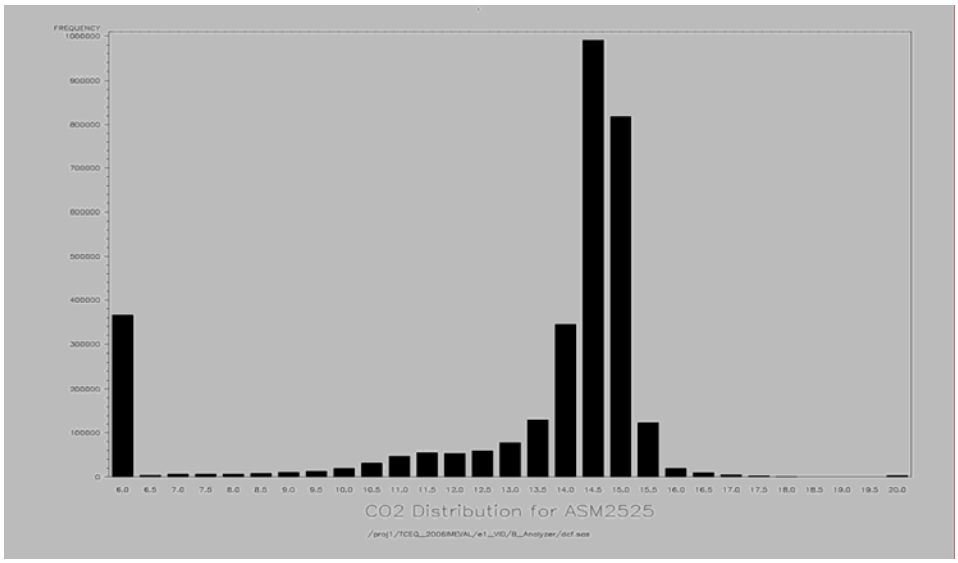
Analyzer Mfg. ID	O_2 >20.5%	O_2 <20.5%	Total
ES	31,828 2.0%	1,560,385 98.0%	1,592,213 100.0%
JB	4,468 41.0%	6,437 59.0%	10,905 100.0%
SE	144,454 42.8%	193,237 57.2%	337,691 100.0%
WW	8,969 1.0%	917,737 99.0%	926,706 100.0%

CO_2 Emissions Concentration Anomalies

Another factor that was found to cause problems with the DCF calculations was inaccuracy in the reported CO_2 emissions concentrations. The tailpipe carbon dioxide concentration for stoichiometric combustion and no air in-leakage should be 15.6% CO_2. CO_2 values lower than 15.6% can occur because of air in-leakage or because some of the carbon is in the form of CO or HC. Any CO_2 values higher than 15.6% would be cause for suspicion.

The distribution of CO_2 values for the ASM2525 inspection is shown in Figure 3-33. It can be seen from the figure that the CO_2 values are concentrated around 15%, as expected. However, a small fraction of CO_2 values do exceed 16%, for 0.5% of ASM2525 inspection records. These records were investigated further.

Figure 3-33. Distribution of CO_2 Values for ASM 2525 Inspection



The rate of high CO_2 concentrations was found to vary slightly among the different analyzer manufacturers, as shown in Table 3-19, although the differences were not as pronounced as those found for the suspicious O_2 concentrations.

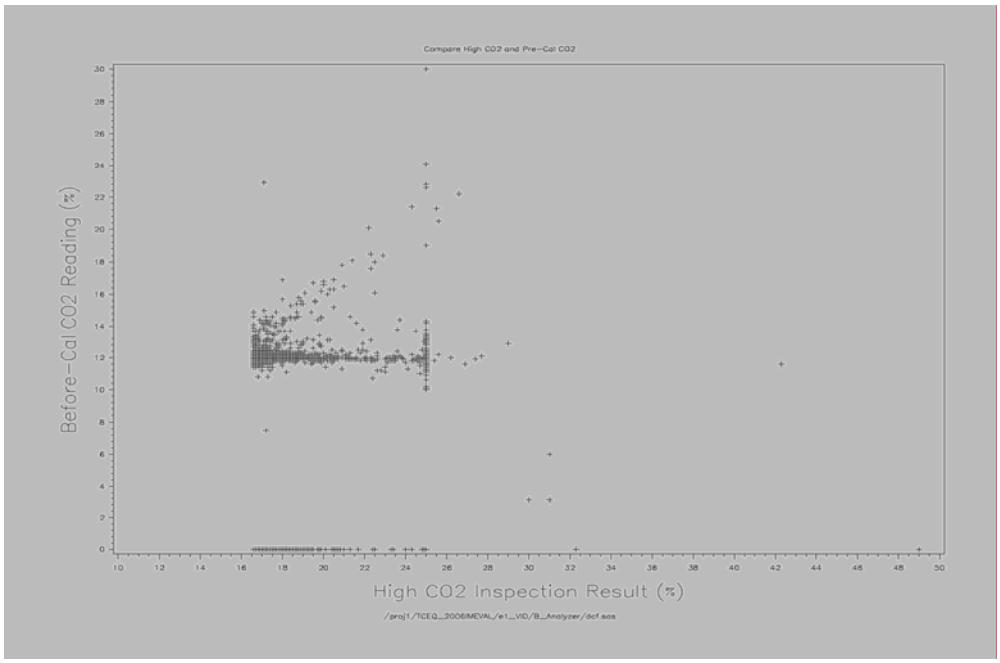
Table 3-19. Number and Percent of Suspicious CO_2 Concentrations (CO_2 >16.5%), by Analyzer Manufacturer, for ASM 2525

Analyzer Mfg. ID	CO_2 >16.5%	CO_2 <16.5%	Total
ES	14,232 0.8%	1,772,880 99.2%	1,787,112 100.0%
JB	6 0.0%	12,822 100.0%	12,828 100.0%
SE	498 0.1%	394,467 99.9%	394,965 100.0%
WW	6,527 0.6%	1,022,345 99.4%	1,028,872 100.0%

The high-CO_2 inspection records were matched to calibration records (described in Section 3.4.1) to find instances where the analyzer responsible for the high-CO_2 inspection record was calibrated within the following 24 hours. The mid-span pre-calibration CO_2 readings were then inspected to determine whether the high-CO_2 records could be attributed to out-of-

calibration analyzers. In Figure 3-34, the pre-calibration CO_2 readings are plotted against the high CO_2 readings found in the inspection record dataset. The plot does not show a correlation between increasingly high-CO_2 inspection results and increasingly high pre-calibration CO_2 levels (which should be close to 12% for the mid-span bottle gas), so analyzer drift does not seem to be responsible for the high CO_2 results.

Figure 3-34. High CO_2 Inspection Results Compared to CO_2 Pre-Calibration Reading



One consequence of recording a CO_2 concentration greater than 15.6% is that the CO/CO_2-based dilution correction factor will be less than 1, indicating a "concentration" condition, rather than a dilution condition. Records with very high CO concentrations will also have a DCF of less than 1. In the TIMS, these DCFs are rounded up to 1; no DCFs of less than 1 are stored. However, just as a high DCF (greater than 1) can act as a flag for a problematic dilution condition, a low DCF (less than 1) can also provide a useful warning that inspection results may be suspect. The equation for the O_2-based DCFs does not allow the O_2 DCF to fall below 1. However, low CO/CO_2-based DCFs can be seen in Figures 3-29 through 3-32. For the ASM2525 inspection, 219 records (less than 0.01% of total inspection records) have DCF CO/CO_2 between 0 and 0.55, and 36,066 records have DCF CO/CO_2 between 0.55 and 0.95 (1.2% of total inspection records).

Extra Vertical and Horizontal Rays

It was noted above that Figures 3-29 to 3-32, with the CO/CO_2-based DCF plotted against the O_2-based DCF, appear to contain three distinct "rays". The majority of points fall near the diagonal 1:1 line, but there is a substantial set of points near a horizontal line at DCF CO/CO_2 =1, and a smaller set of points near a vertical at DCF O_2=1. To investigate the reasons for the rays, the set of inspection records for the ASM2525 test was subdivided into four categories: points falling along each of the diagonal, horizontal rays, vertical rays, and other points that didn't fall neatly into any of the rays. The distributions of emissions concentrations for O_2, CO_2, and CO for records comprising the three rays were then compared, as shown in Figures 3-35 through 3-37.

Figure 3-35 shows that the horizontal ray is comprised of inspection records with high O_2 concentrations. Almost all of the records with O_2 concentrations greater than 4% fall on that ray. (The horizontal ray results from records with high DCF O_2 values and DCF CO/CO_2 values near 1.) A high O_2 concentration results in a high DCF O_2 value, and would seem to indicate a dilution condition (air entering the exhaust stream to add O_2 to the sample), but the DCF CO/CO_2 values remain around 1 in the horizontal ray, indicating that the CO and CO_2 emissions are not being diluted. Figures 3-36 and 3-37 show that the distributions of CO_2 and CO concentration for the horizontal ray are very similar to the distributions for the diagonal ray.

The figures show the opposite result for the vertical ray (comprised of records with high DCF CO/CO_2 and DCF O_2 near 1). Figure 3-35 shows that the O_2 concentration distribution for the vertical ray is similar to that of the diagonal ray. Figure 3-36 shows that the CO_2 concentration for records in the vertical ray was almost always between 6 and 10%, instead of the 15% seen for the diagonal ray. Figure 3-37 shows that the CO concentration for records in the vertical ray was higher than that of records in the diagonal ray.

Overall, what can be seen from Figures 3-35, 3-36, and 3-37 is that the records in each ray were systematically different from the records in each other ray.

Figure 3-35. Distribution of O_2 Concentrations, by "Ray"

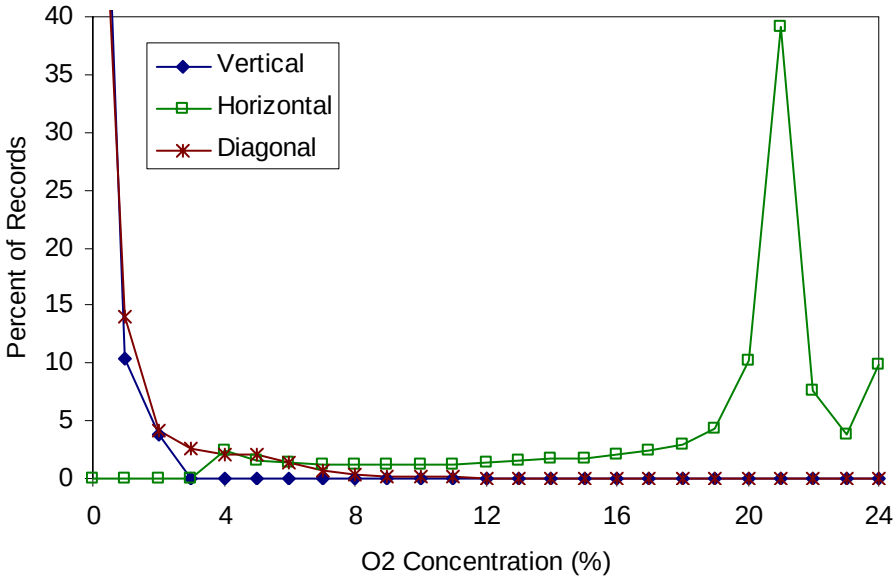


Figure 3-36. Distribution of CO_2 Concentrations, by "Ray"

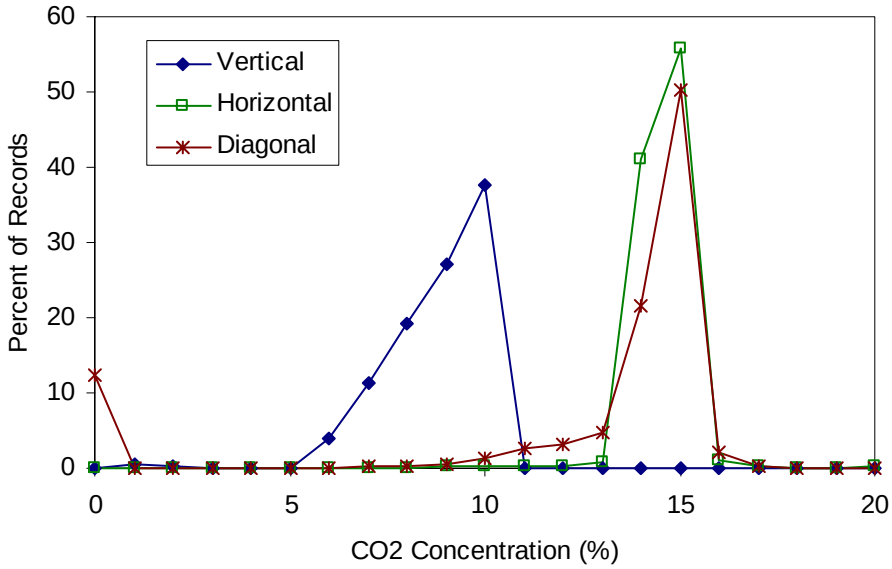
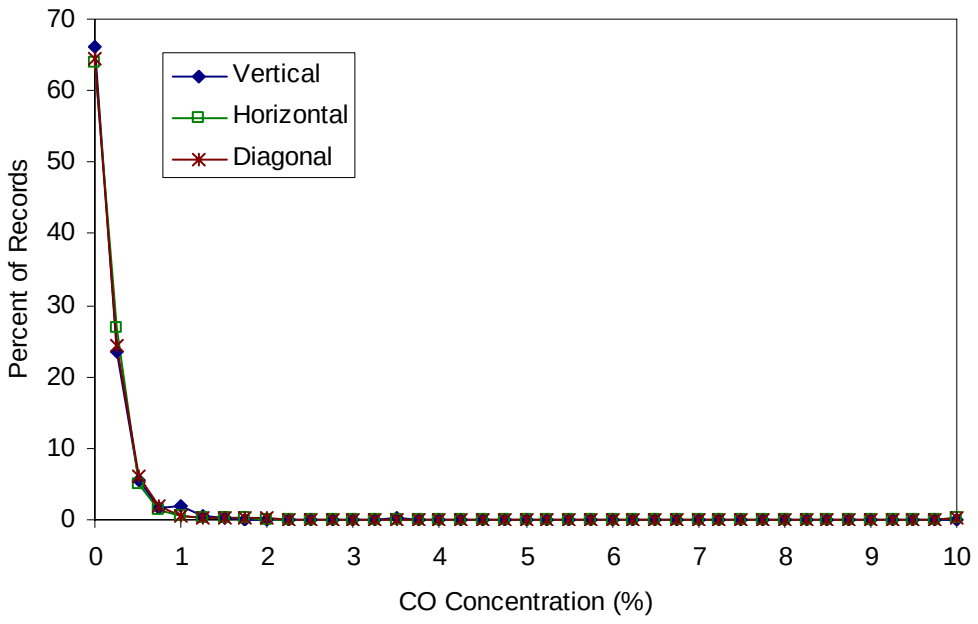


Figure 3-37. Distribution of CO Concentrations, by "Ray"



The distribution of records into each ray-group was tabulated by analyzer manufacturer, as shown in Table 3-20 below. As expected, the manufacturers represented by codes JB and SE contributed a large portion of the records for the horizontal ray. In Figure 3-35 it was seen that this ray includes most of the records with O_2 concentrations near 20.9% (ambient concentration), and in Table 3-18 it was seen that the JB and SE manufacturers contributed the majority of the records with the high O_2 concentrations. Table 3-20 also shows that the JB and SE analyzers were responsible for a greater proportion of the records in the "Other" column than were the ES and WW analyzers. The "Other" group includes all records that didn't fall neatly into one of the rays; these records represent scatter in the data, rather than a systematic problem as represented by the vertical and horizontal rays. It is more difficult to see trends among the analyzer manufacturers for the vertical ray, since there were many fewer records in that ray, but the SE analyzers do represent a somewhat higher rate of records in the vertical ray than the other analyzers.

Table 3-20. Number and Percent of Records in Each Ray by Analyzer Manufacturer, for ASM2525

Analyzer Mfg. ID	Vertical	Horizontal	Diagonal	Other	Total
ES	94 <0.1%	48,397 2.7	1,707,175 95.5	31,446 1.8	1,787,112 100.0
JB	2 <0.1%	4,902 38.2	5,619 43.8	2,305 18.0	12,828 100.0
SE	127 <0.1%	181,928 46.1	164,359 41.6	48,551 12.3	394,965 100.0
WW	86 <0.1%	16,808 1.6	998,916 97.1	13,062 1.3	1,028,872 100.0

3.4.3 Analyzer Gas Audits

One component of a station equipment audit is the gas analyzer audit. This audit uses bottle gases independent of the calibration gas bottles, and the gas is introduced at the tailpipe sampling probe rather than simply at the analyzer inlet (as in a 72 hour analyzer calibration). This type of audit adds an additional level of certainty about instrument measurement accuracy, since it can identify problems with the probe and the line that goes from the probe to the I/M analyzer. If the analyzer fails the gas audit, it must be repaired (if necessary) and successfully re-calibrated before it may be used for additional I/M inspections involving tailpipe measurements.

Bottle gases containing blends of HC, CO, NOx, and CO_2 at zero, low span, and mid span concentration levels are used in a gas audit. The analyzer specification requires that the measured pollutant concentrations fall within 5.5% of the labeled bottle gas value for the low and mid span level gases, in order to pass the gas audit. The nominal bottle gas concentrations for the low and mid span gas audits are listed in Table 3-21 (these are the same as the nominal bottle gas values for low- and mid-span calibrations). Actual labeled bottle gas concentrations may vary up to 5% from the nominal values, so the labeled bottle gas values are recorded in the analyzer and transmitted to the TIMS for each audit.

Table 3-21. Bottle Gas Concentrations for Low and Mid Span Audits

Gas	Low Span Nominal Concentration	Mid Span Nominal Concentration
CO (%)	0.5	8.0
HC (ppm)	200	3200
CO_2 (%)	6.0	12.0
NOx (ppm)	300	3000

The Texas SIP requires that each analyzer be audited at least twice per year. For the two and a half year dataset that is used for this analysis, this should result in an average of 5 audits per analyzer. A frequency distribution of the number of audits per analyzer is shown in Table 3-22. As can be seen from the table, many of the 2,280 analyzers received many more than five audits; in fact, about a third of the analyzers received 10 or more audits. Many of the extra audits result from follow-up audits (re-audits) after an analyzer failed a portion of an initial audit. Additionally, the time differences between consecutive audits indicate that it is standard that analyzers be audited on a two- or three-month cycle, rather than the longer six-month cycle required as a minimum by the SIP.

Table 3-22. Number of Gas Audits per Analyzer Over a 2.5 Year Period

Number of Audits	Number of Analyzers	Percent of Analyzers
1	60	2.6%
2	61	2.7%
3	58	2.5%
4	71	3.1%
5	119	5.2%
6	297	13.0%
7	286	12.5%
8	292	12.8%
9	324	14.2%
10	333	14.6%
11	172	7.5%
12	84	3.7%
13	40	1.8%
14	40	1.8%
15 or more	43	1.9%
Total	**2280**	**100.0%**

The pass/fail results for the gas audit are based on whether or not the analyzer reads a pollutant concentration within 5.5% of the labeled bottle gas value:

$$\text{Difference (\%)} = 100 \times [(\text{Reading} - \text{Bottle Value}) / \text{Bottle Value}]$$

The distribution of percent differences between readings and bottle gas values is shown in Figures 3-38 through 3-45 for CO, HC, CO_2, and NOx, at the low- and mid-span levels. In almost all of the figures, the vast majority of readings fall between -4 and 4% of the labeled bottle gas values. The main exceptions were the low-span HC, with a somewhat wider spread, and the low- and mid-span NOx, which were both biased toward low readings.

Figure 3-38. Percent Difference Between Reading and Bottle Gas, Low-Span CO

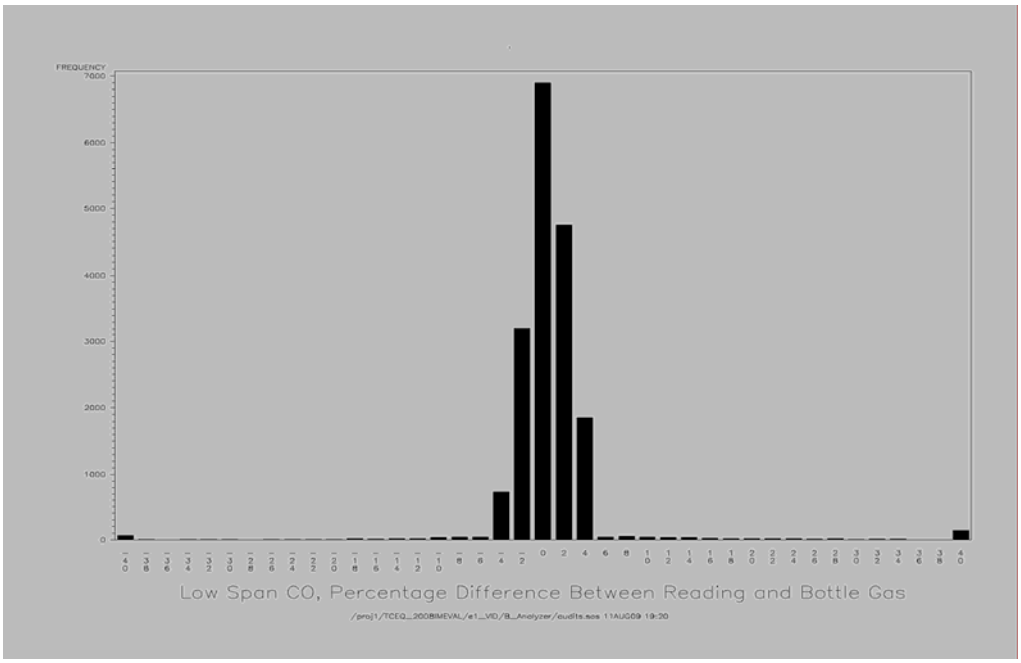


Figure 3-39. Percent Difference Between Reading and Bottle Gas, Low-Span HC

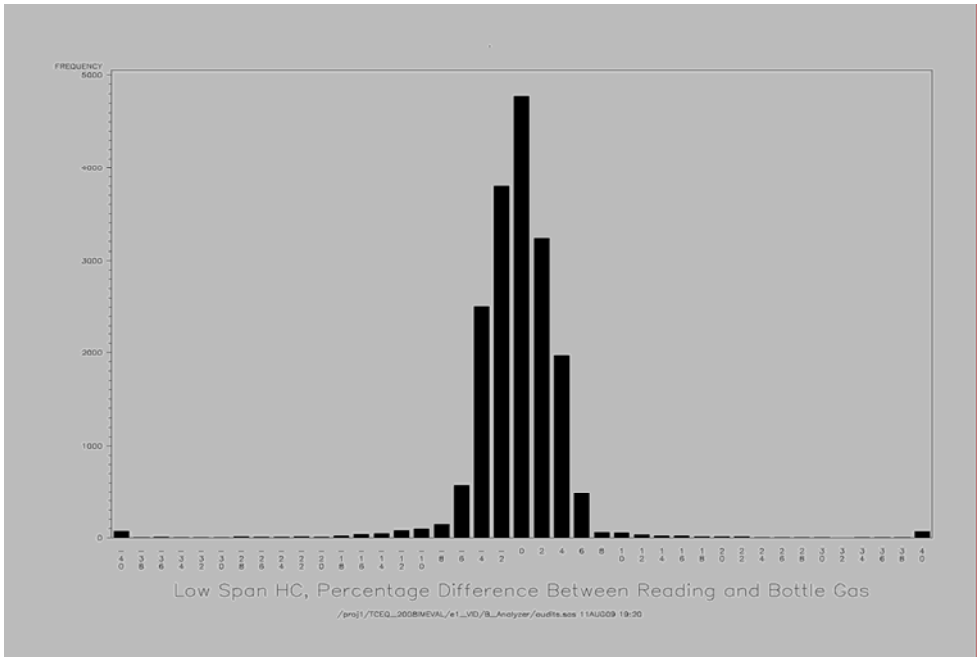


Figure 3-40. Percent Difference Between Reading and Bottle Gas, Low-Span CO_2

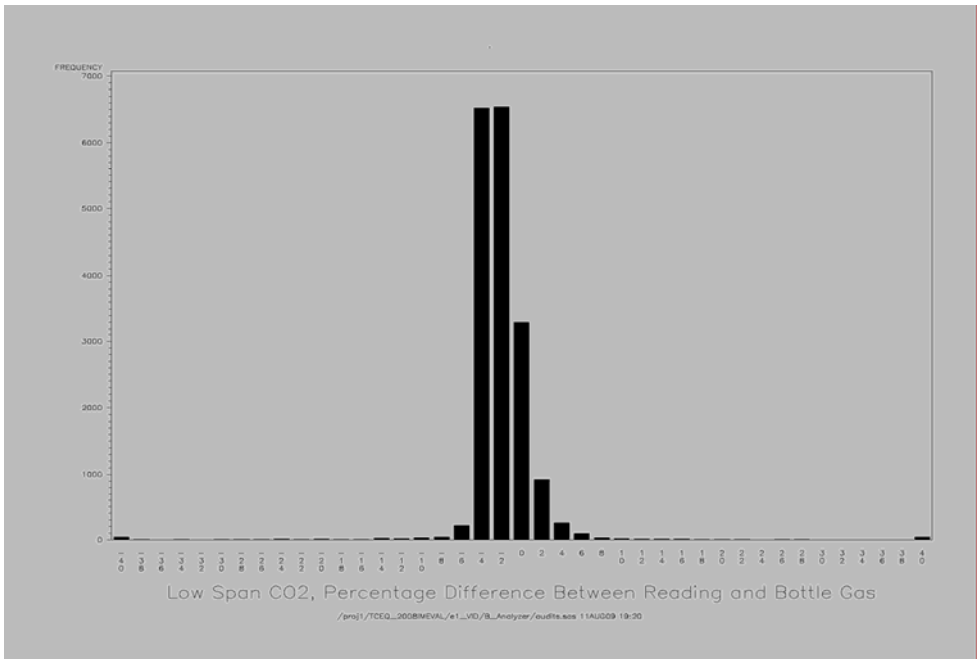


Figure 3-41. Percent Difference Between Reading and Bottle Gas, Low-Span NOx

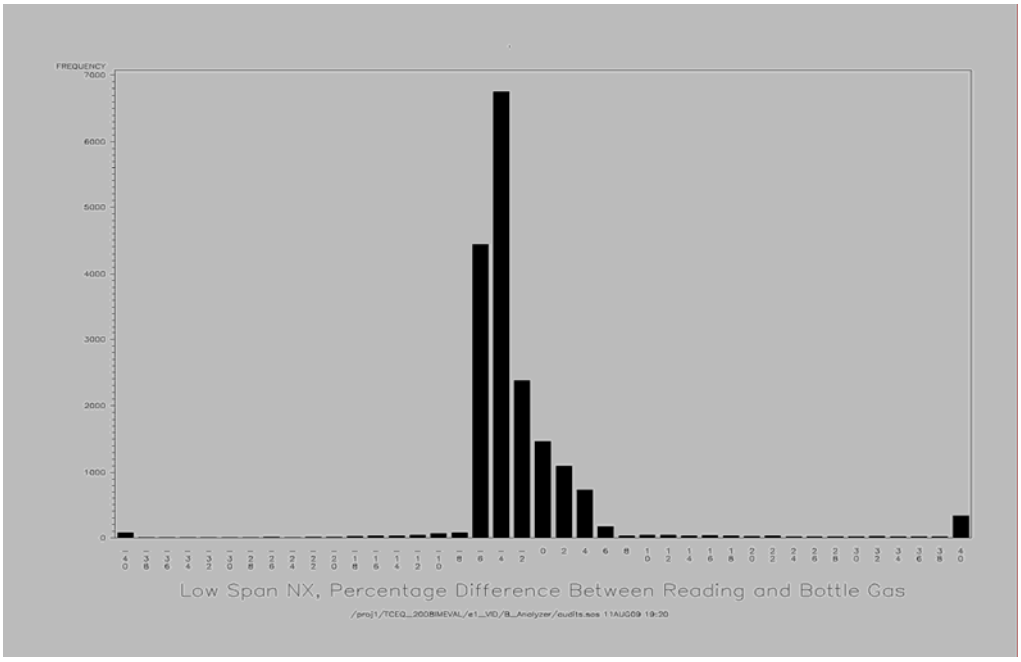


Figure 3-42. Percent Difference Between Reading and Bottle Gas, Mid-Span CO

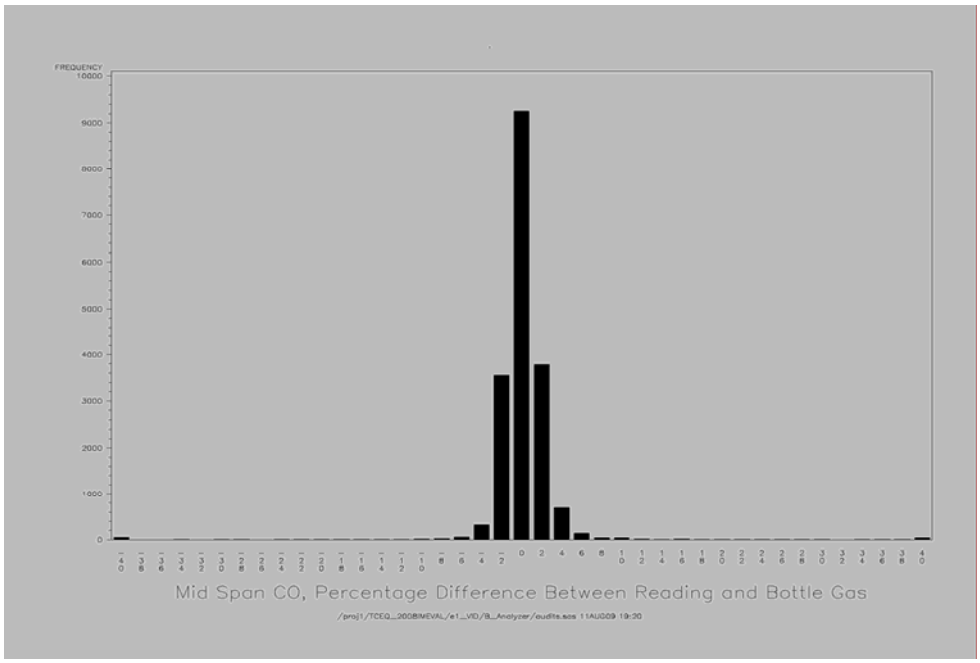


Figure 3-43. Percent Difference Between Reading and Bottle Gas, Mid-Span HC

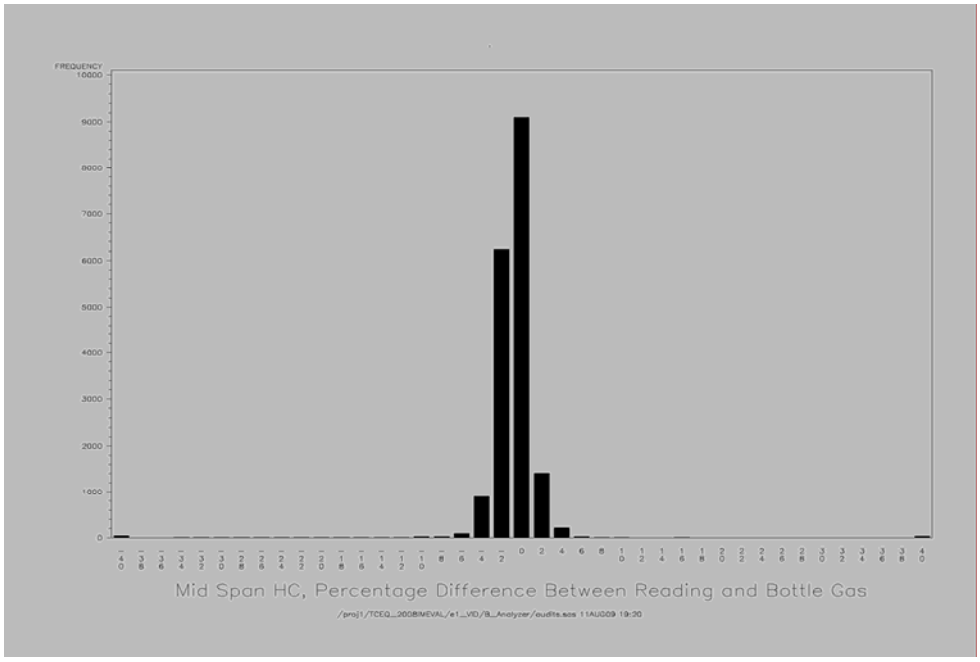


Figure 3-44. Percent Difference Between Reading and Bottle Gas, Mid-Span CO_2

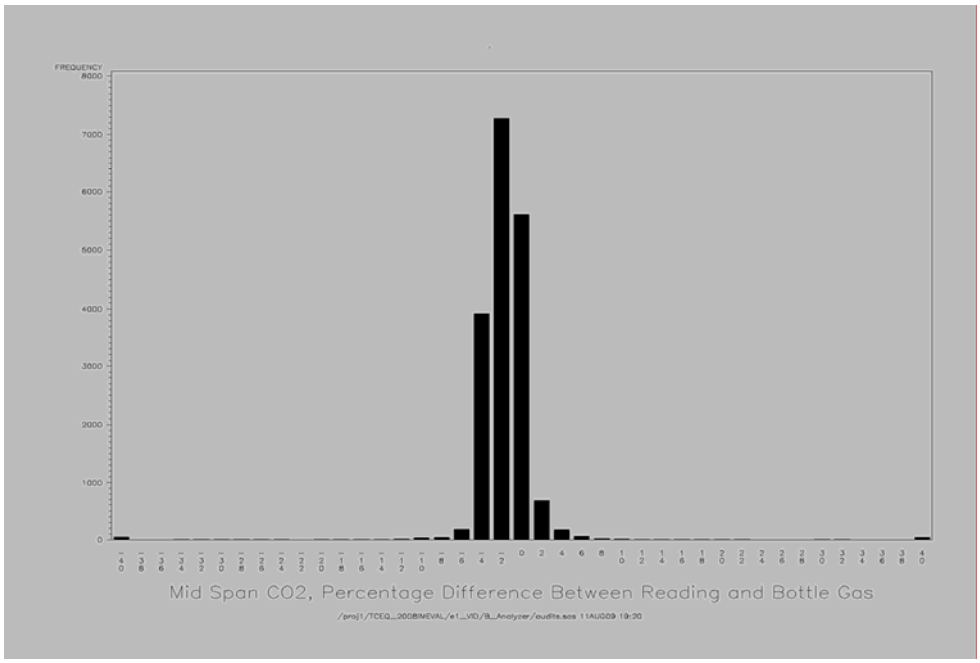


Figure 3-45. Percent Difference Between Reading and Bottle Gas, Mid-Span NOx

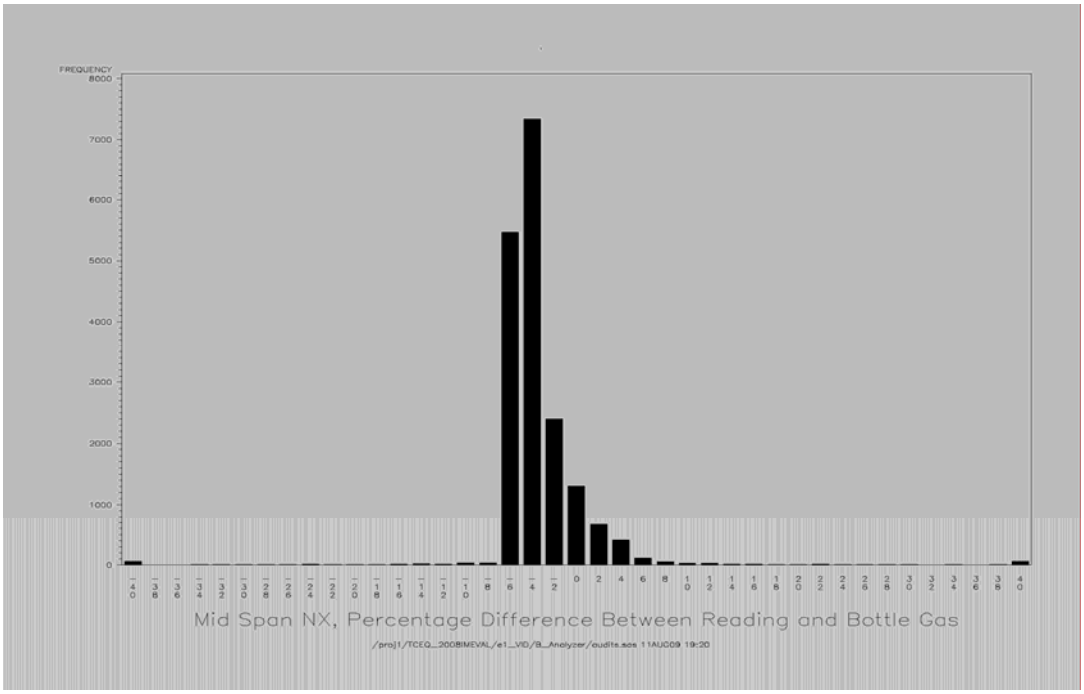


Table 3-23 shows pass/fail results for span gas audits at the low- and mid- span levels. The table includes the pass/fail results that were recorded in the TIMS, as well as newly calculated pass/fail results (based on the labeled bottle gas value entered in the TIMS, the

measured emissions concentration, and a 5.5% tolerance). It can be seen from Table 3-23 that the pass/fail results stored in the TIMS reconcile well with the pass/fail results calculated from the measured span gas values. The largest discrepancy is the 45 audits for which a failing result was calculated, but a passing result was recorded in the TIMS. Almost all of those 45 audits had one or more span gas measurement that was just slightly more than 5.5% different than the labeled bottle gas value, indicating that the discrepancy is probably caused by a slight difference in the rounding of results.

Table 3-23. Span Gas Pass/Fail Results from TIMS Compared to Calculated Results

Calculated Results	TIMS Result			
	Pass	**Fail**	**'N'o Result**	**Total**
Pass	16,019	19	152	16,190
Fail	45	1,957	37	2,039
Comb. Pass & Missing	15	25	0	40
Entirely Missing	3	11	0	14
Total	16,082	2,012	189	18,283

The gas audit procedures specify that if an analyzer fails its gas audit, it must be calibrated (and repaired and re-calibrated as necessary) until it can be brought within the proper tolerance. The calibration data described in the section above was combined with the audit gas data to determine whether the calibrations were actually taking place after the failed audits. In 33% of cases, an analyzer that failed an audit was calibrated or re-audited and passed within the next 60 minutes. In an additional 17% of cases, the failing analyzer was calibrated or re-audited and passed within 24 hours, and another 45% of failing analyzers were calibrated or re-audited and passed within one week. The remaining 6% percent of failed audits took from one week up to three months to achieve a passing audit or successful calibration. It is possible that the audit found more serious problems with these analyzers, and they were taken off-line until an analyzer repair technician was able to undertake repairs on the analyzer.

3.4.4 Analyzer Lockouts

A Texas I/M gas analyzer or dynamometer is required to automatically lock itself out from performing I/M inspections if it is not successfully calibrated or verified on a regular basis. The calibration/verification requirements include:

1) Gas analyzers must be successfully calibrated and verified with BAR-97 calibration-blend gases at least every 72 hours, or they cannot be used for ASM or TSI inspections.

2) Gas analyzers must pass an internal leak check at least every 72 hours, or they cannot be used for ASM or TSI inspections.

3) Dynamometer calibrations must be successfully verified using a coast-down check at least every 72 hours, or they cannot be used for ASM inspections.

4) Analyzers that fail a gas audit (as a component of an overt station audit) must be successfully calibrated and pass a re-audit before being used for ASM or TSI inspections. This requirement is evaluated in the previous section.

Calibration records, dynamometer coast-down check records, leak check records, and vehicle inspection records were used to determine whether analyzer and dynamometer calibrations and checks were taking place as required, and whether un-calibrated/un-checked analyzers or dynamometers were in fact locked out until passing a calibration.

The regularity of the three types of 72-hour calibrations and checks (gas calibration, internal leak check, and dynamometer cost-down check) was investigated first. Each type of calibration/check was analyzed separately, since the different checks and calibrations were often performed at different times and recorded in separate records. It was not found to be meaningful to identify calibration/check lapses by simply calculating the time between passed calibrations and checks. The 72-hour deadline frequently fell on a Sunday, holiday, or other time that the station was not open, so the analyzer or dynamometer would legitimately remain un-calibrated/checked beyond 72 hours, until the station re-opened.

Instead, efforts were made to determine whether analyzers did lock themselves out from performing I/M inspections if more than 72 hours had passed since the previous successful calibration or check. To do this, the dataset of calibration and check records was added to the dataset of I/M inspection records. Only I/M inspection records for the HGB or DFW areas in calendar years 2007 or 2008 were used, and only if the inspection involved a TSI or ASM inspection (safety-only inspections or OBD tests were excluded). Then, for each gas analyzer, any I/M inspections having date/times more than 72 hours after the most recent analyzer gas calibration or dynamometer check were identified. These inspections should not have been allowed by the analyzer software; the analyzer should have been locked out from performing vehicle inspections until it passed a calibration.

The results for each type of calibration or check are shown in Table 3-24. For each calibration or check, the number of I/M inspections taking place while the analyzer should have been locked out is listed. This result is also presented as a percentage of the total number of I/M inspections performed. The total number of I/M inspections is lower for the dynamometer coast-

down checks because TSI inspections do not require a dynamometer and are not included (i.e., TSI tests may be legitimately performed if a dynamometer is locked out). It can be seen from the table that although the percentage of inspections performed by analyzers that were overdue for a calibration or check was small compared to the total inspections performed, a relatively large number of emissions inspections appear to have been performed at times when the analyzers should have been locked out. Notably, more than 3% of ASM inspections were performed at times that the dynamometer should have been locked out.

Table 3-24. I/M Inspections More Than 72 Hours After Successful Calibration or Check

Calibration Type	I/M Inspections 72+ Hours After Passed Calibration or Check	I/M Inspections 72+ Hours After Passed Calibration Or Check (% of total inspections)	Total I/M Inspections
Span Gas Calibration	18,641	0.54%	3,476,572
Leak Check	2,469	0.07%	3,476,572
Dynamometer Check	104,463	3.38%	3,094,082

Table 3-24 lists the number of inspections performed on analyzers that had not passed each of the three calibrations/checks within a 72 hour period. In order to determine why this was occurring, a review of the sequence of calibration/check records and vehicle inspection records for several different analyzers suggested that some analyzers that passed only one type of calibration or check (instead of all three) were still permitted to perform inspections. For example, passing a leak check would reset the 72-hour clock for each of the analyzer's gas calibration, leak check, and dynamometer coast-down check sequences, thereby allowing the analyzer to continue testing even though it had not passed a gas calibration or a dynamometer coast-down check in more than 72 hours.

To further narrow down why inspections were occurring when a lockout should have been in place, two additional analyses were performed:

1. How many inspections were performed on analyzers that had received at least one, but not passed any**,** of the three tests within the past 72 hours? Analysis indicated that 12,694, or 0.37% of total vehicle inspections, were performed on analyzers that had received at least one, but not passed any, of the three tests within the past 72 hours. This suggests that, for these analyzers, merely receiving one of the calibrations or checks would be sufficient to "reset the clock" for all three requirements. Of the 12,694 vehicle inspections that were performed after at least one failing calibration or check was performed, 8,408 of those were performed using a

dynamometer that had failed its most recent calibration. Most of the rest of the 12,694 inspections were performed after a failed span gas calibration.

2. How many inspections were performed on analyzers that had not received any calibrations or checks within the past 72 hours? Analysis indicated 384 inspections, or 0.01% of total vehicle inspections, were performed on analyzers that had not received any calibrations or checks within the past 72 hours. This suggests that, for these analyzers, lockouts aren't enforced for any of these three requirements. This is a very small fraction of the total number of inspections, and could even be attributable to a few missing calibration records. For example, if one calibration record for one analyzer was somehow erased from the TIMS or otherwise not stored in the TIMS, and that analyzer was used for 67 inspections in the 72 hour period before its next calibration, that single missing calibration record would account for a full 20% of the 384 total anomalous inspection records. Note that ERG did not verify whether this was actually the case, since the occurrence of a missing record cannot be confirmed.

Gas Audits and Re-Audits

An analyzer that fails the span gas audit portion of an overt station audit is required to undergo successful analyzer span gas calibration or pass a re-audit before it is again allowed to perform ASM or TSI emissions inspections. The data set of gas audits, calibrations, and re-audits was combined with the ASM and TSI records from the vehicle inspection database (OBD inspection records were excluded, since they do not require use of the gas analyzer) to determine whether analyzers were locked out from the time an initial gas audit was failed until the analyzer was successfully calibrated or passed a re-audit. By comparing the date and time of analyzer audits to the date and time of the vehicle inspections, it was found that analyzers were almost always locked out after failing a gas audit. However, 189 vehicle inspections (less than 0.01% of total vehicle inspections) did take place after an analyzer failed a gas audit, but before that analyzer was successfully recalibrated or passed a re-audit. Manual examination of the results indicates that 55 of these 189 inspections occur in one stretch of consecutive inspections by a single analyzer, with no calibrations listed over a period of months. The remainder of the 189 vehicle inspections occurred singly throughout the dataset, for different analyzers.

3.5 TIMS Emissions Data Checks for Evidence of Station Fraud

ERG examined station triggers in two years of the Texas TIMS to look for evidence of station fraud. The primary goal of this analysis was to look at the existing triggers data from a different perspective that could serve as a comparison to how the triggers data are currently being analyzed. It was not the goal to establish one method as "right" or "superior", but rather to

see if different views of the same data would yield any further insight with regard to detecting station fraud.

A set of station performance parameters known as triggers are calculated in near real-time by TCEQ and used by DPS to help identify stations and inspectors that may be performing fraudulent emissions inspections. Two years of station trigger were examined to look for evidence of station fraud. The trigger data are used by the Texas DPS to help detect cheating at I/M stations. There are 4 triggers for stations: electronic VIN (eVIN), Readiness, Emission Failure and 96tp. The eVIN metric is based on test records where the OBD eVIN does not match the inspector-entered VIN. Mismatches occur due to manual VIN-entry errors or because of possible clean-scanning. The Readiness trigger is based on a comparison of the supported/unsupported readiness monitor signature of a given vehicle with that particular vehicle's "truth table" signature based on its VIN stem. Again, as with eVIN, mismatches suggest possible clean-scanning. The 96tp trigger is based on test records of MY96+ vehicles that received a tailpipe test rather than an OBD test. High values here may be considered indicative of fraudulent testing of OBD vehicles by testing them using a less robust TSI test. The Emission Failure trigger compares the average emission failure rate for a station to the average failure rate for the entire network. High values could be indicative of false-failing vehicles, while low values could signify vehicles are receiving false-passes.

It was found that a metric such as an average +3 standard deviations was more robust in flagging suspect stations than the decile values currently calculated because the triggers data contain data from referee or government run stations that have atypical failure rates or mismatch values, and these values tend to skew the decile values much more than they skew the average +3 standard deviation values. These referee and government stations were removed from the data set when they could be identified, but it is not necessarily clear when a station should be removed from the fraud analysis as some stations that one would think to be under government supervision and thus not a candidate to cheat, are not in fact under government supervision and may indeed be performing fraudulent tests.

For each of the four triggers listed above, an annual average and standard deviation were calculated using all records for each metric and flagged a station if its metric exceed the annual average plus 3 standard deviations in both 2007 and 2008. For the eVIN, Readiness, and 96tp triggers, only high values are indicative of suspicious behavior; however, with the Emissions, both high and low values may be significant. Therefore, for the Emissions trigger vehicles were flagged vehicles if they were 1 standard deviation below the average. This was done because due to the skewed nature of the population, the average minus 3 standard deviations is less than

zero. It should be noted that given the skewed nature of the data in general, the choice of a 3 or 1 standard deviation flag is somewhat arbitrary; however, ERG believes it does provide useful information with regard to stations that are likely performing fraudulent tests at a significantly high rate. More academically robust statistical analyses could be developed if desired, but for the purposes of this study, the standard deviation flags described above are adequate. For the Emission and 96tp triggers, estimates to roughly categorize the test volume for a given station were also made. Tables 3-25 through 3-29 summarize the results of this analysis.

Table 3-25. Stations with High eVIN Trigger Values

Station ID	Station	2 yr avg % Mismatch
1P36597	JESUCHISTRO TIRE SHOP	99.52%
1P37432	CITY PRE OWNED	99.47%
1P34167	EXCEL AUTO CENTER	92.74%
2P36491	JS MOTOR	92.10%
1P37231	SERGIOS ALIGNMENT	90.98%
1P36208	MOCKINGBIRD STATE INSPECTION & REP	86.08%
1P32428	CICO TIRES	85.04%
1P36692	KELS AUTOMOTIVE	83.70%
1P33861	LINDAS STATE INSPECTION #2	83.47%
4P32677	C & E AUTO SERVICE	81.88%
4P33140	EL PASO COLLISION CENTER	81.43%
1P35854	LANCE AUTO REPAIR	77.06%
1P27736	LINDAS STATE INSPECTION	77.05%
1P18012	FERS ALIGNMENT BRAKES & MUFFLERS	75.93%
1P37414	JC`S AUTOMOTIVE CENTER	75.86%
1P33344	MARTINEZ AUTO DETAIL & STATE INSPE	70.69%
4P28171	L A AUTO CLINIC	68.56%
1P32363	GUZMAN MOTORS & TIRES	67.68%
1P36641	GREGS INSPECTIONS	66.65%
1P35091	LINDAS STATE INSPECTIONS #3	66.55%
1P36998	GERS BRAKE SERVICE #3	66.17%
2P34869	PASADENA AUTO COLLISION CENTER INC	64.03%
4P37684	AUTOBAHN COMPLETE CAR CARE CENTER	60.76%
1P35240	A & I AUTO RECYCLERS	60.39%
4P37802	AUTO CORDOVA ELECTRIC	59.87%
1P32181	HINGAS AUTOMOTIVE CO	59.79%
1P37190	MS TIRES AND WHEELS	57.39%
1P32094	TRI-C TIRES & WHEELS	55.93%
2P34516	QUICK STOP INSPECTION	52.68%
1P25321	PETRIE AUTO SALES INC	50.84%
1P28394	OVERSEAS SERVICE HAUS INC	49.51%

Station ID	Station	2 yr avg % Mismatch
1P25610	BRONCO GARAGE	48.88%
1P35822	DRIVERS SELECT	46.72%
2P34452	CORONA CAR CORP	45.83%
1P37182	YOSIAS AUTO SERVICE & REPAIRS	45.78%
1P37422	DUHA GARAGE	44.91%
1P35523	ERNEST TIRE SERVICE INC	44.80%
2P25744	PARSEE AUTO	44.29%
1P37841	CHAMPION AUTO SERVICE	44.27%
1P31791	SOUTH SIDE STATE INSPECTION	42.95%
4P37645	K R INSPECTIONS	41.83%
1P25236	AMERICAS BEST	38.20%
1P36591	METRO CHAMPION AUTO REPAIR	37.56%
1P02156	FRIENDLY CHEVROLET CO INC	36.92%
2P26686	HI TEC AUTOMITVE	36.30%

Table 3-26. Stations with High Readiness Trigger Values

Station ID	Station	2 yr avg % Not Ready
1P35817	INTERNATIONS AUTO SALES	88.86%
1P37284	SAN LUIS STATE INSPECTION	81.12%
1P37977	L E P STATE INSPECTIONS	80.30%
1P26066	J AND L AUTO REPAIR	78.48%
1P37139	JAY 2 INSPECTIONS	76.99%
1P32363	GUZMAN MOTORS & TIRES	75.82%
1P36986	SURFIN & RODS GARAGE	74.72%
1P36419	IMPERIAL INSPECTIONS	74.34%
1P37811	FTW STATE INSPECTIONS	74.20%
1P38012	ESR AUTOMATION	73.80%
1P37415	SCORPION TIRES LLC	73.16%
1P32898	VARGAS INSPECTION	71.98%
1P36208	MOCKINGBIRD STATE INSPECTION & REP	70.49%
1P35785	DLM	69.21%
2P34821	ABC BODY & PAINT	68.73%
1P32287	THREE RICHARDS INC	67.86%
1P37411	R & M AUTO CENTER	67.82%
1P36597	JESUCHISTRO TIRE SHOP	67.57%
1P37988	GERS 4	67.34%
1P37006	JEFFERSON STATE INSPECTION	66.40%
1P31719	COWBOY TIRE SERVICE	65.44%
1P33344	MARTINEZ AUTO DETAIL & STATE INSPE	62.93%
1P37940	JV TIRE SHOP SERVICE	61.58%
1P37893	QUICK CASH STATE INSPECTIONS	61.21%

Station ID	Station	2 yr avg % Not Ready
2P30412	AL HODA CAR CARE	61.10%
2P31289	MUFFLER DEPOT	59.88%
1P36809	MIKES AUTO CARE	57.69%
1P37432	CITY PRE OWNED	57.68%
1P37631	THE WARRIOR SHOP	57.49%
1P37231	SERGIOS ALIGNMENT	57.45%
1P36998	GERS BRAKE SERVICE #3	57.21%
1P36321	A-1 AFFORDABLE MOTORS INC	56.88%
1P32910	ROMEOS TRANSMISSIONS	55.74%
1P37414	JC`S AUTOMOTIVE CENTER	55.25%
1P37104	LCA AUTOMOTIVE & INSPECTION	55.09%
1P28329	BIG D TIRES & INSPECTION	54.45%
1P37724	EQUIA AUTOMOTIVE REPAIR	54.18%
2P36714	STELLA LINK AUTO CARE	53.86%
1P36073	RICO GARAGE	53.62%
1P34167	EXCEL AUTO CENTER	53.56%
1P36937	GERS BRAKE SERVICE #2	52.65%
4P33836	HORIZON AUTO SERVICE	50.44%
4P33140	EL PASO COLLISION CENTER	50.14%
1P37584	HAROLD DISCOUNT TIRE SERVICE	50.13%
1P33861	LINDAS STATE INSPECTION #2	49.60%
2P36491	JS MOTOR	49.51%
1P37289	MGN AUTOMOTIVE	49.16%
2P36381	ABADAN AUTO SERVICE	48.69%
1P36641	GREGS INSPECTIONS	48.57%
1P35854	LANCE AUTO REPAIR	48.48%
1P18012	FERS ALIGNMENT BRAKES & MUFFLERS	46.82%
1P37775	REYES MUFFLER	46.80%
4P32677	C & E AUTO SERVICE	46.75%
1P36306	DISCOUNT TURBO TIRE & INPSPECTIONS	44.73%
1P33865	RODRIGUEZ TIRE SERVICE #2	44.72%
1P33936	3 ACES AUTO SALES	44.66%
4P28631	NATIONS AUTO CENTER	43.29%
4P28171	L A AUTO CLINIC	43.05%
1P33795	COVARRUBIAS CAR SERVICE	43.04%
1P36692	KELS AUTOMOTIVE	42.84%
1P35540	U S DISCOUNT TIRES & CAR SERVICE	42.53%
1P37855	ANY CARS	42.05%
1P35608	BELKNAP AUTO	42.04%
1P37198	MASTER AC STATE INSPECTION	41.77%
1P27629	RODRIGUEZ TIRE SERVICE	41.59%
2P30537	HW 59 PHILLIP 66	41.48%

Station ID	Station	2 yr avg % Not Ready
2P30969	AUTO BELL	41.08%
1P37589	ALVAREZ TIRE SHOP	40.39%
2P36754	AMA AUTOMOTIVE	40.01%
1P32654	CRUZIN STATE INSPECTION	39.75%
1P35016	GERS BRAKE SERVICE	39.37%
1P32390	EMISSIONS & TRANSMISSIONS	38.59%
1P27065	DON PACOS GARAGE	37.49%
2P35794	HI TECH AUTO DIAGNOSTIC INC	37.11%
1P35091	LINDAS STATE INSPECTIONS #3	36.37%
2P34869	PASADENA AUTO COLLISION CENTER INC	35.65%
1P35882	DISCOUNT AUTO SERVICE	35.45%
1P36058	BESTWAY INSPECTIONS	35.19%
1P37182	YOSIAS AUTO SERVICE & REPAIRS	34.63%
1P35692	ROMEROS STATE INSPECTION	33.99%

Table 3-27. Stations with High 96tp Trigger Values

Station ID	Station	> 5 tests/day	~ 5 tests/day	< 1 test/day
1P34970	AMERICAR STATE INSPECTION	77.36%		
1P33144	VALENZUELA INSPECTIONS	55.94%		
2P32413	JOSES AUTO SALE	54.12%		
1P32378	CENTER AUTO SALES LLC	50.52%		
1P32203	IRVING WRECKER SERVICE	46.07%		
2P35801	JOSES AUTO SALE # 2	46.06%		
2P27451	EXPRESS CARE	43.03%		
1P37005	2222 STATE INSPECTION	41.07%		
2P33665	EXPRESS CARE	36.76%		
1P00576	NAGYS DIAMOND	36.56%		
1P32390	EMISSIONS & TRANSMISSIONS	36.07%		
1P36442	C & A INSPECTION AND DETAIL	33.55%		
2P37313	C & H INSPECTIONS	32.89%		
1P36663	MARIAS INSPECTION	32.00%		
2P32598	FULTON TIRES	31.36%		
1P37285	MILLENNIUM DRIVE THRU	31.30%		
2P02227	MC DONALDS GARAGE	29.27%		
1P37811	FTW STATE INSPECTIONS	28.93%		
2P27382	EXPRESS CARE	27.26%		
1P28329	BIG D TIRES & INSPECTION	26.78%		
1P00621	FLORES AUTOMOTIVE	26.73%		
2P36090	HOUSTON`S BEST SERVICE CENTER	26.36%		
1P25185	CEDAR AUTO SALES	25.91%		

Station ID	Station	> 5 tests/day	~ 5 tests/day	< 1 test/day
1P28662	J-L AUTO REPAIR	25.74%		
1P36834	PARRA MOTORS	25.42%		
1P30986	SERRATOS STATE INSPECTION	25.28%		
2P35716	QUIK INSPECTIONS #3	24.67%		
2P33970	JOES STATE INSPECTION	24.66%		
1P33574	DSD	24.57%		
1P37401	RUDYS AUTO INVESTMENTS	22.61%		
1P36324	PARK CITIES INSP	22.33%		
1P37536	TONYS FINA	21.70%		
1P36900	MILLENIUM AUTO REPAIR & STATE INSP		64.70%	
1P36785	CANDELAS INSPECTIONS		62.42%	
1P37961	BENCO AUTO SVC		51.99%	
1P31962	15 MINUTES STATE INSPECTION		48.06%	
2P12089	WAYSIDE INC		40.77%	
2P36745	R AND R AUTO REPAIR		39.77%	
2P37709	JUAN`S AUTO SALES		37.89%	
1P34349	EAST COAST MOTOR SPORTS		37.23%	
1P25147	SOLIS AUTO REPAIR #2		36.67%	
1P37837	E Z AUTO STATE INSPECTION		34.10%	
2P37256	AJG TRANSMISSION		32.45%	
2P36492	JESSES COMPLETE AUTO SERVICE		32.28%	
2P36761	GALINDOS AUTO DIESEL + MARINE REP		30.97%	
2P35133	NETWORK AUTO CREDIT		29.79%	
2P37663	EASTEX INSPECTIONS		27.12%	
1P37621	UNICO AUTOMOTIVE INC		25.59%	
2P11246	SOUTHBELT AUTOMOTIVE CENTER		24.97%	
1P32646	DS AUTO PARTS		24.29%	
1P31752	MILTONS LAKESIDE STATE INSPECTION		21.37%	
1P37809	HORN AUTO		21.23%	
1P26734	CAR CLINIC CENTER		20.08%	
2P37278	COASTAL BAY INSPECTIONS			28.60%

Table 3-28. Stations with High Emission Trigger Values

Station ID	Station Name	> 5 tests/day	~ 5 tests/day	< 1 test/day
2P32154	LANGS MASTER CAR CARE #1 INC	26.05%		
1G25792	TEXAS DEPARTMENT OF PUBLIC SAFETY		67.95%	
1P25236	AMERICAS BEST		25.67%	
1P36133	GARLAND RADIATOR		22.18%	
6P32918	TOKYO AUTOS		21.58%	
1G34843	TEXAS DEPARTMENT OF PUBLIC SAFETY			86.51%
2G34721	TEXAS DEPARTMENT OF PUBLIC SAFETY			84.93%
6G36011	DPS WAIVER BAY			81.86%
2G25739	TEXAS DEPARTMENT OF PUBLIC SAFETY			77.90%
2P37515	KAR KARE AUTO CENTER			21.99%

Table 3-29. Stations with Low Emission Trigger Values

Station ID	Station Name	> 5 tests/day	~ 5 tests/day	< 1 test/day
1P37724	EQUIA AUTOMOTIVE REPAIR	0.21%		
2P31289	MUFFLER DEPOT	0.21%		
1P35817	INTERNATIONS AUTO SALES	0.43%		
2P36381	ABADAN AUTO SERVICE	0.44%		
1P33936	3 ACES AUTO SALES	0.44%		
1P37411	R & M AUTO CENTER	0.47%		
1P32925	TWO BROTHERS STATE INSPECTION	0.51%		
1P32898	VARGAS INSPECTION	0.52%		
1P34970	AMERICAR STATE INSPECTION	0.60%		
1P36809	MIKES AUTO CARE	0.62%		
1P37893	QUICK CASH STATE INSPECTIONS	0.63%		
1P37284	SAN LUIS STATE INSPECTION	0.70%		
2P37514	BERRY INSPECTIONS	0.70%		
1P37006	JEFFERSON STATE INSPECTION	0.71%		
1P27736	LINDAS STATE INSPECTION	0.76%		
1P37631	THE WARRIOR SHOP	0.81%		
1P00621	FLORES AUTOMOTIVE	0.81%		
1P35091	LINDAS STATE INSPECTIONS #3	0.86%		
1P33865	RODRIGUEZ TIRE SERVICE #2	0.92%		
1P37414	JC`S AUTOMOTIVE CENTER	0.96%		
1P27065	DON PACOS GARAGE	0.96%		
4P14328	GS AUTOMOTIVE	0.98%		
2P32041	SAM HOSS AUTO CENTER	0.99%		
1P32363	GUZMAN MOTORS & TIRES	1.03%		

Station ID	Station Name	> 5 tests/day	~ 5 tests/day	< 1 test/day
1P36986	SURFIN & RODS GARAGE	1.03%		
2P30412	AL HODA CAR CARE	1.04%		
2P36738	MEDAS AUTO SERVICE CENTER	1.09%		
1P30947	TIRE AUTO STATION	1.11%		
1P35016	GERS BRAKE SERVICE	1.17%		
1P33795	COVARRUBIAS CAR SERVICE	1.19%		
1P37589	ALVAREZ TIRE SHOP	1.20%		
2P37663	EASTEX INSPECTIONS	1.22%		
6P37467	CLASSIC TOYOTA DBA ROUND ROCK TOYO	1.22%		
1P27003	CARMAX AUTO SUPERSTORES	1.23%		
1P36058	BESTWAY INSPECTIONS	1.23%		
1P36597	JESUCHISTRO TIRE SHOP	1.23%		
1P37886	REYES AUTO REPAIR	1.24%		
2P27129	CARMAX AUTO SUPERSTORES	1.25%		
2P35912	ANTHONYS AUTO SALES	1.26%		
2P34821	ABC BODY & PAINT	1.29%		
1P37415	SCORPION TIRES LLC	1.30%		
2P29938	MIDAS AUTO SERVICE	1.31%		
2P34220	HADJI M SHENI DBA GULF COAST FINAN	1.32%		
1P25121	WESTCLIFF TEXACO	1.39%		
1P36785	CANDELAS INSPECTIONS	1.40%		
1P28504	MCKINNEY OIL X-CHANGE	1.45%		
1P36998	GERS BRAKE SERVICE #3	1.45%		
2P32313	B & B AUTO GLASS & REPAIR	1.45%		
1P32654	CRUZIN STATE INSPECTION	1.46%		
2P28113	NORTHSIDE LEXUS	1.47%		
1P31962	15 MINUTES STATE INSPECTION	1.52%		
2P19567	WOODLANDS TEXACO XPRESS LUBE	1.55%		
1P35319	DEL RIO INSPECTIONS	1.57%		
2P07688	STERLING MC CALL LEXUS	1.63%		
1P33861	LINDAS STATE INSPECTION #2	1.75%		
1P36900	MILLENIUM AUTO REPAIR & STATE INSP	1.76%		
2P29625	COMPLETE CAR CARE	1.81%		
2P33282	CLEAR LAKE VOLKSWAGEN		0.11%	
1P38012	ESR AUTOMATION		0.29%	
1P35854	LANCE AUTO REPAIR		0.49%	
1P37432	CITY PRE OWNED		0.49%	
1P36676	PARS AUTOMOTIVE LLC		0.54%	
2P03622	BENNYS AUTO REPAIR		0.55%	

Station ID	Station Name	> 5 tests/day	~ 5 tests/day	< 1 test/day
2P29466	PEAVYS GARAGE		0.61%	
1P37422	DUHA GARAGE		0.72%	
6P10702	FORREST PONTIAC BUICK GMC TRUCK		0.79%	
1P31005	ARLINGTON ROYAL AUTO SERVICE INC		0.89%	
1P32098	GOODYEAR #4181		0.89%	
1P32198	SHELL RAPID LUBE		0.93%	
1P02964	DAVIDSON CAR CARE		0.95%	
5P22602	ROGER WILLIAMS CHRYSLER DODGE JEEP		1.02%	
1P07571	DON HERRING MITSUBISHI		1.06%	
2P29620	CHAMPION AUTOMOTIVE		1.15%	
1P35099	SATURN OF ARLINGTON		1.16%	
2P02383	GILLMAN ACURA		1.17%	
1P31512	SATURN OF PLANO		1.17%	
2P04030	SHARPSTOWN AUTOMOTIVE		1.18%	
1P37421	DUHA GARAGE		1.21%	
1P33632	VINTAGE CAR WASH DETAIL AND LUBE		1.23%	
1P32066	TRINITY CAR CARE		1.26%	
2P09450	SUPERIOR LINCOLN MERCURY		1.26%	
4G20050	CITY OF EL PASO MUNICIPAL SVC CTR		1.26%	
2P37512	HOOKS ROYAL INVESTMENTS		1.33%	
2P12809	STREATER SMITH HONDA		1.37%	
2G20746	CITY OF HOUSTON POLICE DEPT		1.37%	
2P33704	RICHMOND TIRE & AUTOMOTIVE		1.37%	
1P04198	HUGGINS HONDA		1.38%	
2P30858	AUTO CHECK # 19		1.40%	
2P37499	BC AUTO		1.41%	
2P05003	STAR TOYOTA		1.51%	
1P37855	ANY CARS		1.52%	
1P34167	EXCEL AUTO CENTER		1.53%	
1P34102	KWIK KAR LUBE &TUNE		1.53%	
1P08036	METROPLEX TOYOTA		1.54%	
2F21194	GREATER HOUSTON TRANSPORTATION CO		1.57%	
2P28713	NOAHS SERVICE CENTER		1.63%	
2P10393	GREGS GREASE RACK INC		1.65%	
2P12375	GULLO TOYOTA		1.66%	
2P01238	GENE HAMON FORD INC		1.73%	
6F31011	CASA MECHANICAL SERVICES			0.00%
2P35794	HI TECH AUTO DIAGNOSTIC INC			0.47%

Station ID	Station Name	> 5 tests/day	~ 5 tests/day	< 1 test/day
2G20577	MONTGOMERY COUNTY SHERIFF OFFICE			0.67%
1F21477	VERIZON SOUTHWEST			1.36%
2G20948	FEDERAL BUREAU OF INVESTIGATION			1.37%

As noted earlier, attempts were made to remove Texas DPS station from the analysis based on a list of stations provided, but in Table 3-28 there were still some stations being flagged that should probably not be included in the analysis.

3.6 OBD Inspection Analyzer Communication Performance

ERG analyzed TIMS OBD data to look for proper scanner communication as it is possible that certain models of scanners communicate improperly with certain model year, make, and model vehicles. The objective of this task was to analyze TIMS data to determine if certain models of OBD inspection analyzers appear to have communication problems with certain makes, models, or model year vehicles, which would result in higher or lower fail rates than appropriate for those vehicle categories.

Analysis and Results

For this task, ERG reviewed OBD inspection records to identify all tests with an "N" (no communication/signal) in the "OBD2_DLC_RES" field of the test record. For these records, analysis was performed to identify the following:

- Rate of failure to communicate by analyzer manufacturer
- Rate of failure to communicate by vehicle make
- Rate of failure to communicate by vehicle model
- Rate of failure to communicate by vehicle model year

Results are presented for these four categories below.

73,655 of the 13,614,382 OBD test records had no information stored in the OBD communication result field. All these records had null values for ready result, fault code result, downloaded MIL status, and OBD pass/fail results. 26 OBD test records had vehicle model years earlier than 1996 or later than 2009. 526,788 records were for heavy-duty (HD) vehicles or vehicles of unknown GVWR. All of these records were excluded from the following results, leaving 13,013,913 OBD records in the dataset.

Communication Rates by Vehicle Model Year - Table 3-30 provides a summary of communication rates by model year of vehicles tested in the program.

Table 3-30. OBD Communication Rates by Vehicle Model Year

Model Year	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by model yr
	Count	Percent	Count	Percent	Count	Percent	
1996	851	0.14	458	0.07	618,569	99.79	619,878
1997	758	0.09	519	0.06	809,624	99.84	810,901
1998	635	0.07	464	0.05	940,752	99.88	941,851
1999	908	0.08	588	0.05	1,111,211	99.87	1,112,707
2000	1,063	0.08	711	0.05	1,292,987	99.86	1,294,761
2001	969	0.07	666	0.05	1,365,180	99.88	1,366,815
2002	718	0.05	467	0.03	1,445,728	99.92	1,446,913
2003	723	0.05	464	0.03	1,399,038	99.92	1,400,225
2004	934	0.07	603	0.04	1,400,423	99.89	1,401,960
2005	953	0.07	708	0.05	1,358,327	99.88	1,359,988
2006	506	0.06	422	0.05	877,103	99.89	878,031
2007	137	0.04	155	0.04	351,760	99.92	352,052
2008	5	0.02	12	0.05	26,207	99.94	26,224
2009	1	0.06	1	0.06	1,585	99.87	1,587
Total	9,161	0.07	6,238	0.05	12,998,494	99.88	13,013,893

The "MODEL_YEAR" field from the vehicle test result tables was used to determine model year. From this table, it can be seen that 13,013,893 OBD tests had some type of result in the OBD communication result (OBD2_DLC_RES) field. Values and percentages shown in the table are listed by model year (MY). For example, 810,901 OBD tests were conducted on model year 1997 vehicles, and 519 of these (0.06% of all MY 1997 vehicle OBD tests) had an OBD fail to communicate status. Overall, very low numbers were seen for "failure to communicate" test results, and the overall "failure to communicate" rates were well under 0.1%. Model year 1996 and 1997 vehicles had slightly higher "fail to communicate" rates than did later model years. This is expected, as manufacturers were first implementing OBD in 1996 and 1997 model year vehicles. The slight increase in the "failure to communicate" rate for 2005 and 2006 vehicles may be due to the implementation of the Controller Area Network (CAN) communication protocol into a larger percentage of the overall vehicle fleet. As equipment becomes standardized to CAN, this percentage is likely to drop. The overall program-wide communication rate between vehicles and analyzers is 99.9%.

Communication Rates by Equipment Manufacturer - Table 3-31 provides results of communication rates among the various analyzer manufacturers.

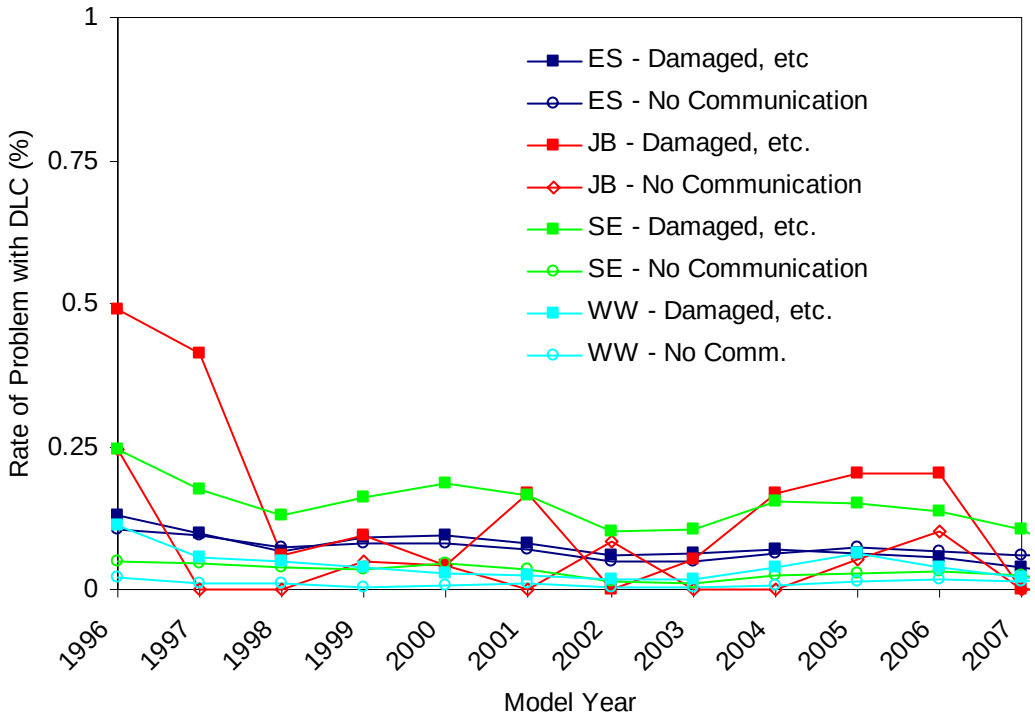
Table 3-31. OBD Communication Rates by Equipment Manufacturer

Equipment Manufacturer (EM)	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by EM	% of tests by EM
	Count	Percent	Count	Percent	Count	Percent		
ES	5,876	0.07	5,497	0.07	7,847,674	99.86	7,859,047	60.39
JB	30	0.14	9	0.04	20,679	99.81	20,718	0.16
SE	1,698	0.15	350	0.03	1,126,960	99.82	1,129,008	8.68
WW	1,557	0.04	382	0.01	4,003,181	99.95	4,005,120	30.78
Total	9,161	0.07	6,238	0.05	12,998,494	99.88	13,013,893	100.00

Again, the percentages shown for the "damaged, inaccessible or cannot be found," the "will not communicate" and the "successfully communicates" columns pertain to all tests conducted by each type of analyzer (not percentage of all tests). The final right two columns provide counts of tests and percentages of tests by each analyzer manufacturer relative to the total number of tests.

The rate at which communication problems were experienced is shown graphically by both analyzer manufacturer and model year, in Figure 3-46. This figure illustrates the trends in rates of problems with communication for analyzers of each manufacturer, over the range of model years that were tested in the data under analysis (inspections between 2007 and 2008). For the most part, the rate of problems with communication was consistently low for each manufacturer.

Figure 3-46 Change in Rate of DLC Communication Problems over Model Year, by Analyzer Manufacturer



Communication Rates by Vehicle Make - To assess communication rates by vehicle make, vehicle registration records were merged with vehicle test records by VIN. The "VEHMK" field from the registration database was reviewed, but found to have numerous inconsistencies and errors. Similarly, the "MAKE" field from the vehicle test result table was evaluated and also found to have a number of inconsistencies. To obtain a consistent "make" list, VINs from the emission test records were decoded using the ERG VIN Decoder, and the "make" output from this decoding process was merged with the vehicle test records and used for this evaluation. A make from the VIN Decoder was unavailable for 146,924 records, so those records were excluded from this analysis. Makes that were represented by 100 or fewer vehicles were also removed from the table, since sample sizes would be too small to provide dependable results.

Table 3-32 provides a summary of communication rates among the various vehicle makes. Except for a small number of very uncommon vehicle makes (Ferrari, Rolls Royce) the incident rates for "damaged, inaccessible, or cannot be found" or "no communication" were very low.

Table 3-32. OBD Communication Rates by Vehicle Make

Vehicle Make	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by make	% of overall tests by make
	Count	Percent	Count	Percent	Count	Percent		
ACURA	72	0.05	41	0.03	152,260	99.93	152,373	1.18
ASTON MARTIN	2	0.40	2	0.40	500	99.21	504	0.00
AUDI	24	0.06	23	0.06	37,029	99.87	37,076	0.29
BENTLEY	2	0.19		0.00	1,054	99.81	1,056	0.01
BMW	125	0.06	88	0.04	208,806	99.90	209,019	1.62
BUICK	92	0.05	66	0.04	180,731	99.91	180,889	1.40
CADILLAC	155	0.08	160	0.09	184,507	99.83	184,822	1.43
CHEVROLET	1,964	0.09	1,204	0.06	2,069,154	99.85	2,072,322	16.06
CHRYSLER	144	0.05	112	0.04	286,937	99.91	287,193	2.23
DAEWOO	8	0.10	9	0.12	7,677	99.78	7,694	0.06
DODGE	528	0.06	361	0.04	829,908	99.89	830,797	6.45
FERRARI	7	0.80	2	0.23	862	98.97	871	0.01
FORD	2,517	0.11	1,521	0.06	2,356,544	99.83	2,360,582	18.32
FORD/MAZDA	14	0.05	19	0.06	30,313	99.89	30,346	0.24
GMC	381	0.10	219	0.06	364,835	99.84	365,435	2.84
HONDA	310	0.03	141	0.01	965,444	99.95	965,895	7.50
HYUNDAI	109	0.07	73	0.05	151,769	99.88	151,951	1.18
INFINITI	25	0.02	27	0.02	123,270	99.96	123,322	0.96
ISUZU	64	0.09	52	0.08	68,075	99.83	68,191	0.53
JAGUAR	19	0.04	14	0.03	45,753	99.93	45,786	0.36
JEEP	83	0.03	85	0.03	308,170	99.95	308,338	2.39
KIA	40	0.03	38	0.03	144,414	99.95	144,492	1.12
LAND ROVER	20	0.07	12	0.04	28,697	99.89	28,729	0.22
LEXUS	55	0.02	59	0.02	306,349	99.96	306,463	2.38
LINCOLN	209	0.14	128	0.08	150,791	99.78	151,128	1.17
LOTUS		0.00		0.00	472	100.00	472	0.00
MASERATI		0.00		0.00	684	100.00	684	0.01
MAZDA	244	0.11	227	0.10	230,871	99.80	231,342	1.80
MERCEDES	72	0.04	47	0.03	184,710	99.94	184,829	1.43
MERCURY	136	0.07	85	0.04	203,366	99.89	203,587	1.58
MITSUBISHI	187	0.09	174	0.08	208,639	99.83	209,000	1.62
NISSAN	289	0.04	285	0.04	719,279	99.92	719,853	5.59
OLDSMOBILE	54	0.06	27	0.03	92,719	99.91	92,800	0.72
PLYMOUTH	30	0.05	34	0.06	56,856	99.89	56,920	0.44
PONTIAC	223	0.08	132	0.05	280,138	99.87	280,493	2.18
PORSCHE	4	0.02	3	0.01	21,787	99.97	21,794	0.17
ROLLS ROYCE	1	0.27	8	2.19	356	97.53	365	0.00
SAAB	14	0.09		0.00	16,184	99.91	16,198	0.13
SATURN	274	0.16	277	0.16	168,157	99.67	168,708	1.31
SCION	4	0.02	2	0.01	19,023	99.97	19,029	0.15
SUBARU	8	0.03	3	0.01	30,929	99.96	30,940	0.24
SUZUKI	7	0.02	7	0.02	34,891	99.96	34,905	0.27

Vehicle Make	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by make	% of overall tests by make
	Count	Percent	Count	Percent	Count	Percent		
TOYOTA	334	0.02	277	0.02	1,354,475	99.95	1,355,086	10.52
VOLVO	28	0.04	24	0.03	76,579	99.93	76,631	0.59
VW	190	0.12	113	0.07	162,626	99.81	162,929	1.26
TOTAL	**9,068**	**0.07**	**6,181**	**0.05**	**12,866,594**	**99.88**	**12,881,843**	**100.00**

Communication Rates by Vehicle Model - To assess communication rates by vehicle models, the following model designation fields were reviewed:

- The "MODEL" field from the vehicle test result tables was seen to have a number of inconsistencies and errors. This is probably because it is a manual keyboard entry.
- veh_modl (derived from the merged registration records) was also seen to have a number of inconsistencies and errors.
- The "MODEL_CD" field from the emission test records was based on table lookup values and therefore appeared to be a more consistent descriptor for the vehicle's model designation. The Texas analyzer specification reports this "model code" is "The NCIC model code or acceptable TCEQ code, otherwise left blank." In order to correlate this "model code" to an actual vehicle model, all vehicle emission test record VINS were decoded using ERG's VIN Decoder, and the vehicle "series" (i.e., model) resulting from this decoding process was merged into the test record. An output table correlating "series" with "model code" was then developed using the most frequently occurring series associated with each model code.

Table 3-33 lists communication rates for each vehicle model code. The series that is shown in the table was derived from the decoded VIN as described above. Records for which model code was missing were excluded from the table. Records for the more uncommon series, i.e. less than 100 inspection records, were also excluded.

It can be seen from the table that only two model codes/vehicle series had "damaged, inaccessible, or cannot be found" or "no communication" rates that were greater than 1 percent, and both of these were for large pickup trucks that comprise a very small portion of the fleet.

Table 3-33. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

Model Code	Series (Model)	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by model	% of overall tests by model
		Count	Percent	Count	Percent	Count	Percent		
16	Express 2500 2WD	1	0.34	1	0.34	288	99.31	290	0.004
17	Express 3500 2WD	0	0.00	0	0.00	257	100.00	257	0.004
88	Delta 88	1	0.04	0	0.00	2413	99.96	2414	0.037
94	Ram Pickup 1500 2WD	40	0.04	11	0.01	102644	99.95	102695	1.573
98	98 Regency Elite	0	0.00	0	0.00	287	100.00	287	0.004
116	Ram Van/Wagon	0	0.00	0	0.00	125	100.00	125	0.002
133	F250 Super Cab	10	0.65	2	0.13	1522	99.22	1534	0.023
175	Sierra 1500 Pickup 4	0	0.00	0	0.00	177	100.00	177	0.003
180	Sierra 1500 2WD	1	0.06	0	0.00	1580	99.94	1581	0.024
181	Sierra 3500 Pickup 2	0	0.00	0	0.00	105	100.00	105	0.002
184	Savanna 2500 2WD	0	0.00	0	0.00	103	100.00	103	0.002
200	Sentra / 200SX	8	0.10	7	0.09	7648	99.80	7663	0.117
230	SLK230	0	0.00	0	0.00	1469	100.00	1469	0.022
231	Truck Regular Bed	8	0.13	1	0.02	6143	99.85	6152	0.094
240	240SX	4	0.39	1	0.10	1015	99.51	1020	0.016
254	Grand Cherokee Lared	23	0.04	9	0.02	58432	99.95	58464	0.895
300	ES300	54	0.05	21	0.02	114637	99.93	114712	1.757
320	S320	0	0.00	0	0.00	871	100.00	871	0.013
400	LS400	4	0.03	1	0.01	12590	99.96	12595	0.193
420	S420	0	0.00	0	0.00	482	100.00	482	0.007
500	528i	10	0.05	2	0.01	21853	99.95	21865	0.335
550	550 Maranello	0	0.00	0	0.00	167	100.00	167	0.003
580		5	4.59	0	0.00	104	95.41	109	0.002
600		1	0.08	2	0.17	1191	99.75	1194	0.018
626	626	52	0.12	38	0.09	43333	99.79	43423	0.665
700	740iL (Auto)	7	0.10	2	0.03	6984	99.87	6993	0.107
850	850	4	0.13	3	0.10	3083	99.77	3090	0.047
900	900S / 900CS	1	0.10	1	0.10	972	99.79	974	0.015
911	911	0	0.00	0	0.00	459	100.00	459	0.007
960	960	3	0.14	2	0.09	2152	99.77	2157	0.033
22C	CL	2	0.25	0	0.00	809	99.75	811	0.012
23C	CL	5	0.51	0	0.00	979	99.49	984	0.015
25T	TL	3	0.22	0	0.00	1345	99.78	1348	0.021

Model Code	Series (Model)	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by model	% of overall tests by model
		Count	Percent	Count	Percent	Count	Percent		
30C	CL	0	0.00	0	0.00	1724	100.00	1724	0.026
32i	325i	0	0.00	0	0.00	123	100.00	123	0.002
32T	TL	7	0.04	1	0.01	16542	99.95	16550	0.253
35R	RL	4	0.08	1	0.02	4721	99.89	4726	0.072
3GT	3000 GT	3	0.22	2	0.15	1351	99.63	1356	0.021
4RN	4Runner SR5	22	0.04	3	0.01	53346	99.95	53371	0.817
85F	850	2	0.10	1	0.05	1907	99.84	1910	0.029
90A	9000S / 9000CD / 900	0	0.00	0	0.00	107	100.00	107	0.002
AA4	A4	9	0.08	3	0.03	11492	99.90	11504	0.176
AA6	A6	2	0.07	2	0.07	2702	99.85	2706	0.041
AA8	A8	0	0.00	1	0.10	987	99.90	988	0.015
ACC	Accord	97	0.07	33	0.02	135086	99.90	135216	2.071
ACV	Achieva SL/SC	0	0.00	3	0.10	2874	99.90	2877	0.044
AER	Aerostar XLT Wagon	3	0.14	0	0.00	2143	99.86	2146	0.033
ALO	Alero Level II	15	0.05	10	0.03	30007	99.92	30032	0.460
ALT	Altima	70	0.04	79	0.05	160499	99.91	160648	2.460
AMG	Amigo/Rodeo 2WD	1	0.13	0	0.00	792	99.87	793	0.012
ARL	RL	0	0.00	3	0.31	953	99.69	956	0.015
ARN	Arnage Red Label	0	0.00	0	0.00	203	100.00	203	0.003
AS4	A4/S4	1	0.09	2	0.18	1123	99.73	1126	0.017
ASP	Aspire	2	0.12	2	0.12	1732	99.77	1736	0.027
AST	Astro 2WD	19	0.12	3	0.02	16374	99.87	16396	0.251
ATL	TL	0	0.00	1	0.01	9662	99.99	9663	0.148
AUR	Aurora	5	0.08	2	0.03	6176	99.89	6183	0.095
AVA	Avalon	21	0.03	16	0.02	74177	99.95	74214	1.137
AVN	Avenger	12	0.26	8	0.17	4580	99.57	4600	0.070
B23	Pickup (not Cab Plus	0	0.00	0	0.00	605	100.00	605	0.009
B40	Pickup (not Cab Plus	0	0.00	0	0.00	181	100.00	181	0.003
BEE	New Beetle	11	0.08	5	0.04	13062	99.88	13078	0.200
BER	Beretta	1	0.12	0	0.00	853	99.88	854	0.013
BLZ	S10 Blazer 2WD	37	0.08	5	0.01	44068	99.90	44110	0.676
BON	Bonneville SE	7	0.05	5	0.03	14506	99.92	14518	0.222
BOX	986 Boxster	3	0.05	0	0.00	6582	99.95	6585	0.101
BRO	Bronco 4WD	2	0.39	1	0.19	511	99.42	514	0.008
BRZ	Breeze	8	0.11	4	0.05	7454	99.84	7466	0.114

Model Code	Series (Model)	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by model	% of overall tests by model
		Count	Percent	Count	Percent	Count	Percent		
BVD	Bravada 4WD	0	0.00	0	0.00	1879	100.00	1879	0.029
C15	C1500 Pickup 2WD	200	0.07	47	0.02	306906	99.92	307153	4.704
C22	C220	6	0.62	2	0.21	963	99.18	971	0.015
C23	C230	1	0.01	1	0.01	11100	99.98	11102	0.170
C25	C2500 Pickup 2WD	9	0.12	5	0.07	7335	99.81	7349	0.113
C28	C280	2	0.04	4	0.09	4473	99.87	4479	0.069
C35	C3500 Pickup 2WD	3	0.21	2	0.14	1427	99.65	1432	0.022
C70	C70	0	0.00	0	0.00	2236	100.00	2236	0.034
CAB	Cabrio Convertible	9	0.26	4	0.11	3485	99.63	3498	0.054
CAM	Camry	119	0.03	82	0.02	385055	99.95	385256	5.900
CAP	Caprice Classic	1	0.05	1	0.05	1873	99.89	1875	0.029
CAR	911	1	0.05	0	0.00	1925	99.95	1926	0.029
CAT	Catera	2	0.04	1	0.02	5659	99.95	5662	0.087
CAV	Cavalier	183	0.14	117	0.09	126471	99.76	126771	1.941
CEN	Century Custom	12	0.03	6	0.01	45525	99.96	45543	0.697
CHA		1	0.05	1	0.05	2120	99.91	2122	0.032
CI1	Civic del Sol	0	0.00	1	0.19	536	99.81	537	0.008
CIE	Cutlass Ciera SL	2	0.15	0	0.00	1311	99.85	1313	0.020
CIR	Cirrus LXi	4	0.06	4	0.06	6821	99.88	6829	0.105
CIV	Civic	71	0.03	51	0.02	244519	99.95	244641	3.747
CL3	CLK320	0	0.00	1	0.03	3446	99.97	3447	0.053
CL4	CLK430	1	0.03	0	0.00	3214	99.97	3215	0.049
CL5	CL500	1	0.11	0	0.00	925	99.89	926	0.014
CL6	CL600	0	0.00	0	0.00	161	100.00	161	0.002
CNC	Concorde LX/LXi	18	0.10	13	0.07	17636	99.82	17667	0.271
CNT	Contour LX/SE	32	0.13	25	0.10	25455	99.78	25512	0.391
COA	Corolla	62	0.03	30	0.01	224294	99.96	224386	3.436
CON	Continental	3	0.03	3	0.03	9737	99.94	9743	0.149
COU	Cougar	22	0.12	12	0.06	18930	99.82	18964	0.290
CRS	Corsica	6	0.18	2	0.06	3325	99.76	3333	0.051
CRV	CR-V	3	0.01	3	0.01	31000	99.98	31006	0.475
CST	Celica	1	0.01	5	0.03	14649	99.96	14655	0.224
CUT	Cutlass GL	4	0.06	0	0.00	6970	99.94	6974	0.107
CVC	LTD Crown Victoria	31	0.07	10	0.02	46959	99.91	47000	0.720
CVN	Caravan	23	0.05	8	0.02	50284	99.94	50315	0.771

Model Code	Series (Model)	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by model	% of overall tests by model
		Count	Percent	Count	Percent	Count	Percent		
CVT	Corvette	13	0.04	22	0.07	30072	99.88	30107	0.461
CW2	E250 2WD	5	2.49	0	0.00	196	97.51	201	0.003
CW3	E350 Super Wagon	1	0.66	0	0.00	151	99.34	152	0.002
DAK	Dakota 2WD	14	0.06	2	0.01	23611	99.93	23627	0.362
DEN	1500 Suburban 4WD Lu	4	0.98	3	0.74	401	98.28	408	0.006
DEV	DeVille	21	0.03	22	0.03	73118	99.94	73161	1.120
DIA	Diamante LS	13	0.16	17	0.21	7995	99.63	8025	0.123
DIS	Discovery Series II;	4	0.08	0	0.00	5140	99.92	5144	0.079
DLT	Delta 88/88LS	3	0.20	0	0.00	1489	99.80	1492	0.023
DUR	Durango 2WD	41	0.13	3	0.01	30706	99.86	30750	0.471
E32	E320W	11	0.04	5	0.02	28196	99.94	28212	0.432
E42	E420	0	0.00	0	0.00	1954	100.00	1954	0.030
E43	E430W	1	0.05	2	0.10	1920	99.84	1923	0.029
E50	E500W	0	0.00	0	0.00	1407	100.00	1407	0.022
E55	E55AMG	0	0.00	0	0.00	508	100.00	508	0.008
EC2	E250 2WD	12	0.46	6	0.23	2587	99.31	2605	0.040
EC3	E350 2WD	2	0.30	5	0.76	651	98.94	658	0.010
ECH	Echo	2	0.03	1	0.02	6500	99.95	6503	0.100
ECL	Eclipse	42	0.11	46	0.12	36984	99.76	37072	0.568
ELD	Eldorado	1	0.02	1	0.02	6447	99.97	6449	0.099
ELL		0	0.00	0	0.00	376	100.00	376	0.006
ELN	Elantra	58	0.13	45	0.10	43501	99.76	43604	0.668
ENV	Jimmy 4WD	0	0.00	0	0.00	119	100.00	119	0.002
EPD	Expedition	165	0.10	83	0.05	165158	99.85	165406	2.533
ES1	Esteem	0	0.00	0	0.00	923	100.00	923	0.014
ESC	Escort SE	28	0.04	20	0.03	70860	99.93	70908	1.086
EST	Esteem	0	0.00	0	0.00	1288	100.00	1288	0.020
EUR	Eurovan GLS	0	0.00	0	0.00	148	100.00	148	0.002
EXC	Excursion Limited 2W	2	0.34	0	0.00	593	99.66	595	0.009
F10	F150 2WD	0	0.00	1	0.90	110	99.10	111	0.002
F15	F150 2WD	152	0.10	34	0.02	154493	99.88	154679	2.369
F25	F250 Super Cab	88	2.55	6	0.17	3353	97.27	3447	0.053
F35	F350 Super Duty 2WD	10	2.41	1	0.24	404	97.35	415	0.006
FBD	Firebird	11	0.06	16	0.08	19556	99.86	19583	0.300
FLE	Fleetwood	2	0.26	0	0.00	769	99.74	771	0.012

Model Code	Series (Model)	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by model	% of overall tests by model
		Count	Percent	Count	Percent	Count	Percent		
FOC	Focus SE	18	0.07	15	0.06	24898	99.87	24931	0.382
FOR	Forester	0	0.00	0	0.00	1105	100.00	1105	0.017
FRT	Pickup King Cab	13	0.04	6	0.02	33295	99.94	33314	0.510
G15	Savanna 1500 2WD	0	0.00	0	0.00	409	100.00	409	0.006
G20	G20	5	0.08	0	0.00	6581	99.92	6586	0.101
G35	G35	0	0.00	0	0.00	12433	100.00	12433	0.190
GAL	Galant ES / GTZ / LS	66	0.10	49	0.08	63763	99.82	63878	0.978
GCK	Grand Cherokee 2WD	4	0.03	4	0.03	12884	99.94	12892	0.197
GOL	Golf / GTI / Jetta W	11	0.21	3	0.06	5239	99.73	5253	0.080
GRA	Grand Prix GT	62	0.10	26	0.04	61596	99.86	61684	0.945
GRM	Grand Am SE	36	0.04	13	0.02	81361	99.94	81410	1.247
GS3	GS300/GS430	5	0.02	6	0.03	21906	99.95	21917	0.336
GS4	GS400	1	0.03	0	0.00	2890	99.97	2891	0.044
GT	Mustang GT	1	0.40	0	0.00	249	99.60	250	0.004
GTI	Golf / GTI / Jetta W	3	0.06	3	0.06	4809	99.88	4815	0.074
GTO	G T O	2	0.09	2	0.09	2265	99.82	2269	0.035
GVT	Vitara / Grand Vitar	2	0.07	0	0.00	3039	99.93	3041	0.047
HOM	Sonoma Pickup 2WD	0	0.00	0	0.00	223	100.00	223	0.003
hom	Sonoma Pickup 2WD	2	0.13	0	0.00	1512	99.87	1514	0.023
HUM		0	0.00	0	0.00	123	100.00	123	0.002
I30	I30	8	0.04	12	0.05	22529	99.91	22549	0.345
IMP	Impala	31	0.02	23	0.02	126885	99.96	126939	1.944
INT	Intrepid SE	51	0.08	40	0.06	67010	99.86	67101	1.028
J30	J30	2	0.06	4	0.13	3088	99.81	3094	0.047
JET	Jetta	73	0.11	50	0.08	64253	99.81	64376	0.986
JMY	Jimmy 2WD	5	0.08	2	0.03	6077	99.88	6084	0.093
L45	LX450	0	0.00	0	0.00	483	100.00	483	0.007
L47	LX470	0	0.00	1	0.02	4861	99.98	4862	0.074
LAN	Lancer ES	11	0.05	9	0.04	20299	99.90	20319	0.311
LCR	Land Cruiser	4	0.09	1	0.02	4340	99.88	4345	0.067
LEG	Legacy	5	0.05	6	0.06	9890	99.89	9901	0.152
LES	LeSabre Custom	10	0.04	3	0.01	24683	99.95	24696	0.378
LHS	LHS	5	0.09	4	0.07	5641	99.84	5650	0.087
LIM	Incomplete	0	0.00	0	0.00	216	100.00	216	0.003
LS6	LS	5	0.04	5	0.04	12634	99.92	12644	0.194

Model Code	Series (Model)	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by model	% of overall tests by model
		Count	Percent	Count	Percent	Count	Percent		
LSS	Delta 88LSS	1	0.10	0	0.00	973	99.90	974	0.015
LUM	Lumina LS	24	0.07	13	0.04	36521	99.90	36558	0.560
M3	M3	23	0.48	21	0.44	4731	99.08	4775	0.073
M5	M5	3	0.33	1	0.11	917	99.57	921	0.014
MAG		0	0.00	6	0.14	4391	99.86	4397	0.067
MAL	Malibu LS	45	0.04	42	0.03	128331	99.93	128418	1.967
MAR	Grand Marquis LS	15	0.05	4	0.01	31536	99.94	31555	0.483
MAU	Grand Marquis LS	0	0.00	0	0.00	436	100.00	436	0.007
MAX	Maxima	46	0.04	60	0.06	103731	99.90	103837	1.590
MET	Geo Metro LSi	4	0.09	0	0.00	4688	99.91	4692	0.072
MGO	Montego Premier	2	0.11	3	0.17	1788	99.72	1793	0.027
MIA	MX5 Miata	20	0.16	5	0.04	12871	99.81	12896	0.197
MIL	Millenia	2	0.02	7	0.07	9368	99.90	9377	0.144
MIR	Mirage	17	0.10	14	0.08	16648	99.81	16679	0.255
MK8	Mark VIII	1	0.14	0	0.00	729	99.86	730	0.011
ML3	ML320	2	0.04	0	0.00	5073	99.96	5075	0.078
ML4	ML430	0	0.00	0	0.00	970	100.00	970	0.015
MOC	Monte Carlo LS	6	0.02	7	0.02	30729	99.96	30742	0.471
MON	Montero Sport 2WD	5	0.03	3	0.02	16086	99.95	16094	0.246
MPV	MPV	3	0.05	2	0.03	6281	99.92	6286	0.096
MR2	MR2 Spyder	1	0.04	1	0.04	2291	99.91	2293	0.035
MTA	Montana 2WD	2	0.04	1	0.02	4768	99.94	4771	0.073
MTN	Mountaineer 2WD	8	0.10	0	0.00	8352	99.90	8360	0.128
MUS	Mustang	56	0.04	34	0.02	144609	99.94	144699	2.216
MX6	626 / MX6	0	0.00	0	0.00	275	100.00	275	0.004
MYS	Mystique GS	10	0.14	6	0.08	7147	99.78	7163	0.110
NAV	Navigator 2WD	72	0.18	34	0.09	39861	99.73	39967	0.612
NEO	Neon ES	26	0.04	24	0.03	72559	99.93	72609	1.112
NSX	NSX	2	0.68	0	0.00	292	99.32	294	0.005
NUB	Nubira	2	0.10	1	0.05	1947	99.85	1950	0.030
OAS	Trooper 4WD	0	0.00	0	0.00	202	100.00	202	0.003
ODY	Odyssey	10	0.03	3	0.01	30891	99.96	30904	0.473
PAS	Passat	43	0.11	16	0.04	38647	99.85	38706	0.593
PAV	Park Avenue	1	0.01	0	0.00	7165	99.99	7166	0.110
PRE	Prelude	8	0.09	3	0.04	8500	99.87	8511	0.130

Model Code	Series (Model)	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by model	% of overall tests by model
		Count	Percent	Count	Percent	Count	Percent		
PRI	Geo Prizm	13	0.06	58	0.25	22729	99.69	22800	0.349
PRO	ProtGgG	40	0.09	52	0.12	43070	99.79	43162	0.661
PRV	Previa 2WD	1	0.31	0	0.00	320	99.69	321	0.005
PRW	Prowler	0	0.00	0	0.00	296	100.00	296	0.005
PTH	Pathfinder	7	0.03	1	0.00	21167	99.96	21175	0.324
PUP	Pickup King Cab	0	0.00	0	0.00	392	100.00	392	0.006
Q45	Q45	3	0.04	2	0.03	7604	99.93	7609	0.117
QST	Quest	3	0.03	1	0.01	11339	99.96	11343	0.174
QTO	A6	3	0.08	0	0.00	3926	99.92	3929	0.060
QUA		0	0.00	0	0.00	165	100.00	165	0.003
QX4	Pathfinder	0	0.00	0	0.00	527	100.00	527	0.008
QXA	Pathfinder	0	0.00	1	0.02	4268	99.98	4269	0.065
R25	Ram Pickup 2WD	1	0.10	0	0.00	1047	99.90	1048	0.016
RAV	RAV4	5	0.03	0	0.00	19754	99.97	19759	0.303
REG	Regal LS	5	0.02	4	0.02	23907	99.96	23916	0.366
RIV	Riviera	4	0.19	1	0.05	2153	99.77	2158	0.033
RNG	Ranger 2WD	35	0.07	9	0.02	47036	99.91	47080	0.721
ROA	RoadMaster ITT Limit	0	0.00	1	0.09	1121	99.91	1122	0.017
ROD	Rodeo 2WD	13	0.07	5	0.03	19066	99.91	19084	0.292
RRV	Range Rover HSE	2	0.04	0	0.00	4560	99.96	4562	0.070
RST	Z3	0	0.00	0	0.00	174	100.00	174	0.003
RX3	RX300	5	0.03	1	0.01	16807	99.96	16813	0.257
S10	S10 Pickup 2WD	40	0.13	10	0.03	29624	99.83	29674	0.454
S20	S2000	4	0.11	1	0.03	3504	99.86	3509	0.054
S30	SC300	1	0.06	0	0.00	1633	99.94	1634	0.025
S40	S40 / V40	5	0.07	4	0.05	7483	99.88	7492	0.115
S70	S70 / V70	4	0.04	2	0.02	10614	99.94	10620	0.163
S80	S80	1	0.01	0	0.00	10450	99.99	10451	0.160
S90	S90 / V90	2	0.18	2	0.18	1118	99.64	1122	0.017
SAB	Sable GS	29	0.08	16	0.04	37649	99.88	37694	0.577
SAF	Safari 2WD	3	0.08	0	0.00	3717	99.92	3720	0.057
SAV	Savanna 1500 2WD	0	0.00	0	0.00	1409	100.00	1409	0.022
SC	SC2 / SL1 / SW1	50	0.21	37	0.16	23557	99.63	23644	0.362
SDK	Sidekick 4dr 4WD	1	0.26	0	0.00	390	99.74	391	0.006
SEB	Sebring LXi	45	0.08	37	0.06	59058	99.86	59140	0.906

Model Code	Series (Model)	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by model	% of overall tests by model
		Count	Percent	Count	Percent	Count	Percent		
SEN	Sentra	52	0.06	53	0.06	85045	99.88	85150	1.304
SEP	Sephia/Spectra	16	0.16	8	0.08	10017	99.76	10041	0.154
SEV	SLS	6	0.04	1	0.01	13613	99.95	13620	0.209
SFT	Swift	0	0.00	1	0.63	159	99.38	160	0.002
SIL	Silhouette	1	0.03	0	0.00	3486	99.97	3487	0.053
SKY	Skylark	5	0.16	9	0.29	3073	99.55	3087	0.047
SL	SL2 / SW2	113	0.22	113	0.22	51959	99.57	52185	0.799
SL5	SL500R	1	0.02	1	0.02	4028	99.95	4030	0.062
SL6	SL600	0	0.00	1	0.33	306	99.67	307	0.005
SLX	SLX 4WD	0	0.00	0	0.00	110	100.00	110	0.002
SNA	Sienna LE	2	0.01	0	0.00	32302	99.99	32304	0.495
SNF	Sunfire	51	0.14	37	0.10	36511	99.76	36599	0.560
SOL	Solara	0	0.00	0	0.00	716	100.00	716	0.011
SON	Sonata	20	0.05	7	0.02	41179	99.93	41206	0.631
SPT	Sportage	1	0.01	1	0.01	9734	99.98	9736	0.149
STA	Stratus SE	40	0.07	35	0.06	55557	99.87	55632	0.852
STS	STS	0	0.00	0	0.00	1500	100.00	1500	0.023
SUB	C1500 Suburban 2WD	10	0.04	11	0.04	26844	99.92	26865	0.411
SUP	Supra	0	0.00	0	0.00	306	100.00	306	0.005
SW	SL2 / SW2	9	0.34	12	0.45	2662	99.22	2683	0.041
SWI	Geo Metro LSi	0	0.00	0	0.00	244	100.00	244	0.004
T10	T100 XTRACAB 2WD	0	0.00	0	0.00	2161	100.00	2161	0.033
TAC	Tacoma Deluxe	20	0.04	2	0.00	46056	99.95	46078	0.706
TAH	Tahoe 2WD	35	0.04	5	0.01	81967	99.95	82007	1.256
TAL		1	0.16	1	0.16	612	99.67	614	0.009
TAM	Formula / Trans Am	0	0.00	0	0.00	378	100.00	378	0.006
TAU	Taurus SE	121	0.06	91	0.05	195243	99.89	195455	2.993
TC	Scion tC	2	0.05	0	0.00	3687	99.95	3689	0.056
TER	Tercel	2	0.04	4	0.09	4678	99.87	4684	0.072
THU	Thunderbird LX	12	0.09	11	0.08	13504	99.83	13527	0.207
TIB	Tiburon	7	0.07	3	0.03	9952	99.90	9962	0.153
TL	TL	0	0.00	0	0.00	5369	100.00	5369	0.082
TOW	Town Car Signature	91	0.10	63	0.07	89413	99.83	89567	1.372
TRA	Tracer LS	3	0.07	1	0.02	4259	99.91	4263	0.065
TRK	Tracker 2WD	0	0.00	0	0.00	1376	100.00	1376	0.021

Model Code	Series (Model)	DLC is damaged, inaccessible, or cannot be found		Vehicle will not communicate with analyzer		Vehicle successfully communicates with analyzer		Total count of tests by model	% of overall tests by model
		Count	Percent	Count	Percent	Count	Percent		
TRP	Trooper 4WD	6	0.14	0	0.00	4204	99.86	4210	0.064
TSP	Transport	1	0.07	0	0.00	1426	99.93	1427	0.022
TUN	Tundra SR5	17	0.06	6	0.02	30821	99.93	30844	0.472
V15	Ram Pickup 2WD	20	0.08	4	0.02	25335	99.91	25359	0.388
V25	Ram Van/Wagon	1	0.07	0	0.00	1464	99.93	1465	0.022
V35	Ram Wagon Bus	0	0.00	0	0.00	207	100.00	207	0.003
V40	S40 / V40	0	0.00	3	0.69	434	99.31	437	0.007
V70	S70 / V70	0	0.00	2	0.05	4048	99.95	4050	0.062
VAN	Vandenplas LWB	0	0.00	0	0.00	2172	100.00	2172	0.033
VCS	Vehicross 4WD	0	0.00	0	0.00	108	100.00	108	0.002
VEN	Venture 2WD Extended	4	0.10	3	0.07	4067	99.83	4074	0.062
VGR	Villager Wagon	3	0.06	1	0.02	5419	99.93	5423	0.083
VIP	Viper SRT-10	0	0.00	0	0.00	1285	100.00	1285	0.020
VIS		1	0.39	0	0.00	257	99.61	258	0.004
VIT	Vitara / Grand Vitar	0	0.00	0	0.00	898	100.00	898	0.014
VOY	Voyager	4	0.03	2	0.02	12549	99.95	12555	0.192
WIN	Windstar GL Wagon	18	0.07	5	0.02	25769	99.91	25792	0.395
WRG	Wrangler 4WD	4	0.01	7	0.03	27530	99.96	27541	0.422
XJ	XJ Sport	0	0.00	1	0.63	157	99.37	158	0.002
XJ6	XJ6 (USA) / Sovereig	0	0.00	0	0.00	1698	100.00	1698	0.026
XJ8	XJ	3	0.04	4	0.05	7837	99.91	7844	0.120
XJR	XJR	0	0.00	0	0.00	1452	100.00	1452	0.022
XJS	XJS	1	0.53	0	0.00	187	99.47	188	0.003
XK8	XK8	1	0.07	0	0.00	1456	99.93	1457	0.022
XPL	Explorer XL	69	0.07	8	0.01	105225	99.93	105302	1.613
XTE	Xterra	2	0.01	0	0.00	25413	99.99	25415	0.389
XXX	Wrangler 4WD	54	0.10	8	0.02	51916	99.88	51978	0.796
YUK	Yukon 2WD	23	0.07	4	0.01	31715	99.91	31742	0.486
Z3	Z3	1	0.03	3	0.10	3042	99.87	3046	0.047
Z3C	Z3	0	0.00	0	0.00	724	100.00	724	0.011
Z3R	Z3	1	0.11	0	0.00	942	99.89	943	0.014
Z8	Z8	0	0.00	0	0.00	103	100.00	103	0.002
ZEP		0	0.00	0	0.00	105	100.00	105	0.002
	TOTAL	**4231**	**0.06**	**2457**	**0.04**	**6523090**	**99.90**	**6529778**	**100.000**

3.7 TIMS Handling of OBD Codes

ERG analyzed TIMS OBD data to look for proper handling of OBD scanner information by the TIMS. Some I/M programs do not follow EPA protocol for determining whether a vehicle passes or fails an OBD inspection when not ready, pending codes, and fail to communicate messages are produced by the OBD scanner. An analysis of the TIMS records for these messages and the resulting designation of the vehicle as pass or fail will verify that Texas is handling these messages correctly.

Program Description and Results of Analysis

Proper handling of various OBD testing conditions is defined in Parts 85.2207 and 85.2222 of Title 40 of the Code of Federal Regulations and also in various OBD implementation guidance documents issued by the US EPA. Appropriate responses to the various test possibilities are summarized here, and served as the basis for analysis in this task. The dataset for this analysis included records for OBD inspections between 1 October 2006 and 31 March 2009. Records for inspections that were aborted were excluded from the dataset, as were records for which either the OBD result or the overall result was not "P"ass or "F"ail. This left 13,529,388 records in the dataset. Because this analysis was performed with the goal of determining whether OBD guidelines are enforced, only records for light-duty vehicles were used. Records for heavy-duty vehicles (>8500 lbs GVWR) for which the OBD test pass/fail results are not enforced and for vehicles with no GVWR given (because these might be heavy-duty vehicles) were also removed from the dataset, leaving 13,000,891 records in the dataset[22]. Finally, re-test inspections on OBD vehicles that included a safety or gas cap re-inspection, but did not include an OBD re-inspection (because the vehicle had passed OBD in a preceding inspection) were also excluded from the dataset, leaving 12,989,744 records in the dataset.

Diagnostic Link Connector Communication Status – According to federal guidelines, a diagnostic link connector (DLC) that is missing, tampered, or otherwise inoperable is a basis for failure, but the vehicle may be "rejected" for a DLC that is inaccessible or cannot be located. Failure to communicate with an OBD analyzer is also a basis for failure. To perform this analysis, the result stored in the "OBD2_DLC_RES" field was compared with that in the "OBD2_PF_FLAG" field. No test results with a "D" (damaged), "N" (connected but will not communicate), "L" (inspector cannot find DLC), or "I" (DLC is inaccessible) in the "OBD2_DLC_RES" should have a "P" in the "OBD2_PF_FLAG". Results of this analysis are shown in Table 3-34.

[22] HD vehicles were identified using the tx96_type field equal to 1 and the tx96_gvw_actual field being greater than zero but less than 8,501.

Table 3-34. Comparison of DLC Communication Status with Overall OBD Test Results

DLC Communication Status	Overall OBD Test Results	
	Fail	**Pass**
"D" (damaged)	4,715	0
"I" (DLC is inaccessible)	2,150	1
"L" (inspector cannot find DLC)	1,749	50
"N" (connected but will not communicate)	6,028	0
Total count of "D", "I", "L", and "N" Tests	14,642	51
"P" (communication successful)	599,604	12,375,447
Total	**614,246**	**12,375,498**

As can be seen in the table, 51 test records have a DLC communication status of "D", "I", "L", or "N", yet have an OBD test result of "pass". For these records, it was noted that no result was given for monitor readiness (which should have been a "pass" in order to pass the OBD inspection) or for number of fault codes stored (which should have been present as well). Additionally, no fields indicate that a fallback tailpipe inspection was performed for those records. It is not clear what led to the passing result for those 51 records. In conclusion, the DLC fail to communicate was enforced on the vast majority of OBD tests conducted on light-duty vehicles during the period of evaluation.

Because successful communication with the OBD unit is critical for all other OBD results, the OBD records with OBD2_DLC_RES results other than "P" were removed from the dataset for the other analyses that comprise the remainder of this section. This left 12,975,051 records in the dataset.

Agreement between OBD test result and overall test result – A vehicle that fails the OBD inspection should fail the overall inspection, excluding any test exceptions such as converting to a backup tailpipe test.

To determine if OBD failures are properly enforced, that is, reflected in the overall inspection disposition, a query was performed to quantify the number of vehicles that failed the OBD portion of the test ("F" in the "OBD2_PF_FL" field) but passed the overall OBD test ("P" in the "OVERALL_RESULTS" field). Table 3-35 shows that only 167 tests were recorded to have failed the OBD portion of the test but passed the overall test. Additional analysis was performed to determine the cause of this apparent discrepancy. 162 of these records contained a passing result for the tailpipe inspection, indicating that these tests were converted to a fallback tailpipe test. For the remaining 5 records, no explanation for the overall passing result could be

found. This is a very small fraction of the total number of inspections performed; more than 99.99% of OBD inspections have agreement between the OBD result and the overall test result.

Table 3-35. Comparison of OBD Test Result with Overall Test Result

Result of OBD Test	Overall Test Result				Total	
	Fail		Pass			
Fail	599,437	4.6	167	0.0	599,604	4.6
Pass	341,148	2.6	12,034,299	92.7	12,375,447	95.4
Total	940,585	7.2	12,034,466	92.8	12,975,051	100.0

Inspector-Entered Malfunction Indicator Light (MIL) bulb check: This is also referred to as the Key On/Engine Off (KOEO) check. The inspector turns the vehicle's ignition key to the "on" position, but does not start the vehicle, in order to illuminate the MIL. Results are manually entered into the analyzer via keyboard by the inspector. If the MIL does not illuminate, the vehicle should fail this OBD portion of the inspection.

To perform this analysis, the results for the inspector keyboard-entered MIL bulb check ("OBD2_MIL_CHECK" field of the test record) were compared with results of the overall OBD test result ("OBD2_PF_FLAG" field), to ensure that a MIL bulb check failure always results in an OBD test failure. The "OBD2_MIL_CHECK" results are "Y" or "K", which is a pass (yes, the MIL did illuminate), and "N", which is a fail (no, the MIL did not illuminate). Table 3-36 shows that one record was found which contained no result for the KOEO MIL Bulk Check Result; rather than passing, a blank result should prevent the inspection from being completed. Additionally, 6 records were found where a KOEO MIL result of "N" (fail) did not receive the failing OBD result that they should have received. However, 7 records out of 13 million is a very small fraction of the total.

Table 3-36. Comparison of KOEO MIL Bulb Check Result with Overall OBD Test Result

Result of KOEO MIL Bulb Check	Overall OBD Test Result		Total
	Fail	Pass	
<blank>	0	1	1
N (fail)	20,363	6	20,369
K (pass)	537	29,683	30,220
P (pass)	578,704	12,345,758	12,924,462
Total	**599,604**	**12,375,447**	**12,975,051**

Inspector-Entered Engine-Running MIL Illumination Status – The key-on engine running result manually entered by the inspector is a basis for failure. No vehicle with an "F" in the "OBD2_MIL_ON_RUN" field should have a "P" in the "OBD2_PF_FLAG" field of the

OBD test record. The "OBD2_MIL_ON_RUN" results are "Y", which is a pass (Y = MIL turned off after the vehicle was started) or "N", which is a fail (N = MIL stayed illuminated after the vehicle was started). Table 3-37 shows that the MIL Illumination Status appears to be enforced as a condition for OBD failure: no inspections were recorded with a MIL Illumination status of "N" and an overall OBD result of "P". However, since the Key-On-Engine-Running MIL Illumination Status is manually entered by the inspector, accuracy of this entry is not automatically enforced by the analyzer.

Table 3-37. Comparison of Inspector-Entered MIL Illumination Status (Engine Running) with Overall OBD Test Result

Result of MIL Illumination Status	Overall OBD Test Result		Total
	Fail	Pass	
<blank>	1	0	1
N (Fail)	107,448	0	107,448
Y (Pass)	492,155	12,375,447	12,867,603
Total	599,604	12,375,447	12,975,051

MIL commanded on – A vehicle with the MIL commanded on and with stored emission control DTCs should fail the OBD inspection, regardless of readiness status. Manufacturer DTCs are ignored in this pass/fail determination. To perform this analysis, all OBD test records were reviewed to determine the overall OBD pass/fail status in comparison with the downloaded MIL command status results. Specifically, any vehicle with "F" in the "OBD2_MIL_STATUS" should also have "F" in the "OBD2_PF_FLAG" field (if DTCs are present). Table 3-38 provides results of this review.

Table 3-38. Comparison of Downloaded MIL Command Status with Overall OBD Test Result

Result of Downloaded MIL Status	Overall OBD Test Result				Total	
	Fail		Pass			
Fail	252,890	1.9	68,361	0.5	321,251	2.5
Pass	346,714	2.7	12,307,086	94.9	12,653,800	97.5
Total	599,604	4.6	12,375,447	95.4	12,975,051	100.0

From Table 3-38, it can be seen that 68,361 test records (0.5% of all OBD test records) have a MIL commanded on status yet receive an overall OBD pass result. However, 68,360 of these tests had no stored DTCs, in which case it is appropriate to pass the test. The single remaining inspection had one DTC stored, and should have resulted in a failed OBD result. In conclusion, the downloaded OBD MIL command status was enforced for almost all OBD tests

conducted on light-duty vehicles (< 8500 lbs. GVWR) with stored DTCs during the period of evaluation.

Readiness Evaluation – Federal guidelines recommend two or fewer unset non-continuous monitors be allowed for 1996-2000 vehicles, and only one or none unset non-continuous monitors be allowed for 2001 and newer vehicles. Vehicles with higher counts of unset non-continuous monitors should not receive a pass result. They should be failed or rejected on the basis of the OBD system's readiness status. Until October 15, 2008, however, Texas used readiness criteria that were slightly different from the federal guidelines: two or fewer unset non-continuous monitors were used as the requirement for vehicles of all model years. After October 15, 2008, Texas changed the criteria to match the federal limits of two unset monitors for 1996-2000 vehicles, and one unset monitor for 2001 and newer vehicles. Where appropriate, results in the section will be presented separately for inspections performed before October 15, 2008, and inspections after that date.

Certain vehicles that are designated as "transitional vehicles" are permitted to receive a tailpipe inspection if they are found to be not ready based on non-continuous monitor status at the time of an OBD inspection. To prevent any confusion of the results, these vehicles were excluded from this analysis of readiness. 33,994 transition vehicles were excluded, leaving 12,941,057 vehicles in the dataset for this analysis.

To perform this analysis, the OBD readiness status of test records was compared on a model-year basis to evaluate conformance with Texas' guidelines. Prior to October 15, 2008, vehicles of any model year with three or more "not ready" non-continuous monitors should have an OBD readiness failure ("F" in the "OBD2_READY_RES" field of the test record), and an OBD test result of fail ("F" in the "OBD2_PF_FLAG" field of the test record). Vehicles with two or fewer "not ready" non-continuous monitors should have an OBD readiness result of pass ("P" in the "OBD2_READY_RES" of the test record). After October 15, 2008, 2001 and newer vehicles with two or more "not ready" non-continuous monitors should have an OBD readiness failure ("F" in the "OBD2_READY_RES" of the test record), and an OBD test record result of fail ("F" in the "OBD2_PF_FLAG" field of the test record), while 2001 and newer vehicles with one or fewer "not ready" non-continuous monitors should have an OBD readiness result of pass ("P" in the "OBD2_READY_RES" field of the test record).

Table 3-39 compares OBD readiness status with the number of unset monitors for all OBD tests. Only non-continuous and "enabled" monitors are presented in this comparison.

Table 3-39. Unset Monitors vs. Test Readiness Status for Inspections Prior to October 15, 2008

Count of Unset Non-Continuous Monitors	Counts of Tests of Vehicles Model Year 1996 through 2000		Counts of Tests of Vehicles Model Year 2001 and newer	
	OBD "Not Ready"	OBD "Ready"	OBD "Not Ready"	OBD "Ready"
0	1	3,051,381	2	5,745,878
1	0	451,727	0	373,973
2	0	263,172	441	179,770
3	72,134	910	53,405	25
4	50,712	555	36,137	4
5	33,541	367	19,094	0
6	1,073	0	1,001	0
7	0	0	2	0
8	0	0	2	0
Total Count	157,461	3,768,112	110,084	6,299,650

Table 3-40. Unset Monitors vs. Test Readiness Status for Inspections After October 15, 2008

Count of Unset Non-Continuous Monitors	Counts of Tests of Vehicles Model Year 1996 through 2000		Counts of Tests of Vehicles Model Year 2001 and newer	
	OBD "Not Ready"	OBD "Ready"	OBD "Not Ready"	OBD "Ready"
0	0	602,053	0	1,597,074
1	0	108,391	0	141,063
2	0	58,489	29,052	1,054
3	16,468	0	16,313	0
4	11,511	0	10,655	0
5	7,694	0	5,412	0
6	251	0	269	0
7	1	0	0	0
8	0	0	0	0
Total Count	35,925	768,933	61,701	1,739,191

Results in Table 3-39 (for the period before October 15, 2008) show that a small number of tests (a total of 3) appear to have received an OBD "not ready" status despite having no unset monitors. Also, a larger number of vehicles with three or more unset readiness monitors still received a readiness result of "pass" (1,832 model year 1996-2000 vehicle tests and 29 model year 2001 and newer vehicle tests). Of these 1,861 records, all but 6 were conducted on a single type of analyzer. Additionally, all of them occur before or during April of 2008. After April of 2008, only two additional records were collected with OBD as "ready" for vehicles with more than two unset monitors.

Results in Table 3-40 (for the period after October 15, 2008) show that 1,054 inspections had a "ready" status for a 2001 and newer vehicle with 2 unset monitors. Most of these result from the transition that occurred on October 15, 2008: 785 of them occurred between October 16 and October 19, 2008. No other disagreements between the number of unset monitors and the OBD readiness result were seen for the post-October 15, 2008, results.

To summarize, the Texas I/M program allowed two non-continuous monitors to be unset for OBD "readiness" for 1996 and newer model year vehicles until October 15, 2008. After October 15, 2008, the Texas I/M program allowed two non-continuous monitors to be unset for OBD "readiness" for 1996-2000 model year vehicles, and one non-continuous monitor to be unset for OBD "readiness" for 2001 and newer model year vehicles. Additionally, three or more unset monitors were allowed in 1,866 inspections by one analyzer type until April 2008, after which they were not allowed.

Readiness Evaluation: Comparison of readiness result with overall pass/fail result – The pass/fail disposition of the readiness result field of the test record was compared with the overall OBD test disposition to see if any vehicles with a "not ready" status (as determined automatically by the analyzer) received an overall OBD test result of "pass". To perform this analysis, the "OBD2_READY_RES" field was compared to the "OBD2_PF_FLAG" fields in the analyzer OBD test records. Note that certain vehicles that are designated as "transitional vehicles" are permitted to receive a tailpipe inspection if they are found to be not ready (based on non-continuous monitor status) at the time of an OBD inspection. As described earlier, to prevent any confusion of the results, these vehicles were excluded from this analysis of readiness. 33,994 transition vehicles were excluded, leaving 12,941,057 vehicles in the dataset for this analysis. The results are shown in Table 3-41.

Table 3-41. Comparison of Readiness Status Field with Overall OBD Test Result

Readiness Status Check	Overall OBD Test Result				Total	
	Fail		Pass			
Fail (Not Ready)	365,161	2.8%	10	0.0%	365,171	2.8%
Pass (Ready)	231,887	1.8%	12,343,999	95.4%	12,575,886	97.2%
Total	597,048	4.6%	12,344,009	95.4%	12,941,057	100.0%

As can be seen in Table 3-41, only 10 of the vehicles with a "not ready" status received an overall "pass" result for the OBD portion of the test. This indicates that the OBD readiness status (as determined by the analyzer and stored in the OBD2_READY_RES" field of the test record) was almost always enforced for OBD tests performed during the period of evaluation.

3.8 TIMS OBD Data Checks for Evidence of Station Fraud

"Clean-piping" is a term used to describe a type of vehicle emissions test fraud in which an inspector substitutes a vehicle with passing emission rates in place of a vehicle with high emission rates in order to achieve a pass record for the high-emitting vehicle. Historically, this has been identified through the use of covert audits, notifications by motorists, and analysis of vehicle emission result trends. For a vehicle receiving an OBD inspection, the analogous practice is typically referred to as "clean-scanning," where a vehicle with no MIL illumination is substituted in place of a vehicle with MIL illumination and stored DTCs in an attempt to receive a passing test result. Although identification of emission results trends is not possible with OBD tests, information downloaded from the OBD system during an inspection may be used to identify possible clean-scanning activities.

For OBD (1996 and newer) vehicles, a comparison of the inspector-entered information against the vehicle-downloaded information via the OBD connection can help verify if all OBD inspections are performed on the correct vehicle. The vehicle-downloaded information contains the vehicle readiness monitor status. Differences between readiness monitors such as "not supported" to "not ready" or "ready" would indicate a different vehicle was used and may be evidence of a clean-scanning. Both the inspector-entered information and the vehicle-downloaded information are recorded in each vehicle inspection record of the TIMS. In this task inspector-entered information was compared to the vehicle-downloaded information to determine if all inspections are performed on the correct vehicle.

Analysis Performed

For this element, ERG performed several types of analyses in an attempt to identify fraud associated with OBD inspections. The following strategies were attempted:

- Comparison of the vehicle's eVIN with the VIN entered during the vehicle inspection. In 2005 EPA required the eVIN to be stored in the vehicle's on-board system.
- Comparison of the rate of VIN discrepancies recorded by each station and inspector.

Comparison of OBD VIN with VIN entered during vehicle inspection - For this analysis, all test records where no OBD VIN was present were excluded. This reduced the dataset from 13,614,382 records to 5,733,777 records. For each of these remaining records, the OBD-downloaded VINs were compared with VINs entered (either via keyboard or barcode scan) during the vehicle inspection. Approximately 6% of these records (345,546 records) were found

to have VIN to VIN discrepancies. Manual investigation of these records showed a number of the OBD VINs or entered VINs were invalid (for example, 104,182 VINs were less than 17 characters in length), and some mismatches were also due to VIN errors in the vehicle test record. An investigation of the VIN discrepancies, shown in Table 3-42, revealed that vehicles from the early years of OBD (1996-1999) had very high rates of discrepancies, with as many as 96% of vehicle records containing a discrepancy. Rates were very low for the later model years. This could be caused by different factors: if earlier OBD software had more problems with VIN errors, it could explain the high rates in the 1996-1999 model years. However, the vehicles that benefit from clean-scanning are those that fail an inspection and that group would also be dominated by the early model-year vehicles, rather than the very new vehicles.

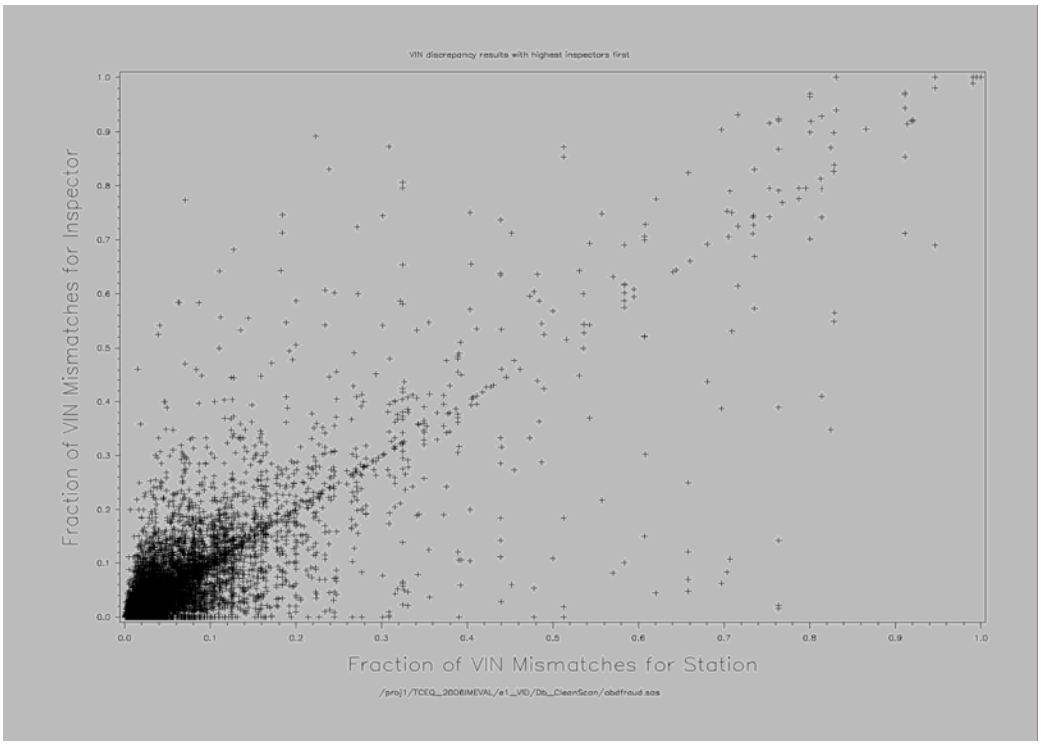
Table 3-42. Rates of OBD-Downloaded and Inspector-Entered VIN Discrepancies, by Model Year

Model Year	Number of OBD Inspections with VIN Mismatch	Percent of OBD Inspections with VIN Mismatch	Total Inspections
1996	13,202	96.06	13,744
1997	14,754	94.31	15,644
1998	14,206	92.53	15,353
1999	16,137	78.32	20,604
2000	61,109	26.67	229,112
2001	51,709	8.89	581,565
2002	51,932	7.68	675,910
2003	48,887	6.60	740,555
2004	31,090	3.59	865,821
2005	22,013	1.64	1,342,521
2006	13,610	1.57	868,050
2007	5,766	1.70	338,659
2008	1,055	4.26	24,794
2009	72	4.98	1,445

Comparison of the rate of VIN discrepancies - A second way of investigating the VIN discrepancies was to compare the rate at which discrepancies were recorded for each station that performed OBD inspections, and for each inspector. The results of this comparison are shown in Figure 3-47. The horizontal axis shows the fraction of OBD inspections that contained a VIN discrepancy for each station, while the vertical axis shows the fraction of OBD inspections with a VIN discrepancy for each inspector. To reduce errors due to small sample size, stations that performed fewer than 100 inspections or inspectors that performed fewer than 20 inspections were excluded from the plot. The large cluster of points at the bottom left corner of the plot includes most stations and inspections: these had a near-zero rate of VIN discrepancies. The

points closer to 1 on the horizontal or vertical axis indicate stations or inspectors that almost always produced OBD records with a VIN discrepancy. These very-high rates could result from practices other than clean-scanning, such as consistently sloppy data entry. In any case, the stations or inspectors with very high rates would be good candidates for further investigation.

Figure 3-47. Rates of OBD-Downloaded and Inspector-Entered VIN Discrepancies, by Station and Inspector



4.0 Repair

ERG used two years of Texas TIMS data to analyze repair activities. The analysis will demonstrate the extent and properties of repairs directed by the I/M program.

4.1 Number and Types of Repairs

The inspectors at I/M stations enter vehicle repair information into the TIMS prior to emissions tests that follow repairs. A simple count of the number of repairs in the TIMS and a distribution of the repair types are evidence that the I/M program is causing repairs to be performed. Because repairs for the DACM program are documented on paper and not electronically, all DACM repairs will be described generally.

In an effort to determine the number and types of repairs performed as a result of the Texas I/M program, two sets of data were analyzed: the TIMS and detailed repair information collected from DPS RERF.

General I/M Repairs

The Texas TIMS, as provided by TCEQ, contains a large number of observations, but relatively little detail on the nature of repairs performed. The five repair categories listed in the TIMS, along with the corresponding number of performed repairs, are presented in Table 4-1 by model year group. Note that compared to the analysis conducted in 2006, Miscellaneous repairs increased from 24.5% to 34.5%.

Table 4-1. Repairs Listed in the TIMS

Repair Type	Model Year	Number of Repairs	% of Repair Type	% of Total
	pre-1980	1	0.00	0.00
	1980-1989	4789	7.33	1.15
	1990-1999	36014	55.15	8.68
	post-2000	24503	37.52	5.90
Fuel System	*Total*	*65307*	*100.00*	*15.74*
	pre-1980	0	0.00	0.00
	1980-1989	5319	10.93	1.28
	1990-1999	30590	62.84	7.37
Ignition / Electrical	post-2000	12774	26.24	3.08
system	*Total*	*48683*	*100.00*	*11.73*
	pre-1980	0	0.00	0.00
	1980-1989	13799	9.14	3.33
	1990-1999	97911	64.88	23.59
	post-2000	39196	25.97	9.44
Emissions system	*Total*	*150906*	*100.00*	*36.36*
	pre-1980	0	0.00	0.00
	1980-1989	572	8.27	0.14
	1990-1999	4096	59.24	0.99
	post-2000	2246	32.48	0.54
Engine Mechanical	*Total*	*6914*	*100.00*	*1.67*
	pre-1980	0	0.00	0.00
	1980-1989	9584	6.69	2.31
	1990-1999	77925	54.42	18.78
	post-2000	55680	38.89	13.42
Miscellaneous	*Total*	*143189*	*100.00*	*34.50*
	Grand Total	***414999***		***100.00***

RERF Repairs

Relative to the TIMS, the separate RERF dataset obtained from DPS contains more comprehensive information about the nature of repairs performed. However, repairs made at RERFs only make up a fraction of overall repairs made throughout the I/M areas statewide. Nonetheless, the distribution of repairs performed at RERFs serves to illustrate the wide variety of repairs undertaken as a result of the Texas I/M program. Table 4-2 shows counts of repairs reported by stations participating in the RERF program.

Table 4-2. Repairs Performed at RERF Stations

Repair Type	Defective, Not Repaired	Repaired	% Repaired	Total Vehicles with This Defect	Defect % of Total
AIS	9	136	93.8	145	0.66
All other types of repairs	81	257	76.0	338	1.55
Battery/Charging System	2	61	96.8	63	0.29
CAT	59	1940	97.0	1999	9.16
Camshaft	8	50	86.2	58	0.27
Cylinder Head	2	18	90.0	20	0.09
EGR	58	1679	96.7	1737	7.96
EVAP	26	623	96.0	649	2.97
Emissions System	42	3841	98.9	3883	17.79
Eng. Cooling	7	376	98.2	383	1.76
Engine Block	3	51	94.4	54	0.25
Engine Exhaust	6	74	92.5	80	0.37
Engine Mechanical	7	263	97.4	270	1.24
Fuel Filter	9	159	94.6	168	0.77
Fuel Pump	5	27	84.4	32	0.15
Fuel System	24	2232	98.9	2256	10.34
Ignition/Electrical System	18	1523	98.8	1541	7.06
Injectors	29	261	90.0	290	1.33
Miscellaneous	56	1730	96.9	1786	8.18
O2 Sensor	103	1844	94.7	1947	8.92
PCM	11	263	96.0	274	1.26
PCV	8	279	97.2	287	1.32
Reed, Check, and other Valves	0	1	100.0	1	0.00
Spark Plug Wires	16	723	97.8	739	3.39
Spark Plugs	19	1022	98.2	1041	4.77
Spark Timing	18	519	96.6	537	2.46
TAC	1	26	96.3	27	0.12
Thermostat	0	1	100.0	1	0.00
Throttle Body	7	130	94.9	137	0.63
Trans/Final Drive	3	240	98.8	243	1.11
Valves (Mechanical)	0	14	100.0	14	0.06
Valves (Oil Seals)	1	16	94.1	17	0.08
Grand Total	881	20941	96.0	21822	100.00

Drive a Clean Machine

Texas has put in place a program to financially assist low income individuals with repairing or retiring vehicles that fail emissions testing. It is called the AirCheckTexas Drive a Clean Machine (DACM) and it is for qualified owners of vehicles that have failed the emissions test or whose vehicles are gasoline powered and 10 years or older. The program was originally created under the Low Income Vehicle Repair Assistance, Retrofit and Accelerated Retirement Program (LIRAP); however, the program is now known as Drive a Clean Machine as the result of further legislative amendments passed in 2007.

To qualify for the DACM program, a vehicle owner's net family income must be no greater than double the federal poverty level, which varies by family unit size. The owner's vehicle must have failed an emissions test, must have a current valid registration, and must have been registered in an I/M program county for the past 12 months. In addition, the vehicle must have passed (or be able to pass) a safety inspection, must be drivable to the repair facility, and (in the case of repairs) must be repaired or retrofitted at a RERF.

Under the older LIRAP program assistance included a minimum of $30 and a maximum of $600 for use in retrofits or repairs performed at RERFs. Assistance increased to a minimum of $600 and a maximum of $1,000 if a vehicle is selected for replacement. Under the newer DACM program the replacement maximum amounts have been revised to $3,000 for a car or truck (current model year and up to 3 model years old) or $3,500 for a hybrid vehicle of the current or previous model year. The new vehicle must also meet the federal Tier 2 Bin 5 or cleaner emission standards, have a gross vehicle weight rating less than 10,000 pounds, and have a total purchase cost not exceeding $25,000.

There were 7,181 total repairs made at RERFs under the DACM program during the evaluation period, with 6,741 being made in the DFW and HGB areas.

4.2 Emissions Changes Associated with Repairs

One way to measure the effectiveness of the Texas I/M program is to assess emissions from vehicles both before and after repairs and to calculate the average emissions change produced by different repair types. Different types of repairs tend to produce characteristic changes in emissions.

In the discussion below, the average emissions and the emissions changes produced by repairs during the evaluation period in the Texas I/M program with similar quantities from the previous 2006 Texas I/M analysis are compared.

Emissions Changes as a Result of Repair

The average emissions of all vehicles in the current analysis that received repairs are shown in Table 4-3b. Both ASM5015 and ASM2525 test results are presented. Average emissions for both inspections prior to and following repair cycles are shown, along with the average change between the two. The corresponding change in emissions for the vehicles in the previous 2006 analysis is shown by the values in Table 4-3a. The average emissions before and after repair in the current analysis are considerably lower than the corresponding values in the previous 2006 analysis. However, the percent emission changes for HC and CO for the time periods are quite close. The average emissions change in the 2006 analysis for HC, CO, and NOx, was -69%, -82%, and -65%, respectively. In the current analysis, the emissions change for HC, CO, and NOx, respectively was -66%, -82%, and -66%.

Tables 4-4a and 4-5a present the same types of emissions averages as those shown in Table 4-3a, but they are stratified by inspection year and model year group, respectively. These tables show that when stratifying by either inspection year or model year, emissions of HC, CO, and NOx all decrease with increasing year, for both the ASM5015 and ASM2525 tests.

Table 4-6 presents the most common repair slates in the Texas TIMS data, as originally presented and discussed in Table 4-1 above. Average before and after repair emissions levels were calculated for each repair slate to determine the emissions effects of different combinations of repair types.

As shown in Table 4-6 for the ASM2525 mode in Texas, seven combinations of the five repair categories dominate the repair slates used in Texas. As before, it is seen that average before and after repair emissions are lower in the current dataset than in the previous 2006 dataset. A similar finding will be seen in Section 5.1. It is possible this is due to the I/M program encouraging vehicle owners to properly maintain their vehicle's emission systems. However, additional analyses would be needed to verify that this is indeed the cause for this observation.

Table 4-3. Average Emissions Before and After Repairs

a) Previous 2006 Texas Data

ASM Mode	N	ASM2525 HC (ppm)				ASM2525 CO (%)				ASM2525 NO (ppm)			
		Before Repair	After Repair	Change		Before Repair	After Repair	Change		Before Repair	After Repair	Change	
				Conc.	(%)			Conc.	(%)			Conc.	(%)
5015	448440	117	42	-74	-63%	0.70	0.14	-0.55	-79%	792	303	-490	-62%
2525	448440	101	31	-70	-69%	0.66	0.12	-0.54	-82%	692	243	-449	-65%

b) Current 2008 Texas Data

ASM Mode	N	ASM2525 HC (ppm)				ASM2525 CO (%)				ASM2525 NO (ppm)			
		Before Repair	After Repair	Change		Before Repair	After Repair	Change		Before Repair	After Repair	Change	
				Conc.	(%)			Conc.	(%)			Conc.	(%)
5015	339658	67	26	-41	-61%	0.42	0.09	-0.33	-79%	488	183	-306	-63%
2525	339658	59	19	-40	-68%	0.40	0.07	-0.33	-82%	416	140	-275	-66%

Table 4-4. Average Emissions Before and After Repairs by Inspection Year

a) Previous 2006 Texas Data

Inspection Year	ASM Mode	N	ASM2525 HC (ppm)				ASM2525 CO (%)				ASM2525 NO (ppm)			
			Before Repair	After Repair	Change		Before Repair	After Repair	Change		Before Repair	After Repair	Change	
					Conc.	(%)			Conc.	(%)			Conc.	(%)
2003	5015	116592	143	52	-91	-64%	0.69	0.15	-0.54	-78%	930	355	-576	-62%
2004	5015	174745	120	43	-77	-64%	0.71	0.15	-0.57	-80%	801	308	-494	-62%
2005	5015	157365	94	35	-59	-63%	0.68	0.14	-0.54	-79%	680	259	-421	-62%
2003	2525	116592	120	38	-82	-68%	0.66	0.13	-0.53	-80%	819	297	-522	-64%
2004	2525	174745	103	31	-72	-70%	0.68	0.12	-0.56	-82%	707	249	-459	-65%
2005	2525	157365	83	25	-58	-70%	0.65	0.11	-0.54	-83%	581	198	-383	-66%

b) Current 2008 Texas Data

Inspection Year	ASM Mode	N	ASM2525 HC (ppm)				ASM2525 CO (%)				ASM2525 NO (ppm)			
			Before Repair	After Repair	Change		Before Repair	After Repair	Change		Before Repair	After Repair	Change	
					Conc.	(%)			Conc.	(%)			Conc.	(%)
2006	5015	30007	73	30	-44	-60%	0.48	0.10	-0.38	-79%	589	217	-373	-63%
2007	5015	136289	75	28	-46	-62%	0.47	0.10	-0.38	-80%	533	199	-335	-63%
2008	5015	133918	62	25	-37	-60%	0.39	0.09	-0.30	-78%	454	172	-282	-62%
2009	5015	39444	53	19	-34	-64%	0.30	0.07	-0.24	-78%	373	138	-235	-63%
2006	2525	30007	64	21	-43	-67%	0.45	0.08	-0.38	-83%	503	167	-336	-67%
2007	2525	136289	66	21	-45	-69%	0.45	0.08	-0.37	-82%	454	153	-301	-66%
2008	2525	133918	55	18	-36	-67%	0.37	0.07	-0.30	-81%	387	132	-254	-66%
2009	2525	39444	45	14	-31	-69%	0.29	0.05	-0.24	-82%	317	106	-211	-67%

Table 4-5. Average Emissions Before and After Repairs by Model Year Group

a) Previous 2006 Texas Data

Model Year	ASM Mode	N	ASM2525 HC (ppm)				ASM2525 CO (%)				ASM2525 NO (ppm)			
			Before Repair	After Repair	Change		Before Repair	After Repair	Change		Before Repair	After Repair	Change	
					Conc.	(%)			Conc.	(%)			Conc.	(%)
pre-1980	5015	329	433	131	-302	-70%	2.24	0.68	-1.56	-70%	1388	816	-572	-41%
1980-1989	5015	78351	240	83	-158	-66%	1.74	0.34	-1.4	-80%	1288	553	-734	-57%
1990-1999	5015	313472	106	40	-67	-63%	0.56	0.12	-0.44	-79%	810	293	-517	-64%
post-1999	5015	56550	0.3	0.5	0.1	33%	0.002	0.002	-0.001	-50%	3	3	0.2	7%
pre-1980	2525	329	385	113	-273	-71%	2.15	0.66	-1.49	-69%	1264	718	-546	-43%
1980-1989	2525	78351	217	64	-153	-71%	1.66	0.3	-1.37	-83%	1142	453	-689	-60%
1990-1999	2525	313472	89	28	-61	-69%	0.53	0.1	-0.43	-81%	703	234	-469	-67%
post-1999	2525	56550	0.3	0.3	0	0%	0.003	0.002	-0.001	-33%	2.8	2.5	-0.3	-11%

b) Current 2008 Texas Data

Model Year	ASM Mode	N	ASM2525 HC (ppm)				ASM2525 CO (%)				ASM2525 NO (ppm)			
			Before Repair	After Repair	Change		Before Repair	After Repair	Change		Before Repair	After Repair	Change	
					Conc.	(%)			Conc.	(%)			Conc.	(%)
1980-1989	5015	24658	226	78	-147	-65%	1.76	0.33	-1.44	-81%	1179	508	-671	-57%
1990-1999	5015	198527	86	34	-52	-60%	0.50	0.11	-0.39	-78%	685	245	-440	-64%
post-2000	5015	116473	0.705	1.144	0.438	62%	0.006	0.004	-0.002	-37%	6.17	7.31	1.14	18%
1980-1989	2525	24658	204	61	-143	-70%	1.69	0.29	-1.40	-83%	1022	403	-619	-61%
1990-1999	2525	198527	75	24	-50	-68%	0.47	0.09	-0.39	-81%	581	187	-394	-68%
post-2000	2525	116473	0.626	0.777	0.151	24%	0.005	0.003	-0.003	-49%	5.49	5.31	-0.19	-3%

Table 4-6. Average Emissions Before and After Repairs by Repair Slate and Model Year Group

a) Previous 2006 Texas Data

Repair Slate	Model Year	ASM Mode	N	HC (ppm)				CO (%)				NO (ppm)			
				Before Repair	After Repair	Change Conc.	Change (%)	Before Repair	After Repair	Change Conc.	Change (%)	Before Repair	After Repair	Change Conc.	Change (%)
Miscellaneous	pre-1980	5015	54	379	141	-238	-63%	3.23	0.97	-2.25	-70%	1106	692	-414	-37%
Engine Mechanical	pre-1980	5015	7	849	99	-750	-88%	2.67	0.73	-1.94	-73%	937	799	-138	-15%
Emissions System	pre-1980	5015	113	332	121	-211	-64%	1.42	0.52	-0.91	-64%	2100	937	-1164	-55%
Emissions System & Misc	pre-1980	5015	3	71	124	53	75%	0.03	0.18	0.15	500%	2771	2049	-722	-26%
Ignition/Electrical System	pre-1980	5015	64	515	121	-395	-77%	1.96	0.47	-1.49	-76%	1213	836	-377	-31%
Fuel System	pre-1980	5015	77	513	146	-368	-72%	2.71	0.67	-2.04	-75%	750	712	-38	-5%
Fuel System & Emissions System	pre-1980	5015	1	397	384	-13	-3%	9.4	9.7	0.3	3%	407	108	-299	-73%
Miscellaneous	1980-1989	5015	13878	229	85	-145	-63%	1.81	0.4	-1.41	-78%	1244	581	-663	-53%
Engine Mechanical	1980-1989	5015	1014	254	83	-172	-68%	2	0.38	-1.62	-81%	1188	562	-626	-53%
Emissions System	1980-1989	5015	33682	220	82	-138	-63%	1.42	0.28	-1.14	-80%	1554	567	-988	-64%
Emissions System & Misc	1980-1989	5015	1487	210	82	-127	-60%	1.82	0.43	-1.39	-76%	1482	640	-842	-57%
Ignition/Electrical System	1980-1989	5015	12754	314	85	-229	-73%	1.94	0.33	-1.61	-83%	964	503	-461	-48%
Fuel System	1980-1989	5015	11420	235	79	-156	-66%	2.19	0.37	-1.82	-83%	971	516	-455	-47%
Fuel System & Emissions System	1980-1989	5015	1078	206	86	-121	-59%	2.04	0.42	-1.62	-79%	1195	606	-589	-49%
Miscellaneous	1990-1999	5015	67424	76	32	-43	-57%	0.45	0.12	-0.34	-76%	611	246	-364	-60%
Engine Mechanical	1990-1999	5015	4213	102	31	-71	-70%	0.54	0.1	-0.43	-80%	603	225	-378	-63%
Emissions System	1990-1999	5015	134348	109	43	-66	-61%	0.52	0.11	-0.41	-79%	1025	332	-692	-68%
Emissions System & Misc	1990-1999	5015	4598	116	52	-64	-55%	0.65	0.2	-0.45	-69%	1156	452	-703	-61%
Ignition/Electrical System	1990-1999	5015	42260	159	47	-112	-70%	0.74	0.14	-0.6	-81%	707	292	-415	-59%

Repair Slate	Model Year	ASM Mode	N	HC (ppm)				CO (%)				NO (ppm)			
				Before Repair	After Repair	Change Conc.	Change (%)	Before Repair	After Repair	Change Conc.	Change (%)	Before Repair	After Repair	Change Conc.	Change (%)
Fuel System	1990-1999	5015	49954	88	31	-57	-65%	0.57	0.1	-0.48	-84%	542	225	-317	-58%
Fuel System & Emissions System	1990-1999	5015	2868	124	49	-75	-60%	0.75	0.17	-0.59	-79%	1016	383	-634	-62%
Miscellaneous	post-1999	5015	17669	0.2	0.4	0.2	100%	0.001	0.001	0	0%	2	3	1.2	60%
Engine Mechanical	post-1999	5015	834	0.7	0.2	-0.6	-86%	0.008	0.001	-0.007	-88%	4	3	-0.2	-5%
Emissions System	post-1999	5015	19270	0.4	0.5	0.1	25%	0.003	0.002	-0.001	-33%	4	3	-0.7	-18%
Emissions System & Misc	post-1999	5015	324	0.4	0.7	0.3	75%	0.002	0.002	0	0%	4	6	1.2	30%
Ignition/Electrical System	post-1999	5015	5882	0.5	0.5	0	0%	0.002	0.002	0	0%	3	3	0.7	23%
Fuel System	post-1999	5015	11848	0.3	0.5	0.2	67%	0.003	0.002	-0.001	-33%	3	3	0	0%
Fuel System & Emissions System	post-1999	5015	224	0.4	1.1	0.7	175%	0.001	0.003	0.002	200%	6	10	4.1	68%
Miscellaneous	pre-1980	2525	54	375	121	-254	-68%	3.08	0.83	-2.25	-73%	1079	606	-472	-44%
Engine Mechanical	pre-1980	2525	7	847	88	-760	-90%	3.22	0.85	-2.37	-74%	911	585	-326	-36%
Emissions System	pre-1980	2525	113	294	103	-191	-65%	1.39	0.52	-0.87	-63%	1938	818	-1120	-58%
Emissions System & Misc	pre-1980	2525	3	63	102	39	62%	0.2	0.16	-0.04	-20%	2696	1665	-1031	-38%
Ignition/Electrical System	pre-1980	2525	64	417	103	-314	-75%	1.93	0.52	-1.41	-73%	967	730	-237	-25%
Fuel System	pre-1980	2525	77	447	128	-319	-71%	2.42	0.66	-1.76	-73%	709	650	-59	-8%
Fuel System & Emissions System	pre-1980	2525	1	357	384	27	8%	9.7	10.1	0.4	4%	416	126	-290	-70%
Miscellaneous	1980-1989	2525	13878	208	66	-141	-68%	1.74	0.36	-1.38	-79%	1104	481	-623	-56%
Engine Mechanical	1980-1989	2525	1014	232	64	-169	-73%	1.97	0.33	-1.64	-83%	1086	466	-620	-57%
Emissions System	1980-1989	2525	33682	197	62	-135	-69%	1.34	0.25	-1.1	-82%	1381	462	-920	-67%
Emissions System & Misc	1980-1989	2525	1487	193	64	-129	-67%	1.74	0.38	-1.36	-78%	1323	516	-807	-61%
Ignition/Electrical System	1980-1989	2525	12754	278	66	-212	-76%	1.85	0.3	-1.55	-84%	846	410	-436	-52%
Fuel System	1980-1989	2525	11420	217	63	-154	-71%	2.1	0.33	-1.77	-84%	864	428	-437	-51%

Repair Slate	Model Year	ASM Mode	N	HC (ppm)				CO (%)				NO (ppm)			
				Before Repair	After Repair	Change Conc.	Change (%)	Before Repair	After Repair	Change Conc.	Change (%)	Before Repair	After Repair	Change Conc.	Change (%)
Fuel System & Emissions System	1980-1989	2525	1078	191	68	-124	-65%	1.99	0.37	-1.62	-81%	1042	501	-541	-52%
Miscellaneous	1990-1999	2525	67424	64	23	-42	-66%	0.44	0.09	-0.35	-80%	532	198	-334	-63%
Engine Mechanical	1990-1999	2525	4213	86	22	-64	-74%	0.51	0.08	-0.43	-84%	533	178	-355	-67%
Emissions System	1990-1999	2525	134348	91	30	-61	-67%	0.49	0.09	-0.4	-82%	896	264	-632	-71%
Emissions System & Misc	1990-1999	2525	4598	98	36	-62	-63%	0.61	0.16	-0.45	-74%	1030	376	-655	-64%
Ignition/Electrical System	1990-1999	2525	42260	130	33	-97	-75%	0.69	0.12	-0.58	-84%	590	232	-358	-61%
Fuel System	1990-1999	2525	49954	74	22	-52	-70%	0.55	0.08	-0.47	-85%	466	178	-288	-62%
Fuel System & Emissions System	1990-1999	2525	2868	107	37	-70	-65%	0.71	0.14	-0.57	-80%	918	311	-607	-66%
Miscellaneous	post-1999	2525	17669	0.2	0.3	0.1	50%	0.002	0.001	-0.001	-50%	1.9	2.5	0.6	32%
Engine Mechanical	post-1999	2525	834	0.9	0.2	-0.7	-78%	0.016	0.001	-0.015	-94%	3.6	0.3	-3.3	-92%
Emissions System	post-1999	2525	19270	0.4	0.3	-0.1	-25%	0.004	0.002	-0.002	-50%	3.5	2.6	-0.9	-26%
Emissions System & Misc	post-1999	2525	324	0.2	0.5	0.3	150%	0.001	0.001	0	0%	0.7	5.4	4.7	671%
Ignition/Electrical System	post-1999	2525	5882	0.4	0.3	-0.1	-25%	0.002	0.001	-0.001	-50%	2.2	2.3	0	0%
Fuel System	post-1999	2525	11848	0.2	0.3	0.1	50%	0.002	0.002	-0.001	-50%	2.8	2.3	-0.6	-21%
Fuel System & Emissions System	post-1999	2525	224	3.1	0.9	-2.3	-74%	0.001	0.003	0.002	200%	13.2	8.7	-4.5	-34%

b) Current 2008 Texas Data

Repair Slate	Model Year	ASM Mode	N	HC (ppm)				CO (%)				NO (ppm)			
				Before Repair	After Repair	Change		Before Repair	After Repair	Change		Before Repair	After Repair	Change	
						Conc.	(%)			Conc.	(%)			Conc.	(%)
Miscellaneous	1980-1989	5015	5747	212	83	-129	-61%	1.76	0.36	-1.40	-80%	1129	523	-606	-54%
Engine Mechanical	1980-1989	5015	339	251	80	-171	-68%	1.90	0.35	-1.55	-81%	1080	499	-582	-54%
Emissions System	1980-1989	5015	9778	211	76	-136	-64%	1.50	0.28	-1.22	-81%	1430	519	-912	-64%
Emissions System & Misc	1980-1989	5015	548	196	92	-103	-53%	1.83	0.46	-1.37	-75%	1274	530	-744	-58%
Ignition/Electrical System	1980-1989	5015	3776	287	76	-211	-74%	1.97	0.32	-1.65	-84%	870	458	-412	-47%
Fuel System	1980-1989	5015	3151	215	79	-136	-63%	2.12	0.37	-1.76	-83%	928	502	-426	-46%
Fuel System & Emissions System	1980-1989	5015	306	290	80	-210	-72%	2.28	0.41	-1.87	-82%	1071	513	-559	-52%
Miscellaneous	1990-1999	5015	57080	63	27	-36	-57%	0.38	0.10	-0.28	-75%	498	194	-304	-61%
Engine Mechanical	1990-1999	5015	2906	82	33	-49	-60%	0.47	0.10	-0.37	-78%	544	213	-331	-61%
Emissions System	1990-1999	5015	77433	92	38	-54	-59%	0.49	0.11	-0.38	-77%	909	290	-619	-68%
Emissions System & Misc	1990-1999	5015	3052	113	51	-62	-55%	0.64	0.16	-0.48	-75%	1055	391	-665	-63%
Ignition/Electrical System	1990-1999	5015	23786	130	41	-90	-69%	0.72	0.14	-0.58	-81%	600	255	-346	-58%
Fuel System	1990-1999	5015	27803	68	27	-41	-61%	0.50	0.09	-0.41	-81%	447	183	-264	-59%
Fuel System & Emissions System	1990-1999	5015	1583	114	49	-65	-57%	0.73	0.15	-0.57	-79%	1012	367	-645	-64%
Miscellaneous	post-2000	5015	46121	0.4	0.8	0.5	118%	0.003	0.003	0.000	-4%	4	5	1.1	26%
Engine Mechanical	post-2000	5015	1858	0.6	1.8	1.2	197%	0.003	0.006	0.003	109%	6	12	5.4	85%
Emissions System	post-2000	5015	34175	0.9	1.4	0.5	50%	0.007	0.004	-0.003	-38%	9	9	-0.6	-7%
Emissions System & Misc	post-2000	5015	741	0.3	2.4	2.1	775%	0.003	0.007	0.004	108%	5	13	8.1	167%
Ignition/Electrical System	post-2000	5015	10955	1.6	1.6	0.0	1%	0.013	0.005	-0.008	-61%	8	11	3.1	40%
Fuel System	post-2000	5015	21048	0.5	1.0	0.5	106%	0.005	0.003	-0.002	-35%	4	7	2.7	66%
Fuel System & Emissions System	post-2000	5015	362	0.8	1.8	0.9	113%	0.014	0.007	-0.007	-50%	10	11	1.7	18%
Miscellaneous	1980-1989	2525	5747	192	65	-127	-66%	1.71	0.32	-1.39	-81%	977	420	-557	-57%
Engine Mechanical	1980-1989	2525	339	228	64	-164	-72%	1.84	0.34	-1.50	-81%	912	407	-506	-55%
Emissions System	1980-1989	2525	9778	190	58	-132	-69%	1.44	0.23	-1.20	-84%	1246	410	-836	-67%

Repair Slate	Model Year	ASM Mode	N	HC (ppm)				CO (%)				NO (ppm)			
				Before Repair	After Repair	Change		Before Repair	After Repair	Change		Before Repair	After Repair	Change	
						Conc.	(%)			Conc.	(%)			Conc.	(%)
Emissions System & Misc	1980-1989	2525	548	190	78	-112	-59%	1.85	0.42	-1.42	-77%	1104	424	-680	-62%
Ignition/Electrical System	1980-1989	2525	3776	261	60	-201	-77%	1.88	0.29	-1.59	-85%	739	361	-377	-51%
Fuel System	1980-1989	2525	3151	194	64	-130	-67%	2.01	0.33	-1.67	-83%	806	399	-407	-51%
Fuel System & Emissions System	1980-1989	2525	306	220	60	-160	-73%	2.13	0.37	-1.76	-83%	896	403	-492	-55%
Miscellaneous	1990-1999	2525	57080	54	20	-34	-64%	0.37	0.08	-0.29	-79%	425	151	-275	-65%
Engine Mechanical	1990-1999	2525	2906	74	23	-51	-69%	0.45	0.08	-0.37	-82%	464	157	-307	-66%
Emissions System	1990-1999	2525	77433	79	26	-53	-67%	0.46	0.09	-0.37	-81%	774	219	-555	-72%
Emissions System & Misc	1990-1999	2525	3052	98	37	-61	-62%	0.62	0.13	-0.49	-79%	924	305	-619	-67%
Ignition/Electrical System	1990-1999	2525	23786	113	29	-84	-74%	0.69	0.11	-0.58	-84%	494	192	-301	-61%
Fuel System	1990-1999	2525	27803	60	19	-41	-68%	0.48	0.08	-0.40	-84%	372	139	-233	-63%
Fuel System & Emissions System	1990-1999	2525	1583	102	37	-64	-63%	0.72	0.12	-0.60	-84%	871	288	-583	-67%
Miscellaneous	post-2000	2525	46121	0.4	0.6	0.2	66%	0.002	0.002	0.000	-8%	4	4	0.1	3%
Engine Mechanical	post-2000	2525	1858	0.5	1.1	0.6	115%	0.003	0.004	0.001	39%	6	7	0.9	15%
Emissions System	post-2000	2525	34175	0.9	1.0	0.1	10%	0.007	0.003	-0.003	-53%	8	6	-2.1	-25%
Emissions System & Misc	post-2000	2525	741	0.2	1.6	1.4	623%	0.003	0.004	0.001	53%	5	12	6.8	139%
Ignition/Electrical System	post-2000	2525	10955	1.3	1.0	-0.3	-20%	0.012	0.003	-0.009	-71%	6	8	1.7	28%
Fuel System	post-2000	2525	21048	0.4	0.6	0.2	42%	0.005	0.002	-0.003	-56%	4	5	1.1	29%
Fuel System & Emissions System	post-2000	2525	362	0.7	1.4	0.7	111%	0.013	0.005	-0.007	-59%	8	11	2.5	30%

Issues with the Repair Data in the TIMS and RERF Datasets

There are several issues with the repair data contained in both the TIMS and RERF datasets that make analysis difficult. Future changes in the way data is collected and stored may alleviate many of these issues. These issues are described below and are very similar to those listed in the 2006 Report.

TIMS Dataset – A general problem with the TIMS dataset is that only five different repair types are accounted for, and these types are too general to permit a detailed analysis of the data. These types include fuel system, ignition/electrical system, emissions system, engine mechanical, and miscellaneous. As listed in Table 4-1, "miscellaneous" repairs make up almost one third of the reported repairs. The addition of more detailed repair types during the collection of data would allow for more specificity in analysis. Previously, the Texas I/M program did have a more detailed list of repair types. However, because TCEQ believed that a large fraction of inspectors did not fill out the repair list correctly, TCEQ adopted the simpler list which was used during this evaluation period.

It is recommended that Texas use more specific repair categories in the software to ask inspectors, "Which of the following repairs were performed?" An "Other" category should not be provided since that does not provide any useful information. The repair choices that inspectors see and choose from should be only those that apply to the technology of the vehicle being inspected. The answers to this question should be convenient for the inspector to use and will provide the repairs that are known to most greatly affect tailpipe emissions.

Another problem, described in the costs section below, exists in the reported values of repair costs. A large number of repairs with a cost of $0 exists in the dataset, along with some extremely high (greater than $2,000) costs as well. The source of these errors is not clear, but the erroneous costs make it difficult to comprehensively assess costs across the entire dataset.

RERF Dataset – The RERF dataset, while very specific with respect to the type of repair performed, lacks cost information for each individual repair performed. Repair costs are only reported as a total of all repairs performed each time a particular vehicle reports to a RERF.

It should also be noted that while the RERF dataset contains extensive vehicle, facility, and cost information, no emissions data from I/M testing is available in it.

4.3 Overall Success of Repairs to Vehicles Failing OBD

The objective of this task was to determine whether vehicles failing the OBD inspection are being properly repaired. ERG performed an analysis of the TIMS data for OBD failures and the presence of an illuminated MIL and diagnostic test codes before the repair and their non-existence after the repair. This will provide evidence that the I/M program is having a positive effect on the fleet. This analysis is analogous to the tailpipe emissions changes observed with repairs in Section 4.2.

Since OBD test pass/fail results are not enforced on Class 2 vehicles (vehicles over 8500 lbs GVWR), Class 2 vehicles were excluded from this analysis. This left a dataset of 12,985,807 OBD inspection records available for the analysis.

Analysis and Results

For this task, ERG analyzed vehicle inspection records to identify tests with OBD failures, and then determine how many of those failures were subsequently corrected. To exclude test failures associated with readiness, test failures due to OBD/analyzer communication problems, and OBD tests failures converted to ASM tests, some very specific definitions of OBD "fail" and "pass" were created. An OBD test failure was defined to be any test record with one or more stored DTCs, coinciding with the OBD MIL command status of "on," an OBD test disposition of "fail," and an overall test disposition of "fail." A passing result for an OBD test was defined as a downloaded OBD MIL commanded status of "off" and an OBD test disposition of "pass". These new definitions were needed in order to fully control the analysis of MIL status, but they did leave some inspections that did not qualify as either a full "fail" or a full "pass" (i.e., OBD test was passed but overall I/M test was failed, etc).

Next, all individual vehicle I/M cycles that contained at least one failed OBD test were identified. I/M cycles were defined to be a single test, or a series of tests, performed on a vehicle until the vehicle passed the overall inspection and received a certificate or until the vehicle received a waiver and a certificate (or until March 31, 2009, the end of the evaluation period). Thus, if a vehicle failed the initial OBD test, the I/M cycle for that vehicle would be the initial failure, and any and all subsequent tests, until the vehicle passed its inspection and received a certificate, until a waiver and certificate were granted, or until the end of the evaluation period. Once the vehicle was issued a certificate, its next test (most likely for the following year's I/M inspection) would be a new I/M cycle. Any I/M cycles that began on or after January 1, 2009, were excluded from the analysis, since it would be possible that cycles starting so near the end of the date range of the dataset could have included additional re-inspections after March 31, 2009,

and there would be no information for those inspections. There were 10,737,242 I/M cycles that started before January 1, 2009, in the dataset.

After grouping by I/M cycle for vehicles with OBD failures (as previously defined), 193,791 I/M cycles were seen to include at least one failed OBD test. Of these cycles, 154,765 (79.9%) had a final OBD test disposition of "pass," which for purposes of this analysis was defined as a test with a downloaded MIL status of "pass" (MIL not commanded on) and an OBD test disposition of "pass." The remaining 39,026 vehicles never received repairs sufficient to extinguish their MILs and pass the OBD test; for these vehicles it was learned that:

- 30,004 of them received the initial failing result but did not ever report for a re-inspection.
- Around 1,400 of them received a re-inspection as a Heavy Duty vehicle, which they were able to pass (see Section 6 for a discussion of various means for identifying fraudulent inspections).
- Additional re-inspections may have occurred after March 31, 2009, which would increase the overall "repaired" numbers.

It should be noted that the two allowed unset monitors could mask existing malfunctions in some of these repaired outcomes. The influence of this masking will be explored in Section 4.4.

4.4 Success of Repairs to Specific Emission Control Systems Failing OBD

An analysis of evaporative OBD diagnostic codes and their associated repairs was also performed. Some OBD diagnostic test codes are related to evaporative emissions control components on vehicles. An analysis of the TIMS will reveal those instances where these codes were found before repair and were non-existent after repairs were made.

The objective of this task was to review vehicle inspection results to identify OBD test failures associated with evaporative emissions control systems (evap system). The extent of failures associated with evap systems was quantified, and analysis of subsequent test results was performed to indicate how effective the program is in correcting the evap systems problems.

The effectiveness of repairing some other types of failures was also explored, and a comparison was also made between gas cap test results and OBD evap system results.

Analysis and Results

This task was performed as a continuation of the analysis in Section 4.3. It uses combinations of vehicle and I/M cycle defined in that section. However, for this task, failure modes were assigned to failing inspection records based on the DTCs contained in the failed test records. In addition to analysis of test records with evap system failures (failures with DTCs within the range of P0440 - P0455), analysis was also performed to identify and quantify repairs for the following types of OBD failures:

- Codes pertaining to insufficient oxygen sensor performance (DTCs within the range of P0130 through P0167),
- Codes pertaining to exhaust gas recirculation (EGR) malfunctions (DTCs within the range of P0400 through P0408),
- Codes pertaining to secondary air injection system (AI) malfunctions (DTCs within the range of P0410 through P0417), and
- Codes pertaining to insufficient catalytic converter (catalyst) performance (DTCs within the range of P0420 through P0434)

These four additional categories of codes were included with this analysis because the "readiness status" of these systems, as well as the evap system, is specifically monitored by non-continuous monitors; therefore, the extent to which malfunctions may be masked by unset readiness monitors during a retest, which could result in a false pass, can be quantified. In this analysis, the extent of this potential masking is quantified along with the overall repair rates.

For each of the failure categories, a failed inspection is defined as any inspection that contains at least one test record with stored DTCs, a downloaded OBD MIL commanded status of "on," an OBD test disposition of "fail," and an overall test disposition of "fail." Passed inspections were those which had a final test in that I/M cycle with a downloaded MIL status of "pass" (not commanded on) and an OBD test disposition of "pass."

To quantify the upper limit to which readiness may be masking unrepaired malfunctions during OBD retests, the following distinctions of "repaired" vehicles were made:

- **Total Repaired –** This is the count of all vehicles that had at least one fail test with the final test classified as repaired. No regard is given to which (if any) monitors remain unset.
- **Repaired with Unset Monitors –** This is the count of all "repaired" vehicles that have an unset monitor that may be masking the failure mode seen in the initial fail test. For example, if a vehicle fails for an evap system malfunction, then the evap

system monitor is unset on the final "pass" test for this vehicle, thereby possibly masking an unrepaired evap system malfunction. Once this monitor becomes set, any unrepaired malfunction would result in a stored evap system DTC and MIL re-illumination.

- **Confirmed Repaired –** These are the vehicles whose monitors for which the initial failure occurred are set in the final test, indicating that specific type of failure is not being masked by an unset readiness code. Therefore, there is much higher confidence that these "confirmed repaired" vehicles are indeed properly repaired.

During this analysis of readiness status, some vehicles that failed for a certain system (e.g., EGR) were found to have a "not monitored" status for that monitored system (e.g., EGR not monitored). This is likely due to erroneous readiness status retrieved from certain vehicles and stored in that vehicle's test record. Since by definition this is impossible (a system with a stored code must be monitored), this subset of results was classified as "ready."

With regard to criteria used for categorizing "pass" and "fail" tests, it should also be noted that pending DTCs (also referred to as "soft" DTCs) are trouble codes that are insufficient for illuminating the MIL, generally because the number of successive repeat failures necessary for MIL illumination has not occurred. In accordance with EPA guidance, vehicles are not failed for pending DTCs (stored DTCs but no MIL illumination) in the Texas program. Results from this repair analysis follows that strategy, and therefore only defines tests with MIL illumination and stored DTCs as "fail" tests, and only considers MIL illumination (without regard to stored DTCs) in determining whether a vehicle is successfully repaired.

Finally, it should be kept in mind that when reviewing repair analysis results, a failed OBD test record could contain more than one DTC. In Texas, up to 10 DTCs may be stored in the test record, and all stored DTCs were used for this analysis. Therefore, some vehicles will be included in more than one set of results. For example, repair results for vehicles with both oxygen sensor DTCs and catalytic converter DTCs will be included in both the oxygen sensor repair analysis and the catalytic converter repair analysis. Because of the inter-dependence of the various systems (e.g., an oxygen sensor failure may lead to a future catalytic converter failure), distinctions were not made regarding the number or types of DTCs in the original fail records. Rather, vehicles were categorized as "repaired" when the MIL was extinguished and the analyzer assigned an overall OBD pass result, regardless of the number or type of DTCs seen in the initial test failure.

Table 4-7 provides a summary of vehicle repairs performed over the period of evaluation. Since this analysis was performed on 2007 through March 31, 2009, data, it is possible that some of the un-repaired vehicles were repaired later in 2009. This would increase the "repaired" counts from the numbers shown in this table.

Table 4-7. System Specific Repair Analysis for Vehicles

Type of Failure (DTC category)	Total vehicles failed (with indicated failure mode DTCs)	Total repaired vehicles (MIL off)		Repaired vehicles with failure mode monitors not yet set		Confirmed Repairs (failure mode monitors set)	
Evap System	44,085	35,667	80.9%	18,153	41.2%	17,514	39.7%
O_2 Sensor	41,393	30,967	74.8%	1,558	3.8%	29,409	71.0%
EGR System	36,840	27,227	73.9%	3,740	10.2%	23,487	63.8%
AI System	2,616	1,879	71.8%	505	19.3%	1,374	52.5%
Catalyst	43,099	32,879	76.3%	10,411	24.2%	22,468	52.1%

As previously indicated, many vehicles were failed with more than one DTC. Therefore, results from some vehicles may be included in more than one category in Table 4-7. Also, only categories directly monitored with non-continuous monitors are tabulated in Table 4-7. Other failure categories for which readiness status would be more difficult to assess are excluded from the table. Table 4-7 indicates that readiness status may be masking 4-40% of vehicles that pass OBD retests based on MIL status with these types of failures. I/M program modifications that would require confirmation of specific failure-mode monitors being set would likely reduce the extent of potential false passes but at the expense of a potential increase in motorist inconvenience especially for difficult to set monitors. ERG is not aware of any programs where this is currently performed.

A comparison was also made between OBD evap system results and gas cap test results, on a by-test basis, for all OBD tests conducted during the period of evaluation. Table 4-8 presents a summary of these results.

Table 4-8. Comparison of OBD Evaporative Emission Control System Test Results with Gas Cap Test Results

OBD Evap System Test Results	Gas Cap Test Result				Total	
	Pass		Fail			
Pass	12,705,649	98.2	115,516	0.9	12,821,165	99.1
Fail	114,948	0.9	5,209	0.04	120,157	0.9
Total	12,820,597	99.1	120,725	0.9	12,941,322	100.0

As can be seen from this table, approximately 0.9% of the tests had failed the OBD portion of the test with evap system DTCs, and gas cap failures were seen in 0.9% of the tests. The OBD evap system monitoring is designed to be a more comprehensive test since it assesses the integrity of the entire control system, but the OBD evap fail rate may be artificially lowered in part by unset evap system readiness monitors. Evap systems generally require a fairly complex series of vehicle operating conditions before this monitor is set. Although most vehicles passed both tests, very few vehicles (0.04%) failed both tests. Allowable pressure decay limits and even the manner the tests are administered may contribute to this difference in fail rates.

4.5 Average Repair Costs

Both the Texas TIMS and the RERF datasets contain costs for repairs performed. For both datasets, repair costs are manually entered by inspectors. This information was analyzed to determine the amount of money being spent by Texas motorists to repair their vehicles as a result of the I/M program.

Texas TIMS Data

To effectively analyze average change in emissions due to repairs, as well as repair costs, repair slates were determined for each vehicle for a given I/M cycle. A repair slate is a concatenation of the set of repair types performed in a repair event. In the Texas TIMS data, the five different repairs types listed in Table 4-1 were combined to produce the seven most common repair slates, which account for approximately 98% of all vehicle and I/M cycle combinations. These slates are presented in Table 4-9.

Approximately one-third of the repair costs in the Texas TIMS were recorded as $0. It is not clear why this is the case. Because of the large number of repair records affected, no attempt was made to correct the costs as part of this analysis. Nonetheless, the existence of so many repair costs with a value of $0 significantly affected the average and median repair values calculated. Table 4-9 presents the number of records with a cost of $0 by repair slate. Note that about 13-27 % of most slates listed contained $0 repair costs, but fuel system and miscellaneous repairs contained a much higher percentage (about 38% and 58%, respectively).

It was also noted than many of the repair costs listed in the TIMS seemed to be unusually large; many records were in excess of $2000, with some as high as $100,000. It is suspected that these repair costs reflect data entry errors by on-site technicians. Figure 4-1 presents a plot of histogram of repairs that cost more than $2000.

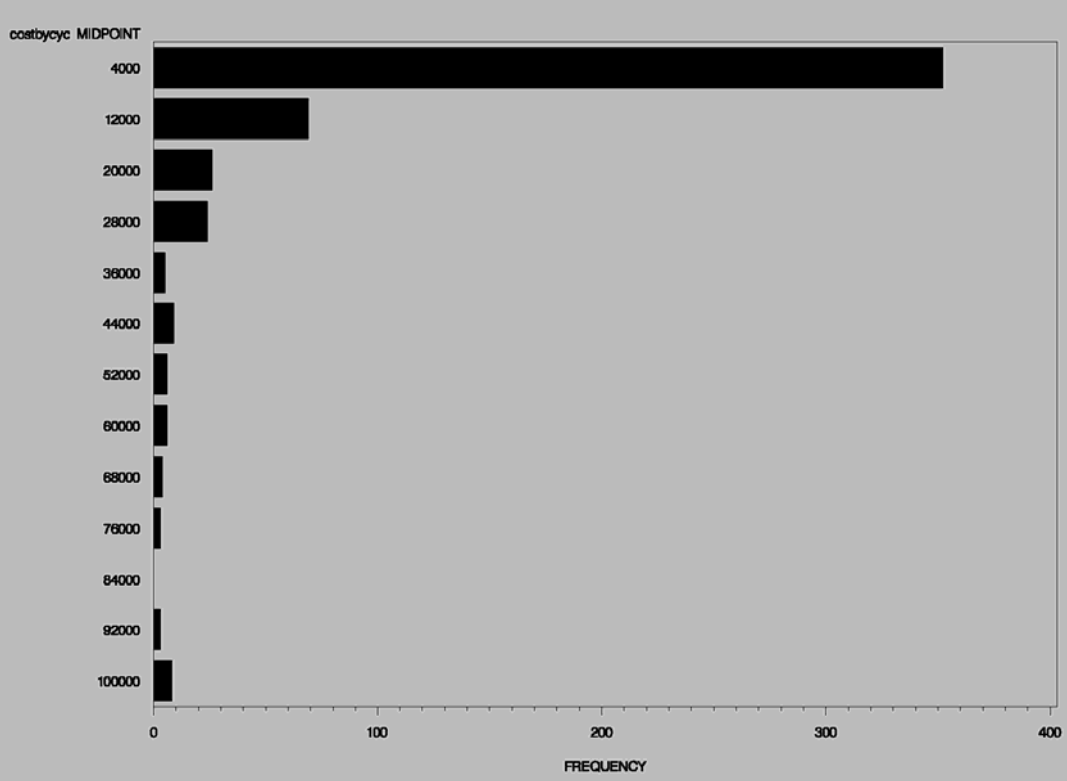
Table 4-9. TIMS Records with a Repair Cost of $0, by Slate

Repair Slate	Cost > 0	Cost = Zero	Total	% of Cost = 0
Fuel System & Emissions System	1966	290	2256	12.85
Emissions System & Miscellaneous	3764	592	4356	13.59
Engine Mechanical	4376	1585	5961	26.59
Ignition / Electrical System	33822	8959	42781	20.94
Fuel System	36017	22057	58074	37.98
Miscellaneous	53987	73272	127259	57.58
Emissions System	101116	33174	134290	24.70
Total (of Selected Repair Slates)	*235048*	*139929*	*374977*	*37.32*

Table 4-10 presents median and mean repair costs for each of the repair types specified in the Texas TIMS. Mean and median are calculated twice, once including the $0 and >$2000 repair costs found in the dataset (unedited), and once without (edited). According to the unedited dataset, vehicle owners performed 382,103 repairs while spending approximately $47.3 million. According to the edited dataset, which leaves out $0 cost and greater than 2,000 cost observations, vehicle owners performed 240,665 repairs while spending almost $41.4 million.

Figures 4-2 and 4-3 present mean repair costs by inspection year and model year, for both the unedited and edited TIMS datasets. There is a significant amount of variability in the unedited data when compared to the edited data. As shown by these plots, repair costs as a whole have not increased from year to year.

Figure 4-1. Repairs with Cost Greater than $2000



costbycyc MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
4000	352	352	68.35	68.35
12000	69	421	13.40	81.75
20000	26	447	5.05	86.80
28000	24	471	4.66	91.46
36000	5	476	0.97	92.43
44000	9	485	1.75	94.17
52000	6	491	1.17	95.34
60000	6	497	1.17	96.50
68000	4	501	0.78	97.28
76000	3	504	0.58	97.86
84000	0	504	0.00	97.86
92000	3	507	0.58	98.45
100000	8	515	1.55	100.00

/proj1/TCEQ_2008IMEVAL/e2_Repair/ABE_CountCostEmiss/proc2A.sas 24OCT09 21:50

Table 4-10. Average Repair Costs

		Original Dataset			Costs Between $0 and $2000		
Year of Inspection	**Repair Slate**	**Number of Repairs**	**Median Repair Cost**	**Mean Repair Cost**	**Number of Repairs**	**Median Repair Cost**	**Mean Repair Cost**
2006 (Oct 1 - Dec 31)	Fuel System and Emissions System	252	$200	$245	214	$225	$289
2006 (Oct 1 - Dec 31)	Emissions System & Miscellaneous	463	$152	$463	408	$178	$232
2006 (Oct 1 - Dec 31)	Engine Mechanical	624	$75	$184	401	$150	$266
2006 (Oct 1 - Dec 31)	Ignition / Electrical System	4757	$85	$129	4001	$100	$152
2006 (Oct 1 - Dec 31)	Fuel System	5941	$45	$116	3869	$100	$152
2006 (Oct 1 - Dec 31)	Miscellaneous	10816	$0	$65	4828	$50	$98
2006 (Oct 1 - Dec 31)	Emissions System	14614	$125	$167	11326	$150	$208
2007	Fuel System and Emissions System	1016	$195	$271	900	$220	$293
2007	Emissions System & Miscellaneous	1819	$152	$216	1573	$180	$239
2007	Engine Mechanical	2540	$86	$192	1790	$144	$239
2007	Ignition / Electrical System	17100	$85	$148	13803	$109	$156
2007	Fuel System	23421	$40	$125	14841	$115	$163
2007	Miscellaneous	47787	$0	$50	20990	$50	$96
2007	Emissions System	56617	$125	$177	43182	$150	$211
2008	Fuel System and Emissions System	796	$197	$250	682	$225	$292
2008	Emissions System & Miscellaneous	1635	$160	$238	1396	$190	$250
2008	Engine Mechanical	2127	$105	$245	1615	$150	$247
2008	Ignition / Electrical System	16349	$80	$132	12607	$112	$155
2008	Fuel System	22263	$25	$124	13583	$101	$153
2008	Miscellaneous	52401	$0	$46	21792	$50	$95
2008	Emissions System	49134	$120	$177	36491	$152	$211
2009 (Jan 1 - Mar 31)	Fuel System and Emissions System	192	$168	$237	166	$200	$274
2009 (Jan 1 - Mar 31)	Emissions System & Miscellaneous	439	$152	$420	370	$179	$244
2009 (Jan 1 - Mar 31)	Engine Mechanical	670	$120	$227	524	$150	$253
2009 (Jan 1 - Mar 31)	Ignition / Electrical System	4575	$73	$131	3359	$104	$155
2009 (Jan 1 - Mar 31)	Fuel System	6449	$12	$98	3645	$102	$155
2009 (Jan 1 - Mar 31)	Miscellaneous	16255	$0	$41	6276	$45	$89
2009 (Jan 1 - Mar 31)	Emissions System	13925	$120	$165	9940	$157	$216

Figure 4-2. Mean Repair Costs by Model Year and Inspection Year (Unedited Dataset)

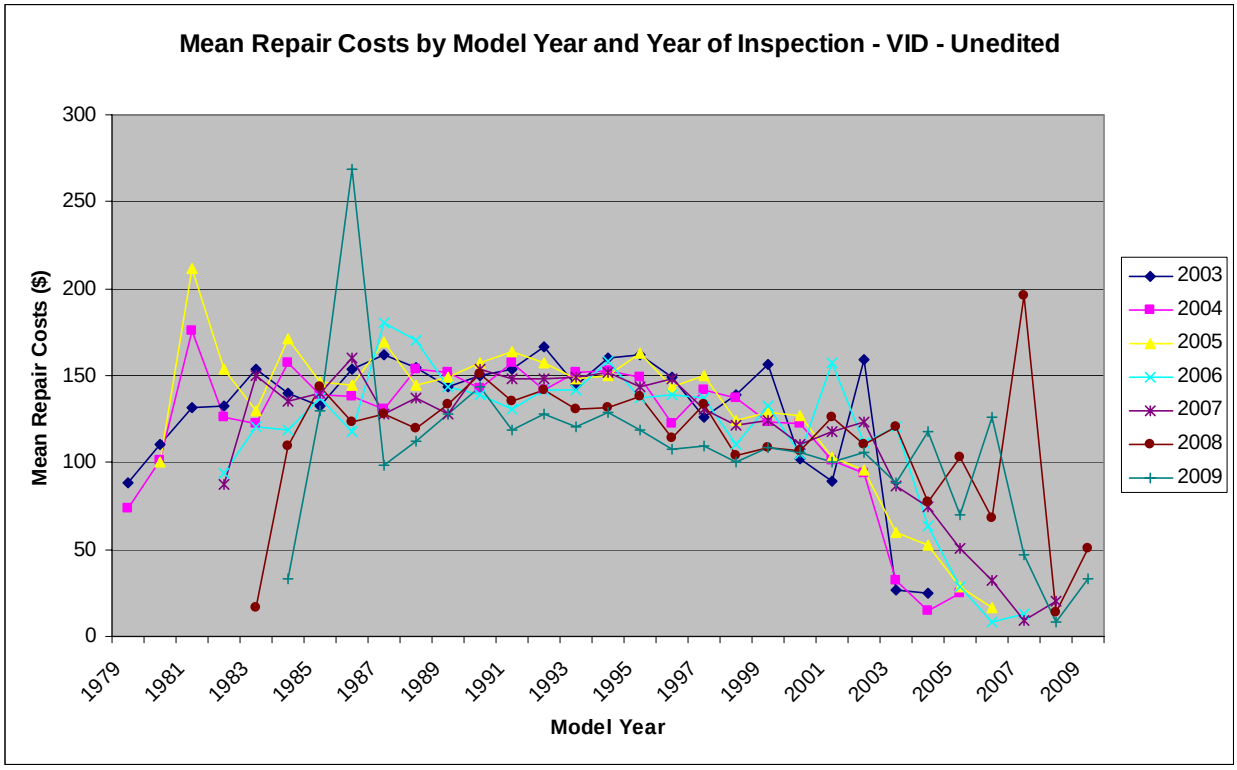
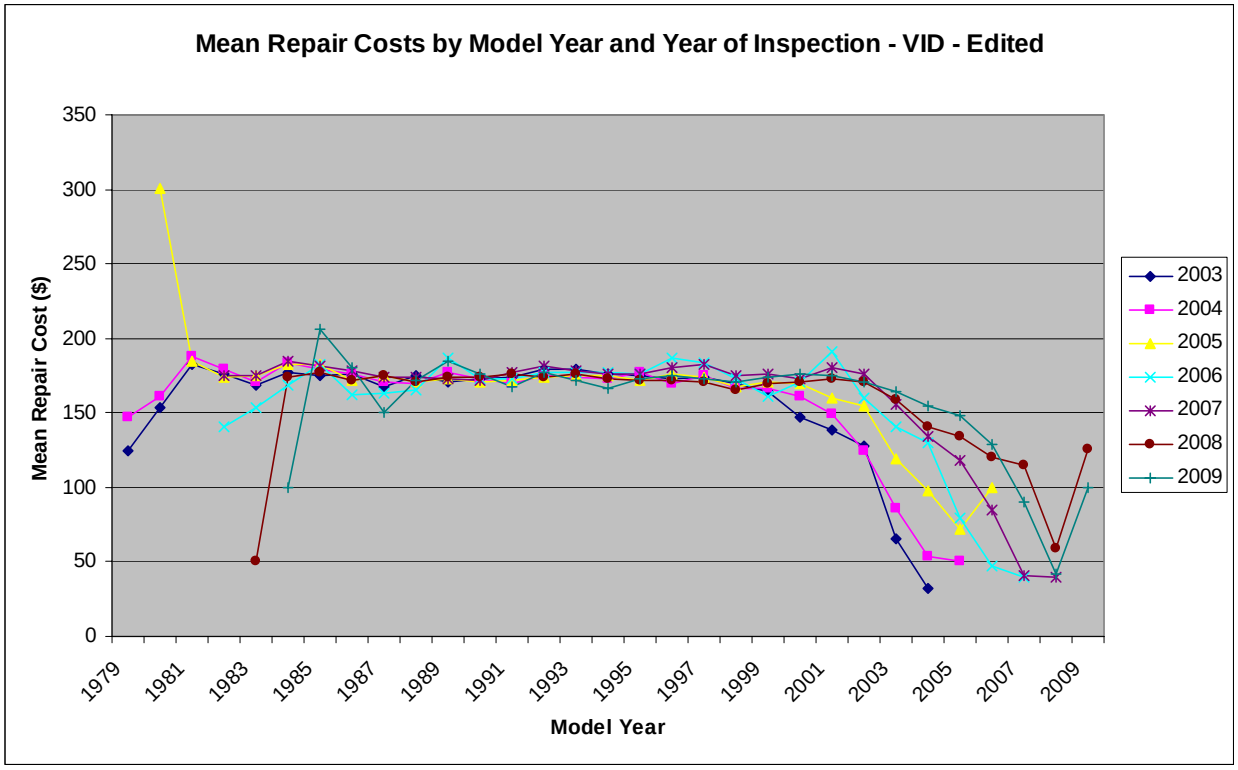


Figure 4-3. Mean Repair Costs by Model Year and Inspection Year (Edited Dataset)



Figures 4-4 and 4-5 present the percentile distribution of repair costs for the most common TIMS repair slates, for both the unedited and edited datasets. The unedited data contains repairs with an average cost of $0 for all repair slates, but miscellaneous repairs costing $0 extend well into the 50th percentile, considerably more than the other slates.

For both datasets, the range of average costs was most limited for miscellaneous repairs, while the greatest variation in average costs was visible in repairs performed on both the fuel and emissions systems.

Figure 4-4. Distribution of Repair Costs by Slate (Unedited Dataset)

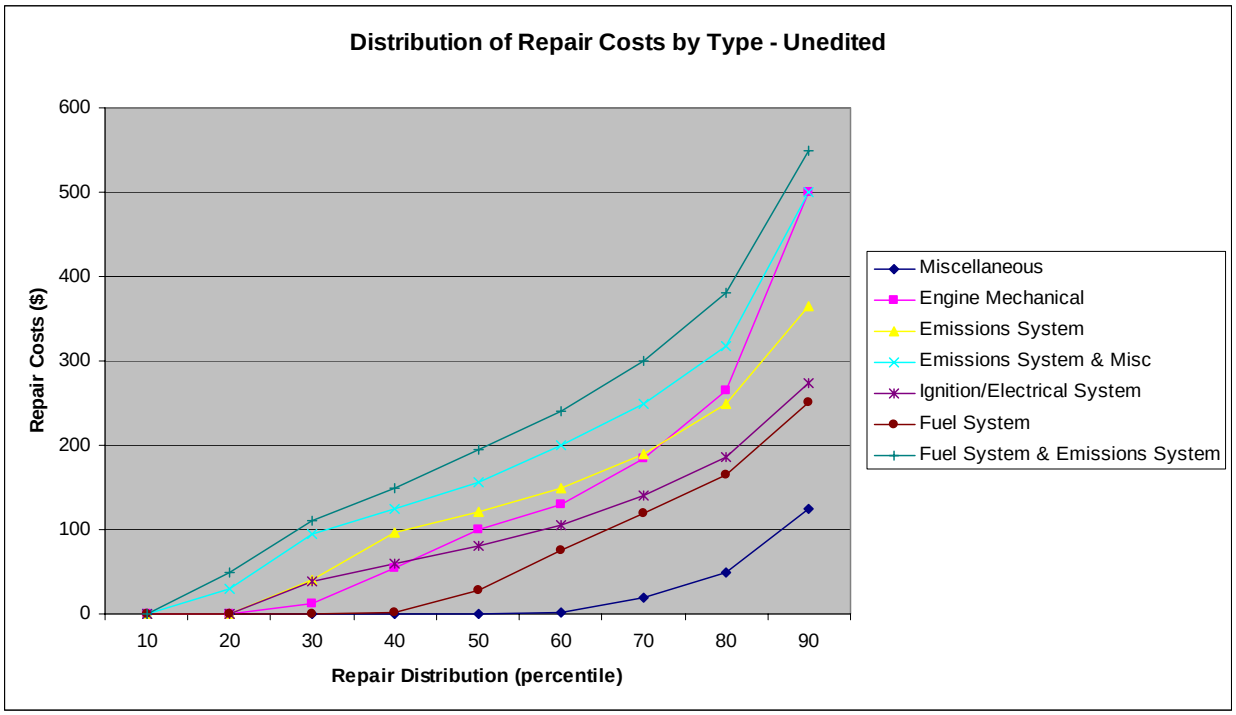
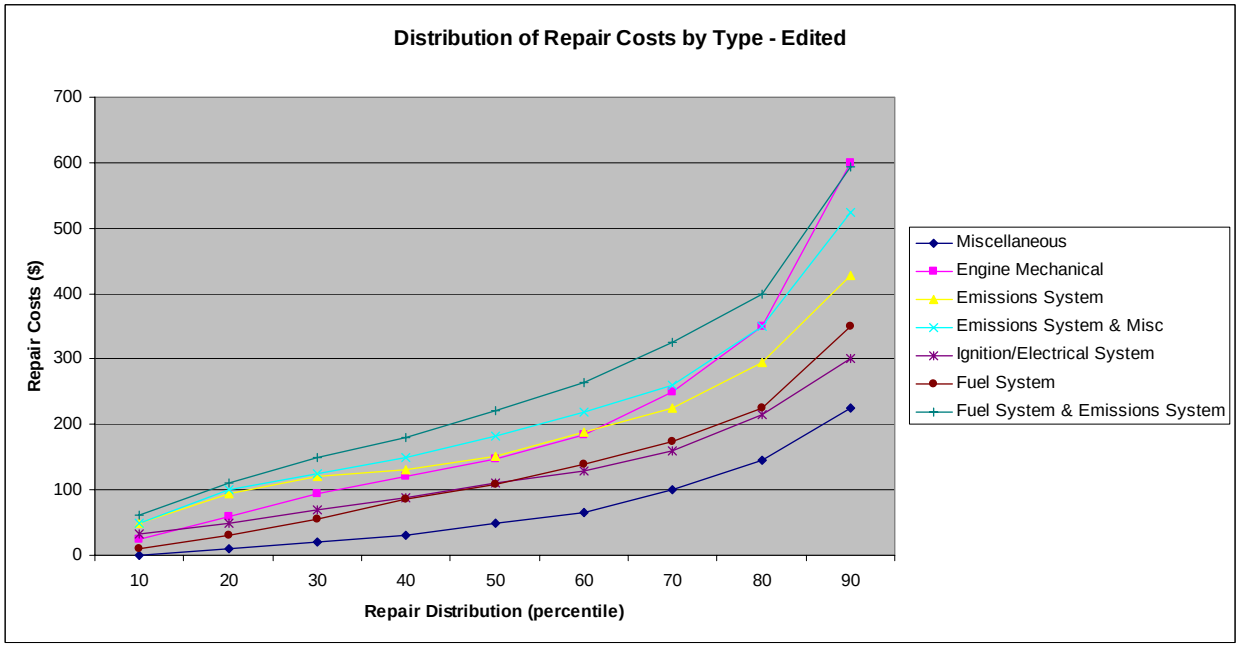


Figure 4-5. Distribution of Repair Costs by Slate (Edited Dataset)



RERF Data

Overall, vehicle owners spent over $12.6 million on 21,968 repairs at RERFs. The mean and median repair costs were $589 and $613, respectively.

To effectively analyze average change in emissions due to repairs, as well as repair costs, repair slates were determined for each vehicle for a given I/M cycle. A repair slate is a concatenation of the set of repair types performed in a repair event. In the RERF data, the different repair types listed in Table 4-2 were combined to produce the nine most common repair slates, which account for approximately 29% of all vehicle and I/M cycle combinations. To simplify the aggregation of individual repairs into meaningful repair slates, some repairs were combined into a single "sub-slate". For example, repairs to ignition/electrical systems, spark plugs, and spark plug wiring were all considered to be similar repairs.

The most common repair slates observed are presented in Table 4-11.

Table 4-11. Common RERF Repair Slates

Repair Slate	Frequency	Percent
Catalyst	204	2.47
Emissions System & O2 Sensor	215	2.60
Emissions System & Evap	215	2.60
EGR	219	2.65
Emissions System	223	2.70
Ignition/Electrical System/Spark Plugs	245	2.97
Fuel System	274	3.32
Emissions System & Catalyst	363	4.39
Emissions System & EGR	442	5.35
Other Repair Slates	5863	70.95

Table 4-12 presents median and mean repair costs for each of the repair slates developed for the RERF dataset.

Table 4-12. RERF Repair Slate Average Costs

Year of Inspection	Repair Slate	Number of Repairs	Median Repair Cost	Mean Repair Cost
2006 (Oct 1 - Dec 31)	Catalyst	26	$441	$406
2006 (Oct 1 - Dec 31)	EGR	32	$356	$387
2006 (Oct 1 - Dec 31)	Emissions System	31	$291	$307
2006 (Oct 1 - Dec 31)	Emissions System & Catalyst	35	$560	$544
2006 (Oct 1 - Dec 31)	Emissions System & EGR	69	$300	$373
2006 (Oct 1 - Dec 31)	Emissions System & Evap	31	$225	$291
2006 (Oct 1 - Dec 31)	Emissions System & O2 Sensor	61	$342	$388
2006 (Oct 1 - Dec 31)	Fuel System	38	$263	$372
2006 (Oct 1 - Dec 31)	Ignition/Electrical System/Spark Plugs	29	$348	$406
2006 (Oct 1 - Dec 31)	Other Repair Slates	788	$574	$539
2007	Catalyst	99	$540	$533
2007	EGR	103	$298	$383
2007	Emissions System	128	$320	$355
2007	Emissions System & Catalyst	197	$457	$508
2007	Emissions System & EGR	228	$338	$366
2007	Emissions System & Evap	99	$260	$328
2007	Emissions System & O2 Sensor	140	$352	$407
2007	Fuel System	159	$338	$388
2007	Ignition/Electrical System/Spark Plugs	119	$355	$436
2007	Other Repair Slates	2754	$590	$552
2008	Catalyst	61	$566	$585
2008	EGR	73	$369	$392
2008	Emissions System	47	$240	$299
2008	Emissions System & Catalyst	101	$552	$573
2008	Emissions System & EGR	119	$336	$380
2008	Emissions System & Evap	70	$286	$331
2008	Emissions System & O2 Sensor	13	$427	$428
2008	Fuel System	55	$440	$428
2008	Ignition/Electrical System/Spark Plugs	79	$409	$482
2008	Other Repair Slates	1759	$591	$581
2009 (Jan 1 - Mar 31)	Catalyst	18	$596	$681
2009 (Jan 1 - Mar 31)	EGR	11	$531	$535
2009 (Jan 1 - Mar 31)	Emissions System	17	$300	$566
2009 (Jan 1 - Mar 31)	Emissions System & Catalyst	30	$630	$678
2009 (Jan 1 - Mar 31)	Emissions System & EGR	26	$489	$470
2009 (Jan 1 - Mar 31)	Emissions System & Evap	15	$269	$303
2009 (Jan 1 - Mar 31)	Emissions System & O2 Sensor	1	$356	$356
2009 (Jan 1 - Mar 31)	Fuel System	22	$530	$554
2009 (Jan 1 - Mar 31)	Ignition/Electrical System/Spark Plugs	18	$418	$620
2009 (Jan 1 - Mar 31)	Other Repair Slates	562	$622	$616

Figure 4-6 presents mean repair costs by inspection year and model year, for the RERF TIMS dataset. Average repair costs tend to fall in the $400 - $600 range, which is significantly higher than the$150 - $175 range seen in the TIMS data.

Figure 4-6. Mean Repair Costs by Model Year and Inspection Year - RERF

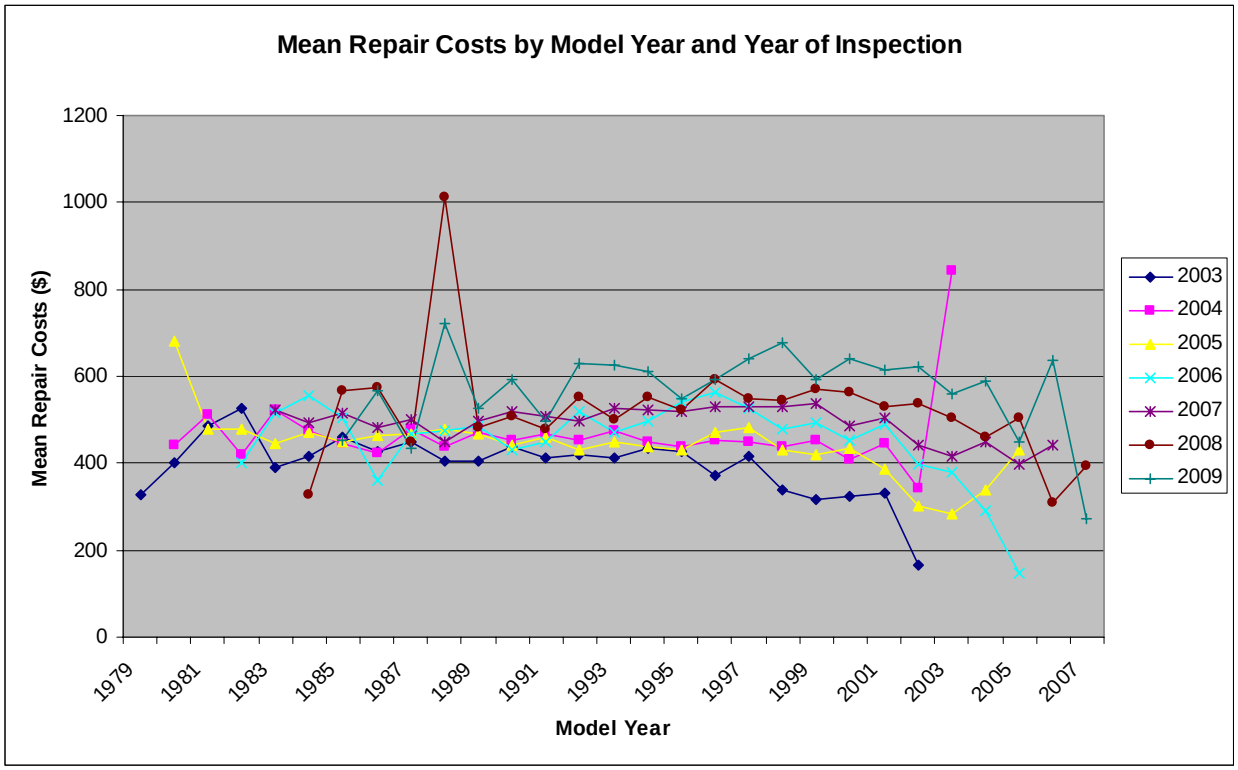
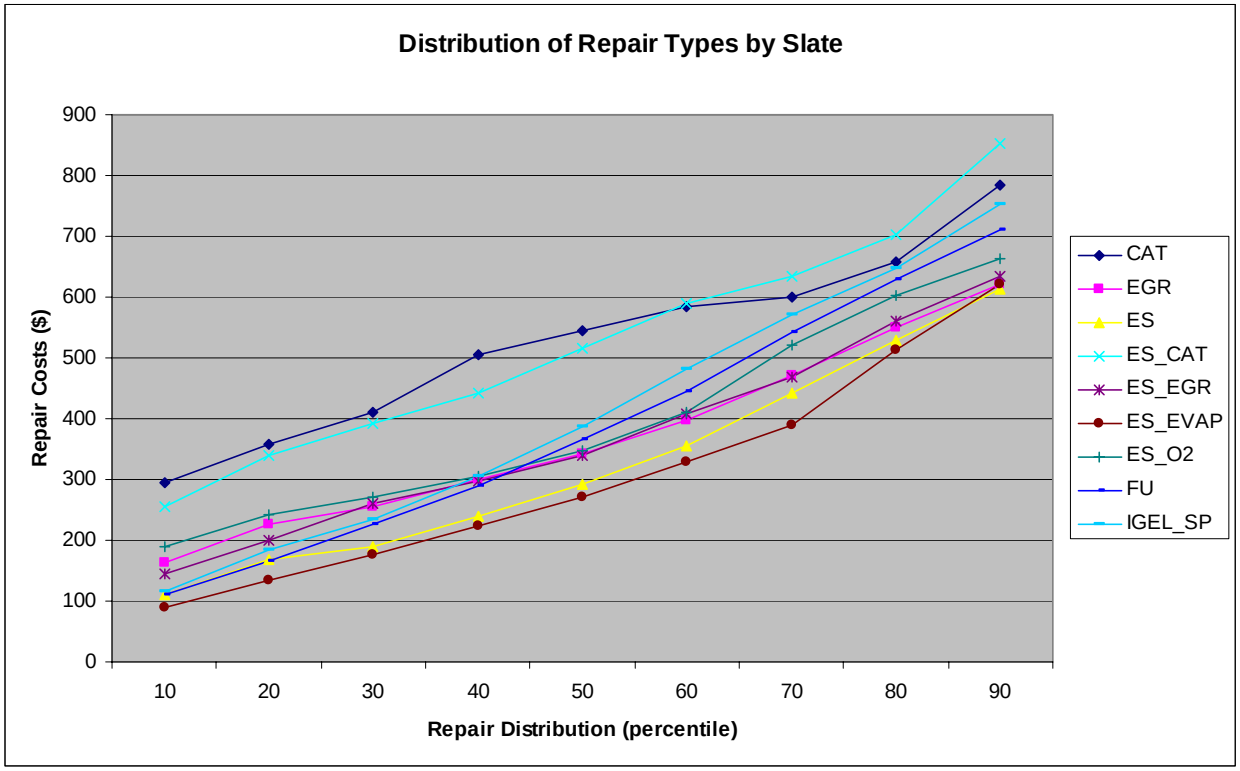


Figure 4-7 presents the percentile distribution of repair costs for the most common RERF repair slates.

Figure 4-7. Distribution of Repair Costs by Slate - RERF.



5.0 Estimates of I/M Benefits

The Annual Benefit is the size of the fleet's "saw tooth" emissions profile that occurs during each cycle as the vehicles in the fleet are repeatedly inspected and repaired. The saw tooth is produced for each vehicle by the annual change in emissions downward from I/M-induced repair and then upward from emissions degradation during the long period before the next I/M cycle. The analyses presented in Sections 5.1 and 5.2 are annual benefits based on the TIMS data alone (Section 5.1) or pairing the TIMS data with RS data (Section 5.2). The work in Section 5.3 uses the Reference Method to obtain a cumulative I/M benefit using RS measurements taken in a reference area, in this case San Antonio, and comparing them to measurements taken in the DFW and HGB areas.

5.1 Estimate of the Annual I/M Benefit from TIMS Data

ERG used two and a half years of the Texas TIMS to calculate the Annual I/M Benefit of I/M program. Although using TIMS or in-program data is often done for estimating the Annual I/M Benefit, the approach has at least two inherent problems. In spite of these problems the TIMS data was used to estimate the Annual I/M Benefit because it is relatively easy to do.

The first problem is a consequence of using the fast-pass ASM algorithm in the I/M program. When the vehicle passes the final test of its annual I/M sequence, the ASM test is a fast-pass test instead of a full-duration ASM test. It is known from analysis of ASM data that fast-pass ASM values tend to be higher than the emissions values that are ultimately achieved using a full-duration ASM test. Therefore, the change in emissions caused by the repair is underestimated when fast-pass tests are used at the end of the I/M sequence. ERG has built models that attempt to predict full-duration ASM test values from fast-pass ASM values. While models can be built, there remains a large amount of uncertainty in the predicted full-ASM value. Therefore, the TIMS ASM test values have not been corrected for fast passes. Accordingly, the calculated benefit of I/M-induced repairs tends to underestimate the emissions reduction.

The other source of bias is produced by regression toward the mean. Because of the emissions variability of the ASM measurements, vehicles that fail the ASM test tend to have a positive random error component in their measured ASM emissions values. This means that the calculated average difference between the before-repair test value and the after-repair test value for the dataset will almost always show a decrease even if the repairs produced no real emissions benefit. For this analysis, there was no correction made for this regression-toward-the-mean

effect. Accordingly, regression toward the mean tends to overestimate the calculated benefit of I/M-induced repairs.

The TIMS contains emissions measurements obtained from a vehicle when it first is inspected for its annual inspection and emissions measurements after it has been repaired and meets the Texas I/M requirements. The difference between these two emissions can be expected to represent the improvement in emissions as a result of the repairs. The sum of all of these emissions changes for all vehicles that received repairs are an estimate of the Annual I/M Benefit using in-program data. Note that this difference is measured by the difference in emissions before and after the I/M inspection. Therefore, it represents the change in emissions concentration only at the inspection event. It does not measure the increase in emissions caused by emissions degradation between annual inspection cycles.

Four I/M sequence categories were considered in this analysis. All the various failure patterns described in Section 3.3 were combined into these four categories for the purposes of calculating the Annual I/M Benefit. In addition to using these categories for the in-program data calculation, these same I/M sequence categories will be used in Section 5.2 to calculate the Annual I/M Benefits using out-of-program data. The I/M sequence categories are as follows:

- **Single Pass** (1P) – A vehicle completes its annual I/M requirement with a pass on the first inspection.
- **Single Fail** (1F) – A vehicle receives a single inspection, and it is a fail. The dataset does not contain any evidence that the vehicle returns or any information that it may have been waivered.
- **Initial Fail, then Final Fail** (FF) – A vehicle fails its first annual emissions inspection and then, perhaps after a series of repairs and re-inspections, fails its last annual inspection.
- **Initial Fail, then Final Pass** (FP) – A vehicle fails its first annual emissions inspection and then ultimately passes its last annual inspection to meet the I/M requirements.

The largest numbers of sequences in the evaluation period were 1Ps since most vehicles pass their initial ASM inspection each year. 1Ps make up about 90.1% of all sequences. The FP sequences are the next most common and make up about 8.3% of all sequences. The 1F and FF sequences are the least common and make up 1.1% and 0.1% of the sequences. Since vehicles with 1P and 1F sequences are tested only initially (because there is only one test), the final emissions values equal the initial emissions values. Consequently, vehicles with 1P and 1F sequences do not contribute to the calculated Annual I/M Benefit. The vehicles with FF

sequences do have different values for the initial and final average emissions; however, the values are not greatly different, which is probably because repairs to these vehicles were not entirely successful.

ERG calculated the average emission values using completed I/M cycles and presented the results in various ways. Tables 5-1 and 5-2 document the average emission concentration values for ASM and TSI tests, respectively; in both the DFW and HGB I/M program areas during this evaluation period. The values also show the apparent change in emissions concentrations at the inspection event. In the last row of each table it can be seen that ASM HC decreased 13 to 18%, ASM CO decreased 28 to 36%, ASM NO decreased 13 to 16%, TSI HC decreased 28 to 29%, and TSI CO decreased 28 to 34%. As described above, these changes are confounded by the effects of the fast-pass algorithm and by regression toward the mean.

The second block of data in each of Tables 5-1 and 5-2 shows the emissions averages for the two I/M program areas categorized by the two major I/M sequence categories, 1P and FP. These two categories make up over 98% of the I/M sequences in the datasets. The table shows that, of course, for the 1P category the change in emissions is 0% since these vehicles simply initially pass. However, for the FP category, the ASM measurements and TSI measurements show large emissions decreases from 63 to 84%. These reductions are for the vehicles that were failing when they entered the sequence, were repaired, and left the sequence as passing vehicles. Thus, these vehicles are the source of the Annual I/M Benefit. The apparent changes in the emissions concentrations as a result of repair are substantial for the FP sequences. The remaining blocks of data in the tables show that the emissions average concentrations and emissions reductions for DFW and HGB have approximately the same values.

Another observation that can be made from the data in Tables 5-1 and 5-2 is that the final concentrations of the FP vehicles are comparable to, but slightly larger than, the final concentrations of the 1P vehicles. This seems to indicate that vehicles that fail initially can be repaired to produce large emissions reductions, but as a group, they cannot be repaired to emission levels as low as vehicles that initially pass. One of the factors that complicate this comparison is that the technologies of the 1P vehicles and FP vehicles are probably quite different. Tables 5-3 and 5-4 contain these same values from the 2006 Report and are included here as a point of reference. In general, the emission percent reduction values were larger in the 2006 Report. It is possible this could be due to the I/M program effectively encouraging owners to maintain their vehicles. However, additional analyses would be needed to verify that this is indeed the cause for this observation.

Table 5-1. Annual I/M Benefit Using TIMS Data for ASM Emissions

			ASM HC (ppm)						ASM CO (%)						ASM NO (ppm)					
			5015			2525			5015			2525			5015			2525		
Area	**Seq.**	**Count**	**Initial**	**Final**	**% Red.**	**Initial**	**Final**	**% Red.**	**Initial**	**Final**	**% Red.**	**Initial**	**Final**	**% Red.**	**Initial**	**Final**	**% Red.**	**Initial**	**Final**	**% Red.**
DFW	1P	1,242,445	64.63	64.63	0.00%	40.52	40.52	0.00%	0.195	0.195	0.00%	0.132	0.132	0.00%	434.52	434.52	0.00%	307.34	307.34	0.00%
	FP	114,413	179.68	65.49	63.55%	155.22	46.44	70.08%	1.114	0.205	81.55%	1.047	0.160	84.76%	1297.32	462.90	64.32%	1088.42	351.34	67.72%
	1P + FP	1,356,858	74.33	64.70	12.95%	50.19	41.02	18.28%	0.272	0.196	28.13%	0.209	0.134	35.77%	507.27	436.91	13.87%	373.20	311.05	16.65%
HGB	1P	1,000,998	64.94	64.94	0.00%	41.30	41.30	0.00%	0.192	0.192	0.00%	0.133	0.133	0.00%	432.88	432.88	0.00%	311.56	311.56	0.00%
	FP	92,806	181.38	66.04	63.59%	156.80	46.73	70.20%	1.106	0.201	81.86%	1.043	0.158	84.88%	1261.82	463.48	63.27%	1061.95	352.96	66.76%
	1P + FP	1,093,804	74.82	65.03	13.08%	51.10	41.76	18.27%	0.269	0.193	28.51%	0.210	0.135	35.75%	503.21	435.47	13.46%	375.23	315.07	16.03%
DFW &	1P	2,243,443	64.77	64.77	0.00%	40.87	40.87	0.00%	0.193	0.193	0.00%	0.132	0.132	0.00%	433.79	433.79	0.00%	309.22	309.22	0.00%
HGB	FP	207,219	180.44	65.73	63.57%	155.93	46.57	70.13%	1.110	0.203	81.69%	1.045	0.159	84.81%	1281.42	463.16	63.86%	1076.56	352.07	67.30%
	1p + FP	2,450,662	74.55	64.85	13.01%	50.60	41.35	18.28%	0.271	0.194	28.30%	0.210	0.135	35.76%	505.46	436.27	13.69%	374.11	312.85	16.38%

Table 5-2. Annual I/M Benefit Using TIMS Data for TSI Emissions

			TSI HC (ppm)						TSI CO (%)					
			Curb Idle			High Idle			Curb Idle			High Idle		
Area	**Seq.**	**Count**	**Initial**	**Final**	**% Red.**	**Initial**	**Final**	**% Red.**	**Initial**	**Final**	**% Red.**	**Initial**	**Final**	**% Red.**
DFW	1P	164,392	67.303	67.303	0.00%	35.737	35.737	0.00%	0.180	0.180	0.00%	0.175	0.175	0.00%
	FP	12,806	472.859	85.459	81.93%	266.783	47.949	82.03%	1.677	0.274	83.65%	1.269	0.246	80.59%
	1P + FP	177,198	96.612	68.615	28.98%	52.434	36.620	30.16%	0.288	0.187	35.21%	0.254	0.180	29.07%
HGB	1P	133,775	66.152	66.152	0.00%	35.501	35.501	0.00%	0.183	0.183	0.00%	0.173	0.173	0.00%
	FP	9,633	452.337	83.524	81.53%	263.543	47.361	82.03%	1.699	0.269	84.19%	1.261	0.236	81.29%
	1P +FP	143,408	92.093	67.319	26.90%	50.819	36.298	28.57%	0.284	0.188	33.77%	0.246	0.177	28.02%
DFW &	1P	298,167	66.787	66.787	0.00%	35.631	35.631	0.00%	0.181	0.181	0.00%	0.174	0.174	0.00%
HGB	FP	22,439	464.049	84.628	81.76%	265.392	47.697	82.03%	1.686	0.272	83.88%	1.266	0.242	80.89%
	1P + FP	320,606	94.591	68.035	28.07%	51.712	36.476	29.46%	0.286	0.187	34.57%	0.250	0.179	28.61%

Table 5-3. 2006 Report Annual I/M Benefit Using TIMS Data for ASM Emissions

I/M Program Area	I/M Sequence Category	Sequence Count	ASM HC (ppm)						ASM CO (%)						ASM NO (ppm)					
			5015			2525			5015			2525			5015			2525		
			Initial	Final	Change (%)	Initial	Final	Change (%)	Initial	Final	Change (%)	Initial	Final	Change (%)	Initial	Final	Change (%)	Initial	Final	Change (%)
DFW + HGB	1P + FP	4,043,021	82.6	68.1	-18%	55.9	42.6	-24%	0.300	0.199	-34%	0.237	0.139	-41%	553.2	463.8	-16%	429.0	348.0	-19%
DFW + HGB	1P	3,634,897	68.0	67.8	0%	41.9	41.7	0%	0.199	0.198	0%	0.137	0.136	0%	461.6	460.2	0%	343.9	342.8	0%
	FP	408,124	212.7	70.2	-67%	181.1	49.9	-72%	1.200	0.204	-83%	1.134	0.162	-86%	1,368.4	495.9	-64%	1,186.6	394.3	-67%
DFW	1P + FP	2,214,458	81.9	68.0	-17%	55.1	42.3	-23%	0.3	0.2	-33%	0.2	0.1	-40%	550.3	464.1	-16%	424.3	346.5	-18%
HGB	1P + FP	1,828,563	83.4	68.1	-18%	56.9	42.9	-25%	0.3	0.2	-35%	0.2	0.1	-43%	556.6	463.4	-17%	434.6	349.9	-20%
DFW	1P	1,998,674	68.0	67.8	0%	41.6	41.6	0%	0.205	0.204	0%	0.140	0.139	0%	461.9	460.8	0%	342.3	341.4	0%
	FP	215,784	211.2	69.6	-67%	179.9	49.5	-72%	1.225	0.213	-83%	1.158	0.170	-85%	1,369.0	494.8	-64%	1,184.4	393.2	-67%
HGB	1P	1,636,223	68.0	67.8	0%	42.1	42.0	0%	0.192	0.191	0%	0.133	0.133	0%	461.3	459.4	0%	346.0	344.5	0%
	FP	192,340	214.3	70.9	-67%	182.4	50.3	-72%	1.171	0.194	-83%	1.107	0.153	-86%	1,367.7	497.1	-64%	1,189.0	395.5	-67%

Table 5-4. 2006 Report Annual I/M Benefit Using TIMS Data for TSI Emissions

I/M Program Area	I/M Sequence Category	Sequence Count	TSI HC (ppm)						TSI CO (%)					
			Curb Idle			High Idle			Curb Idle			High Idle		
			Initial	Final	Change (%)	Initial	Final	Change (%)	Initial	Final	Change (%)	Initial	Final	Change (%)
DFW + HGB	1P + FP	421,937	121.6	76.5	-37%	65.8	40.8	-38%	0.37	0.22	-39%	0.31	0.20	-33%
DFW + HGB	1P	386,985	75.3	75.1	0%	39.9	39.8	0%	0.21	0.21	0%	0.20	0.20	0%
	FP	34,952	634.2	92.1	-85%	352.2	51.6	-85%	2.04	0.32	-84%	1.49	0.27	-82%
DFW	1P + FP	211,413	122.8	77.1	-37%	64.1	39.5	-38%	0.38	0.23	-38%	0.31	0.21	-32%
HGB	1P + FP	210,524	120.4	75.8	-37%	67.5	42.1	-38%	0.35	0.21	-40%	0.30	0.19	-35%
DFW	1P	194,331	75.8	75.6	0%	38.6	38.5	0%	0.23	0.22	0%	0.21	0.21	0%
	FP	17,082	657.5	94.5	-86%	354.2	50.5	-86%	2.13	0.35	-83%	1.53	0.30	-81%
HGB	1P	192,654	74.8	74.5	0%	41.3	41.1	0%	0.20	0.20	0%	0.19	0.19	0%
	FP	17,870	611.9	89.7	-85%	350.3	52.5	-85%	1.95	0.29	-85%	1.46	0.25	-83%

5.2 Estimate of the Annual I/M Benefit from Paired I/M and RS Data

ERG used remote sensing data taken in the I/M areas to determine the Annual I/M Benefit produced by the I/M program. This was done by pairing RS data with the TIMS inspection data by vehicle, and comparing the before-I/M and after-I/M RS levels.

A vehicle can be measured by RS at any time before or after its annual I/M inspection. By aligning all of the RS measurements with respect to the time of I/M repair, the average of the RS measurements will reveal the change in emissions produced by the I/M program and the rate of emissions degradation between I/M inspections. However, it is important to understand that the set of vehicles with RS measurements before the I/M inspection does not contain the same vehicles as those with RS measurements after the I/M inspection. Because of the large emissions variability of emissions measurements, the average RS emissions versus time before and after I/M inspection will have a considerable amount of error even when millions of RS observations are used. Nevertheless, the calculation provides an estimate of the benefits of the I/M program that is independent of the I/M program itself.

Preparation of RS Data – In this task, the RS data were collected in the HGB area and the DFW area to evaluate the Annual I/M Benefit. The goal was to use the RS data already being collected by the Texas DPS as an independent means of measuring the benefit.

The RS data provided by DPS started out with about 12 million records. However, only those records that were collected during or after March 2007 were used for this analysis. Prior to that time, negative values for RS concentrations were dropped from the dataset, likely resulting in a biased distribution of emissions concentrations. Only the March 2007 through August 2008 RS data were selected for this analysis, which left 8.5 million records in the dataset. For all of the analyses with the out-of-program (RS) data, the vehicle license plate was a crucial variable. The license plate allows for matching with inspection and maintenance records as well as determining the county of registration for the vehicle. Therefore, any records that had missing license plate information were removed. This left 7.3 million records in the RS dataset. Because this analysis was only concerned with the HGB and DFW areas, only RS data collected in HGB and DFW were kept in the dataset. This left 6.2 million remaining RS records: 3.1 million records collected in the HGB area and 3.1 million records collected in the DFW area.

The RS records provided to ERG did not contain any information about the vehicle except the license plate number and the county where the vehicle was registered at the time of the RS measurement. For the Comprehensive Method [Reference 2] calculations, it is important to determine the fleet characteristics of the vehicles measured by RS in the I/M area. Therefore,

it was important to determine the vehicle characteristics such as age, technology, and odometer. The potential sources of this information were the registration data, the I/M data, and the ERG VIN decoder. The records from the I/M program do contain odometer and other vehicle characteristics information; however, there are no I/M records for vehicles registered outside the I/M areas. The registration data contained vehicle make and model year, but did not contain odometer, vehicle technology information, or vehicle odometer information. Because of this, the vehicle odometer could not be used in the comparison of fleet characteristics. In the 2006 performance of this analysis, the ERG VIN decoder was used to provide the vehicle characteristics information which included vehicle make, model year, type (car or truck), metering, and emission control systems. However, limiting the RS dataset to only those records that had a successful match to a VIN-decoder result dropped the number of RS records from 6.2 million to 3.5 million records – a significant reduction. Also, in the 2006 analysis, the vehicle technology information that comes exclusively from the VIN decoder did not get used in the finally analysis procedure. The only stratification variable was the vehicle model year, which is available from the registration records. Therefore, for the current analysis, it was decided not to use the VIN decoder results to obtain additional vehicle information.

The RS records provided to ERG by DPS were already checked for validity by the RS data collection contractor. Therefore, there was no check made for the validity of the values within each of the RS data fields with the exception of the missing variable information discussed above. However, the vehicle specific power (VSP) for each vehicle using the RS speed, acceleration, and the slope at the RS site was calculated. The slope for the RS site was not included in the RS data. These data were provided separately by DPS. Once the sites and slopes were matched to the RS records and the VSP calculations were done, a VSP filter was applied. Any records with a VSP outside the range of 5-25 kW/Mg were removed from the dataset. This left 5.2 million remaining records: 2.5 million records in the DFW and 2.7 million records in the HGB area.

Calculation of the Annual I/M Benefit – The calculation of the Annual I/M Benefit was done using the Comprehensive Method outlined by EPA. [Section 6.2 of Reference 2] In this method, RS data taken in the I/M area is paired with I/M inspections by vehicle.

ERG calculated the time between the RS reading and the I/M test and put each observation into a month bin – for example, 1 month before the initial test, 2 months before the initial test, 3 months before initial, 1 month after the final test, 2 months after the final test, 3 months after final, etc. Any RS readings that occurred within the I/M cycle, that is, between the initial test and the final test, were removed from the analysis, because for these mid-cycle

observations it was not possible to determine the state of repair of the vehicle at the time of the RS measurement.

ERG also created a variable to describe the sequence of I/M inspection results for each vehicle inspected. There were four I/M sequence categories outlined in EPA's description of the Comprehensive Method calculations: 1) vehicles that passed their initial I/M tests (1P), 2) vehicles that failed their initial I/M test and then eventually passed (FP), 3) vehicles that failed their I/M test and did not come back for another test (1F), and 4) vehicles that failed their I/M test and failed all other subsequent I/M tests (FF).

The average RS concentrations for HC, CO, and NO by month bin, by I/M sequence category, and also by model year group were examined. Because the Texas I/M program is an annual program, the plots were limited to only the RS matches that happened up to 6 months before and 6 months after the I/M test. The HC, CO, and NO plots for the entire dataset are shown in Figures 5-1 through 5-3 for the HGB area and in Figures 5-3 through 5-6 for the DFW area. These figures show the RS averages (indicated by the dots) and the uncertainties associated with these averages at a 95% confidence level (indicated by the lines).

Figure 5-1. Average RS HC Versus Month from the I/M Test
RS Readings from the HGB Area

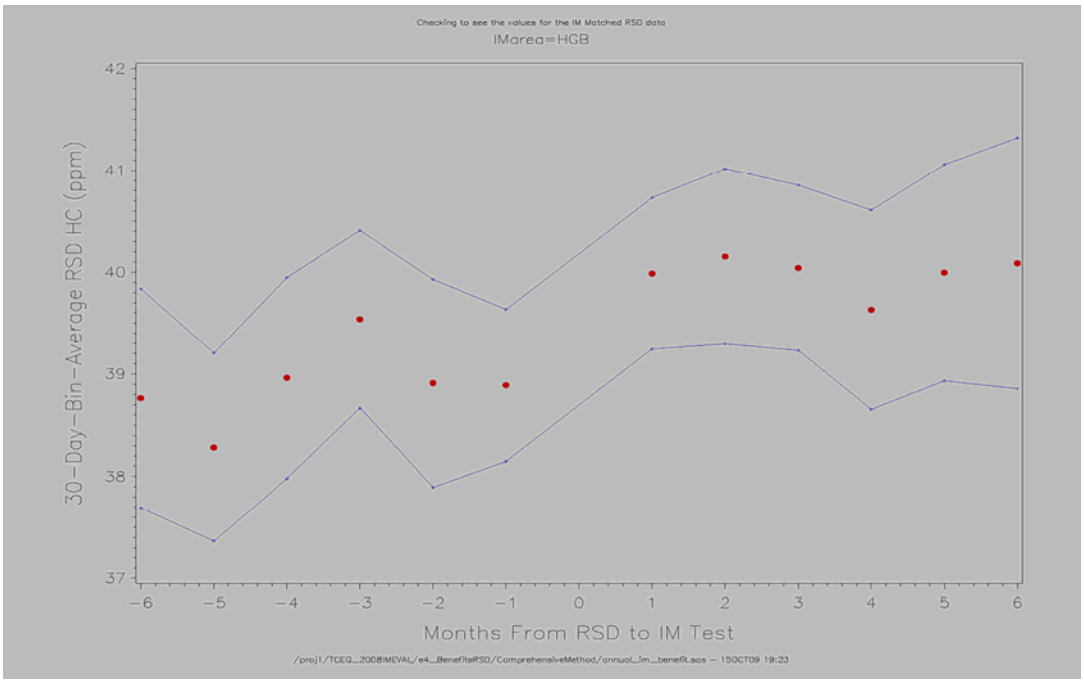


Figure 5-2. Average RS CO Versus Month from the I/M Test RS Readings from the HGB Area

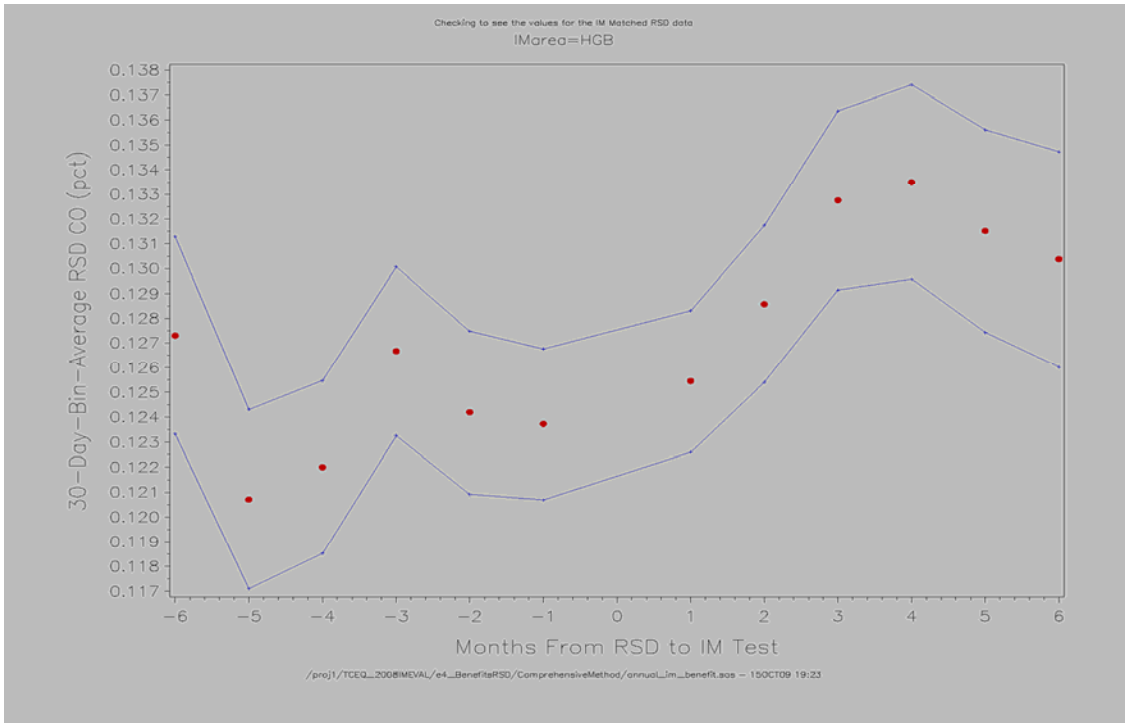


Figure 5-3. Average RS NO Versus Month from the I/M Test RS Readings from the HGB Area

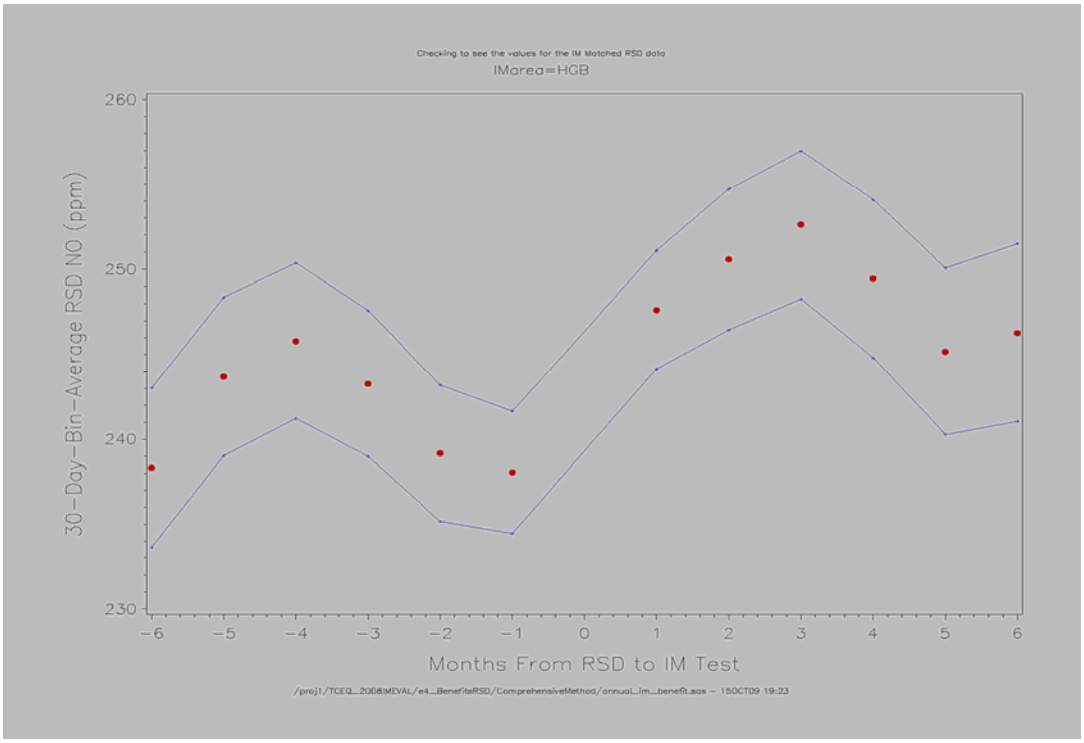


Figure 5-4. Average RS HC Versus Month from the I/M Test RS Readings from the DFW Area

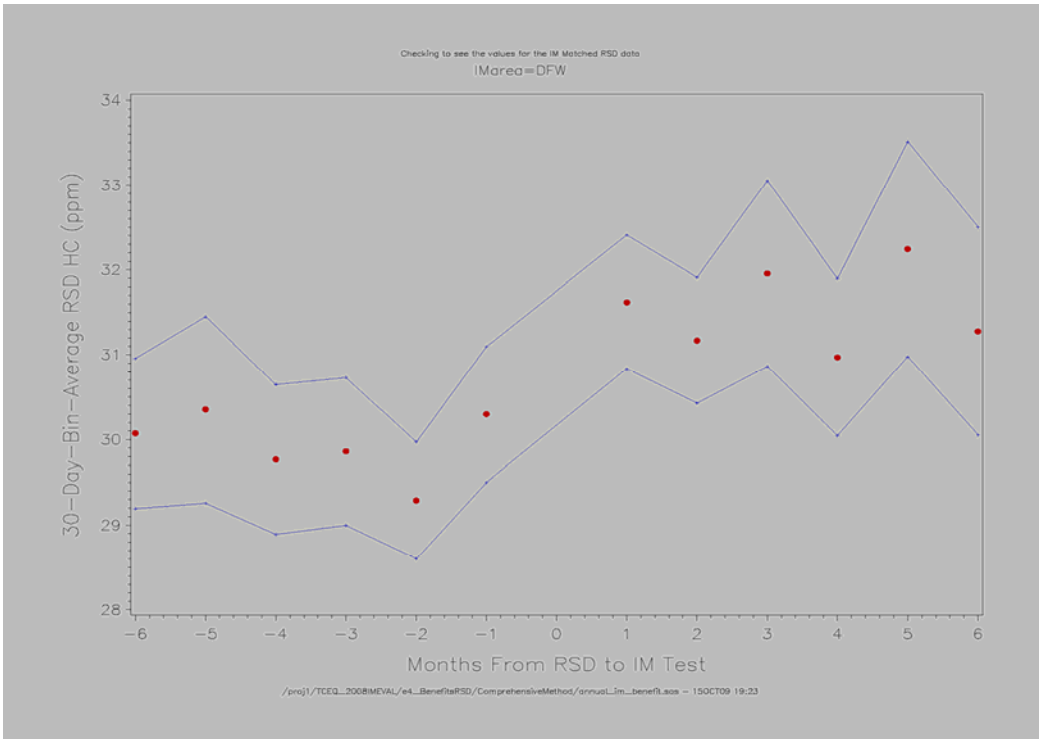


Figure 5-5. Average RS CO Versus Month from the I/M Test RS Readings from the DFW Area

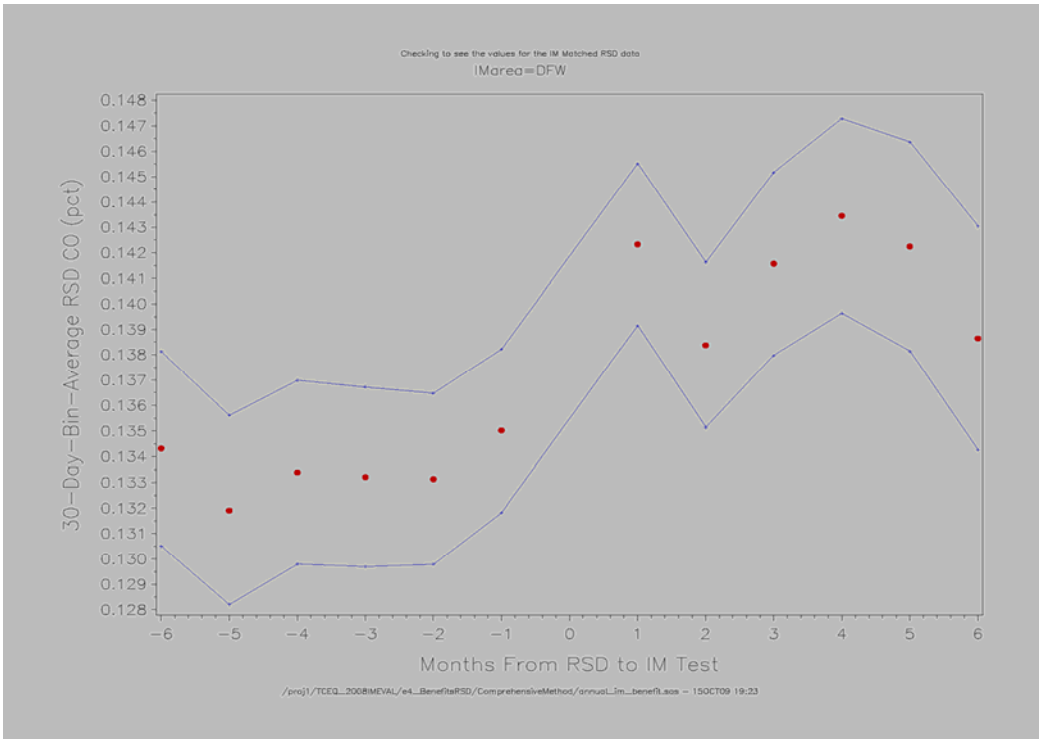
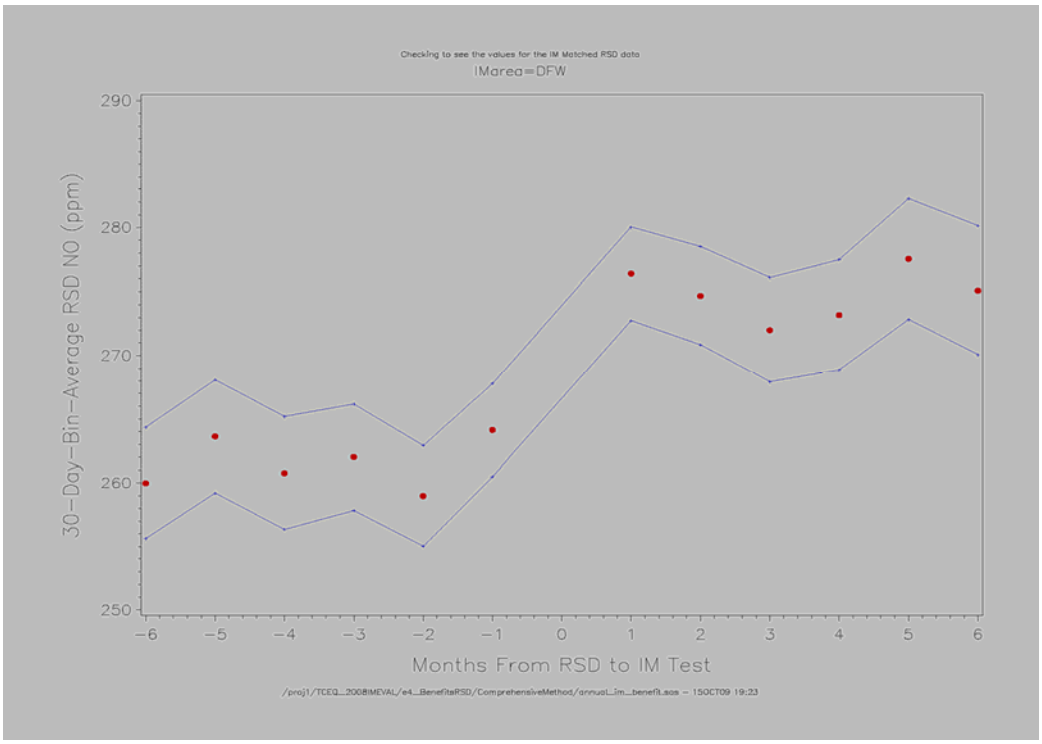


Figure 5-6. Average RS NO Versus Month from the I/M Test RS Readings from the DFW Area



These figures above do not show a drop in the average RS emissions from before to after I/M. However, when the plots are done on a dataset that has been stratified by the I/M sequence category, some I/M benefits start to become evident. Table 5-5 shows the number of records in the RS-matched-with-I/M dataset (for both HGB and DFW) that fall into each I/M sequence category. The table clearly demonstrates that the 1P and FP I/M sequence categories dominate the I/M program. At this point, the separate effects of the 1P and FP categories are examined.

Table 5-5. Number of Vehicles in Each I/M Sequence Category for the Dataset of RS Events Matched with I/M Tests

I/M Sequence Category	HGB		DFW	
	Number of Vehicles	Percent	Number of Vehicles	Percent
Pass Initial (1P)	1,254,701	95.3%	1,373,743	95.4%
Fail Initial (1F)	0	0.0%	3	0.0%
Fail Initial, Fail Final (FF)	44	0.0%	94	0.0%
Fail Initial, Pass Final (FP)	57,850	4.4%	62,351	4.3%
Other Misc. Sequences	4,123	0.3%	3,410	0.2%
Total	1,316,718	100.0%	1,439,601	100.0%

The plots of mean RS concentrations versus time from I/M inspection were repeated, this time separately for the 1P and FP categories. Figures 5-7, 5-9, and 5-11 show the time trend of the monthly average RS HC, CO, and NO for the HGB area for vehicles that passed initially (1P). Below these figures are Figures 5-8, 5-10, and 5-12 for the corresponding vehicles that failed initially and then ultimately passed (FP).

The 1P plots, which describe 95.3% of the vehicles in the HGB area, show small emission increases from the month before to the month after the I/M test. There is no evidence of a decrease in emissions in the two months before the I/M inspection that could be attributed to pre-inspection repairs. If anything, the long term time trend is generally upward, which may be attributed to the general long term emissions deterioration of these vehicles.

The FP plots, which describe 4.4% of the vehicles in the HGB area, show downward jogs in the emissions at the time of the I/M inspection. The jogs are substantial: -14% HC, -31% CO, and -9% NO. Examining the overall trend of each plot shows that downward jogs at the I/M inspection interrupts the generally upward trend of emissions deterioration, which is what the I/M program is designed to do.

Grouping vehicles of all I/M sequence categories results in a slightly increasing trend from before to after I/M as was seen in Figures 5-1, 5-2, and 5-3. This is because while the FP vehicles show substantial emissions decreases, they make up only 4.4% of the fleet. The other 95.3% of the fleet is made up of 1P vehicles that have slight emissions increases, as an expected result of general long term degradation. The plots for the emissions for the DFW area (not shown here) generally illustrate this same trend.

Figure 5-7. Average RS HC vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = 1P

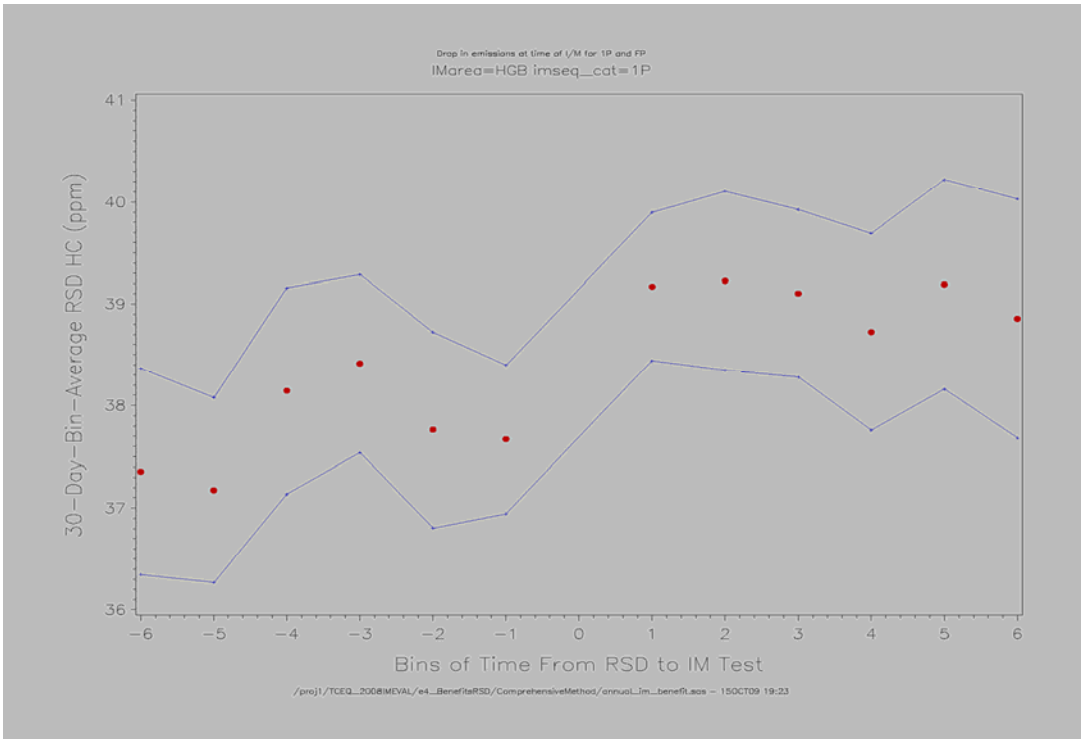


Figure 5-8. Average RS HC vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = FP

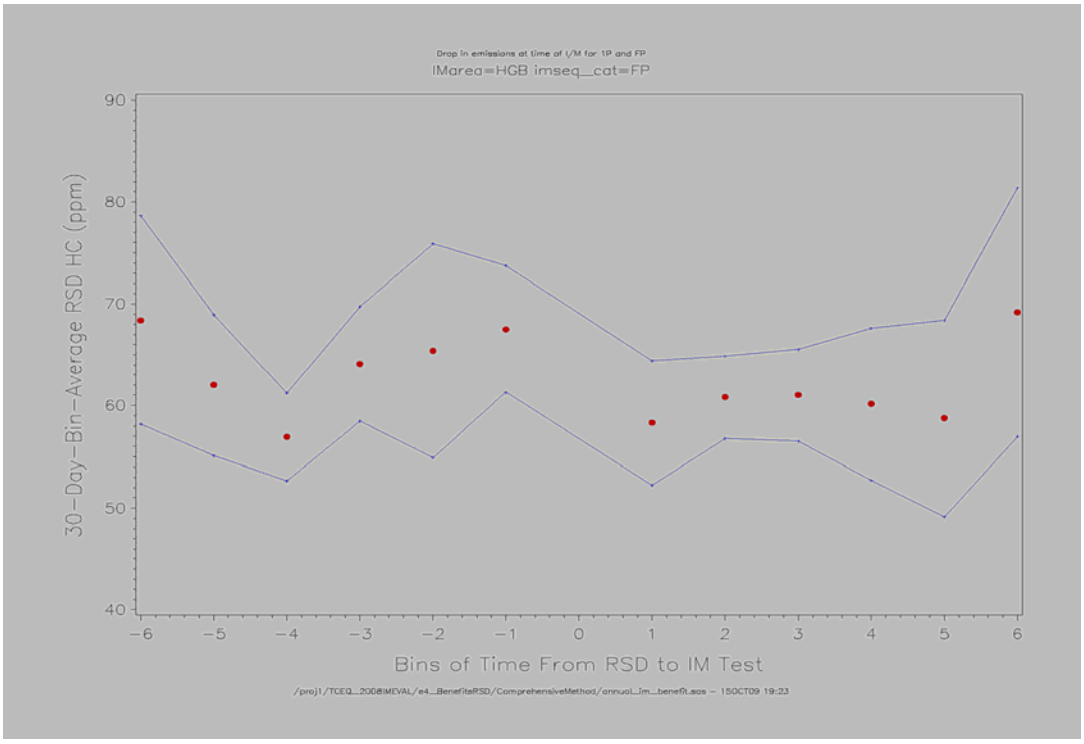


Figure 5-9. Average RS CO vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = 1P

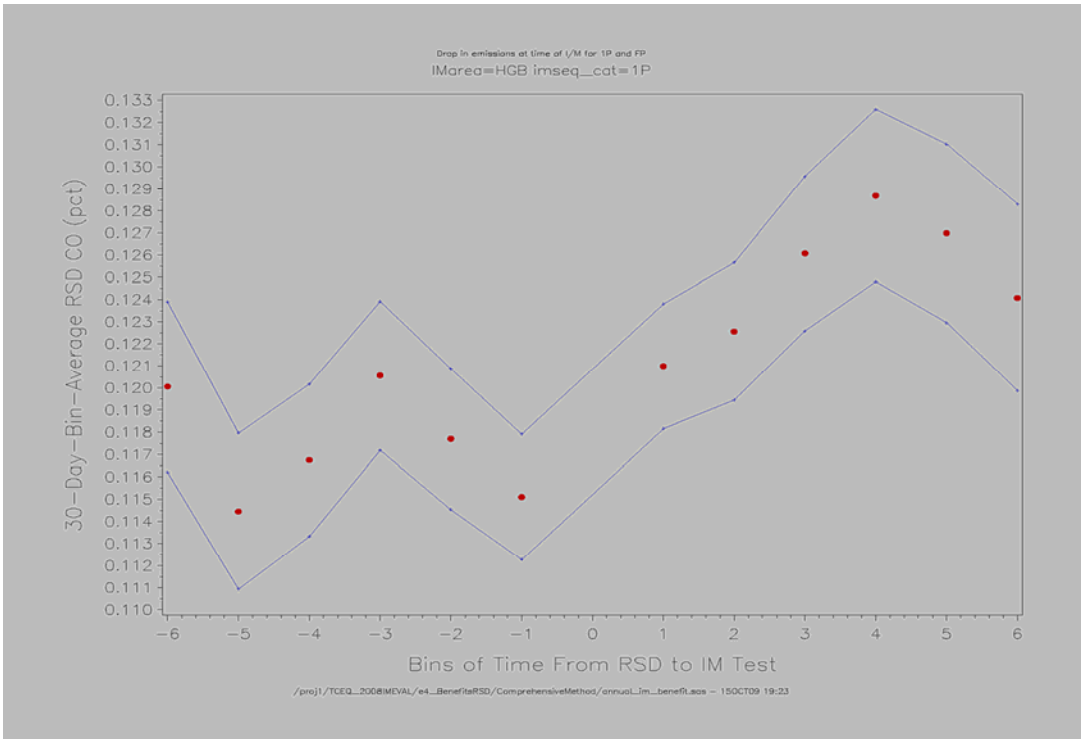


Figure 5-10. Average RS CO vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = FP

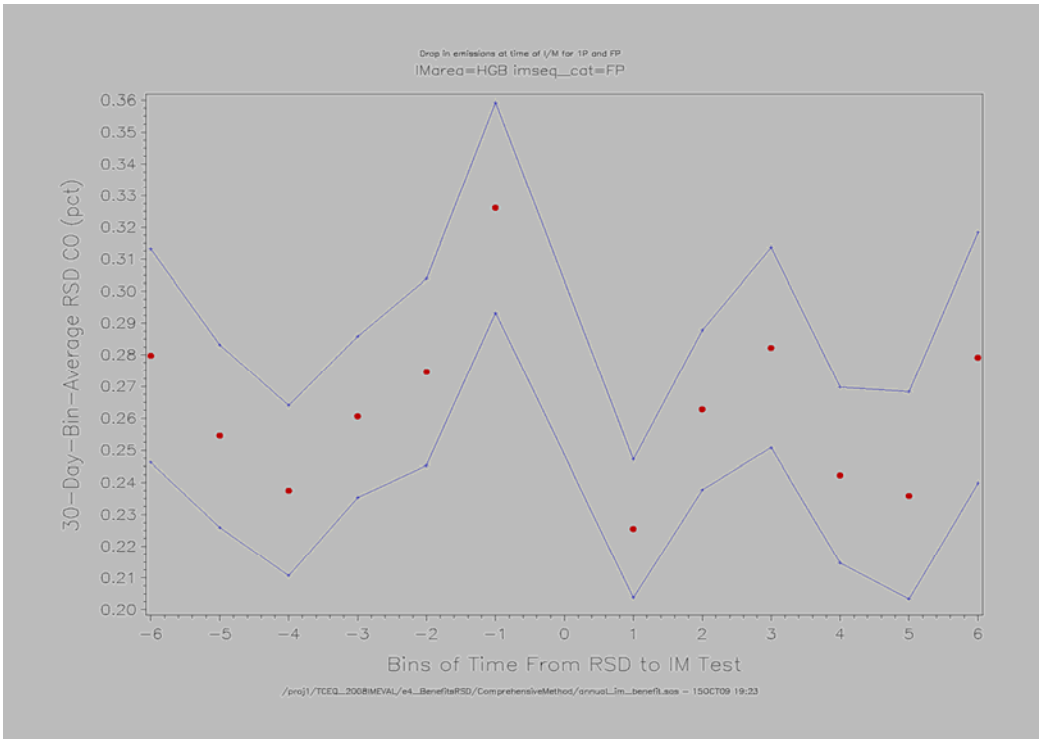


Figure 5-11. Average RS NO vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = 1P

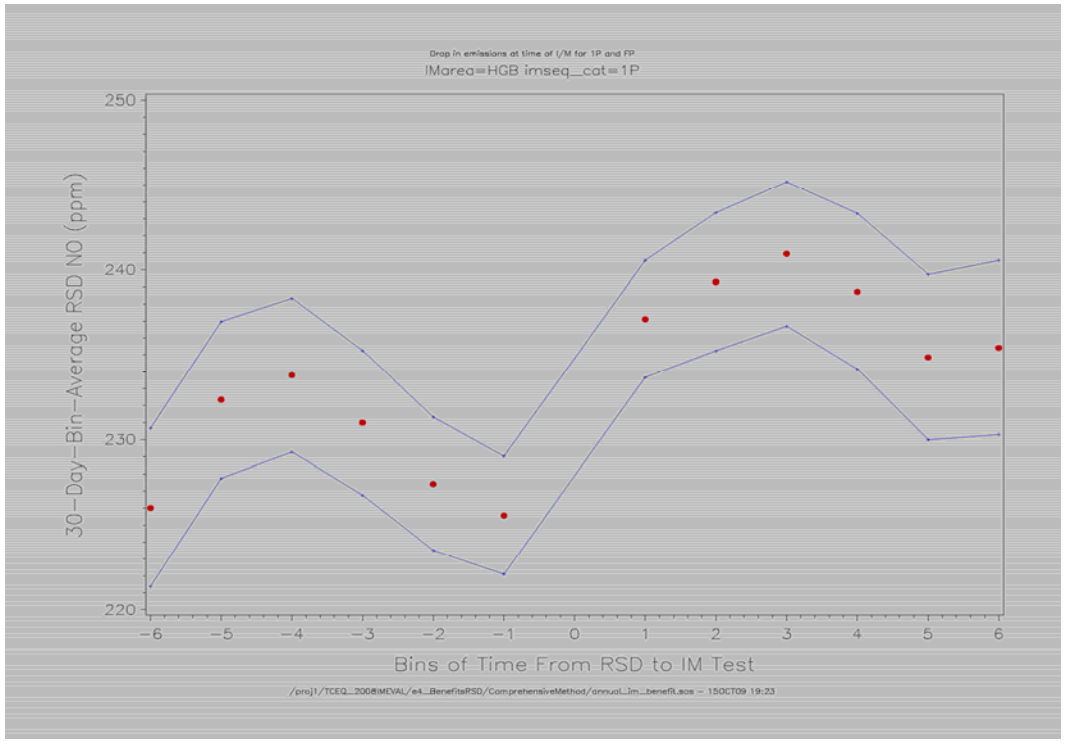
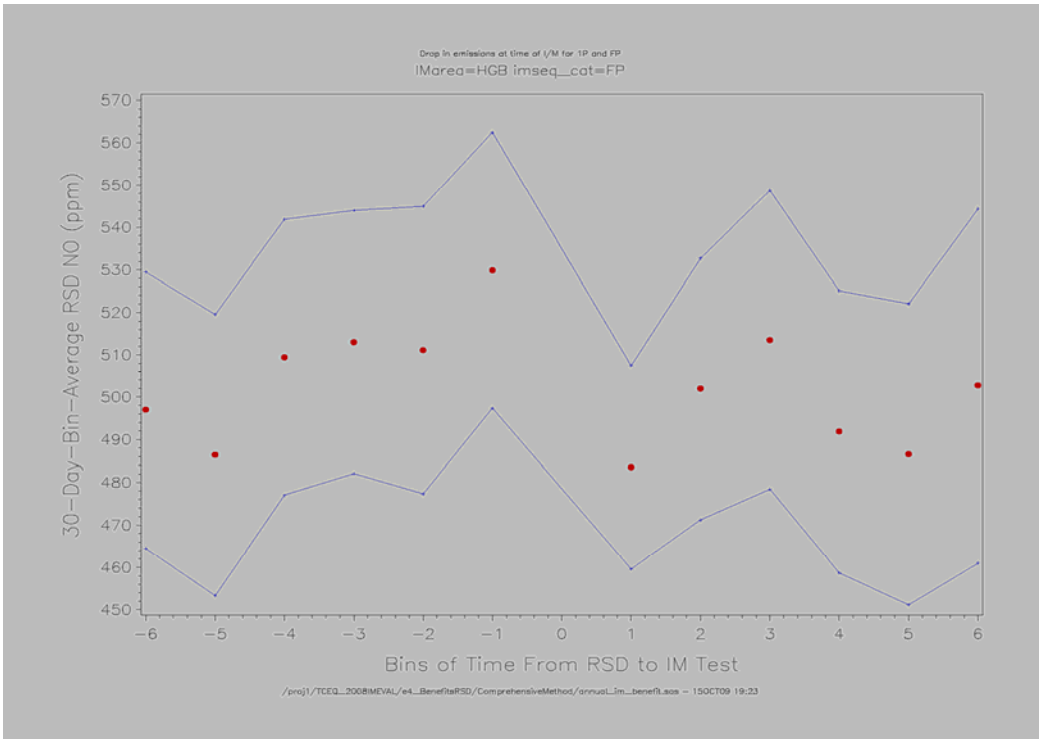


Figure 5-12. Average RS NO vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = FP



To quantify the Annual I/M Benefit, the month bins were combined to obtain a single average RS concentration before the I/M test and another average RS concentration after the I/M test. The before bin consists of all RS measurements that happened between 31 and 90 days prior to the initial I/M test. The RS measurements that happened from 1 to 30 days prior to the I/M test were not included in the bin to minimize the effect of pre-inspection repairs on the before average. This binning methodology was suggested by EPA in the documentation for the Comprehensive Method. The after bin contains all RS tests that happened between 1 and 90 days following the final I/M test.

The calculations for the before and after I/M RS averages were done for the entire RS matched I/M dataset, and were also done separately for each of the two major I/M sequence categories, FP and 1P. In addition, averages were calculated by model year group. At the beginning of this analysis, when the fleet characteristics of the I/M fleet were compared to the fleet characteristics of the set of vehicles with RS measurements matched to I/Ms, the RS-matched fleet was found to contain a larger percentage of new vehicles. Therefore, each of the I/M category bins were also separated by model year group. The benefit for each model year group could be weighted by the percentage of vehicles in each model year group in the I/M fleet to translate the benefits observed in the RS-matched fleet to the I/M fleet.

These before and after I/M average RS measurements for the FP vehicles and the 1P vehicles were plotted for both the HGB and DFW areas in Figures 5-13 through 5-24. Each plot contains a separate line for each of four model year groups, with the before I/M RS measurement on the left and the after I/M RS measurement on the right. The lines highlight the differences between these RS averages and the error bars show the 95% confidence level uncertainties for the respective averages. The plots for FP vehicles in Figures 5-13 to 5-18 show that in most cases the emissions of FP vehicles decrease; however, in many cases the decrease is not statistically significant – even with over 100,000 RS observations in the FP category. The plots for 1P vehicles in Figures 5-19 to 5-24 show that in most cases the emissions of 1P vehicles increase across the I/M inspections; however, in many cases the increase is not statistically significant even with over 2-million RS observations in the 1P category.

Figure 5-13. Average RS HC by Model Year Group Before and After I/M Test for HGB Vehicles with I/M Sequence Category = FP

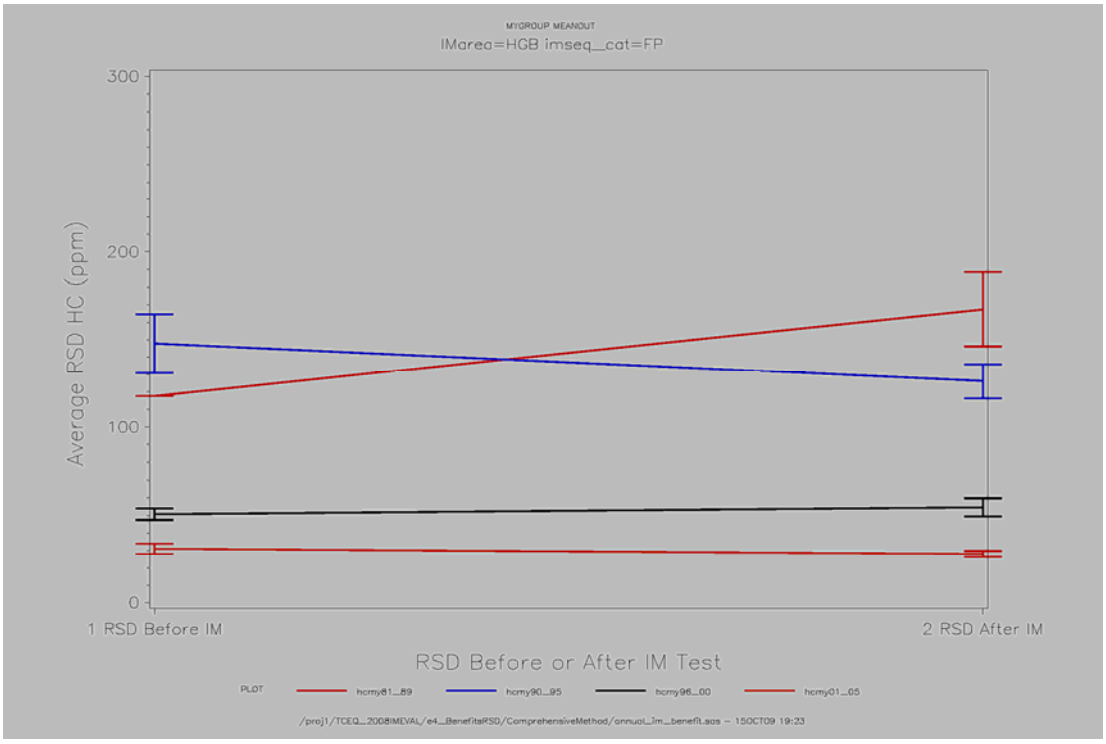


Figure 5-14. Average RS HC by Model Year Group Before and After I/M Test for DFW Vehicles with I/M Sequence Category = FP

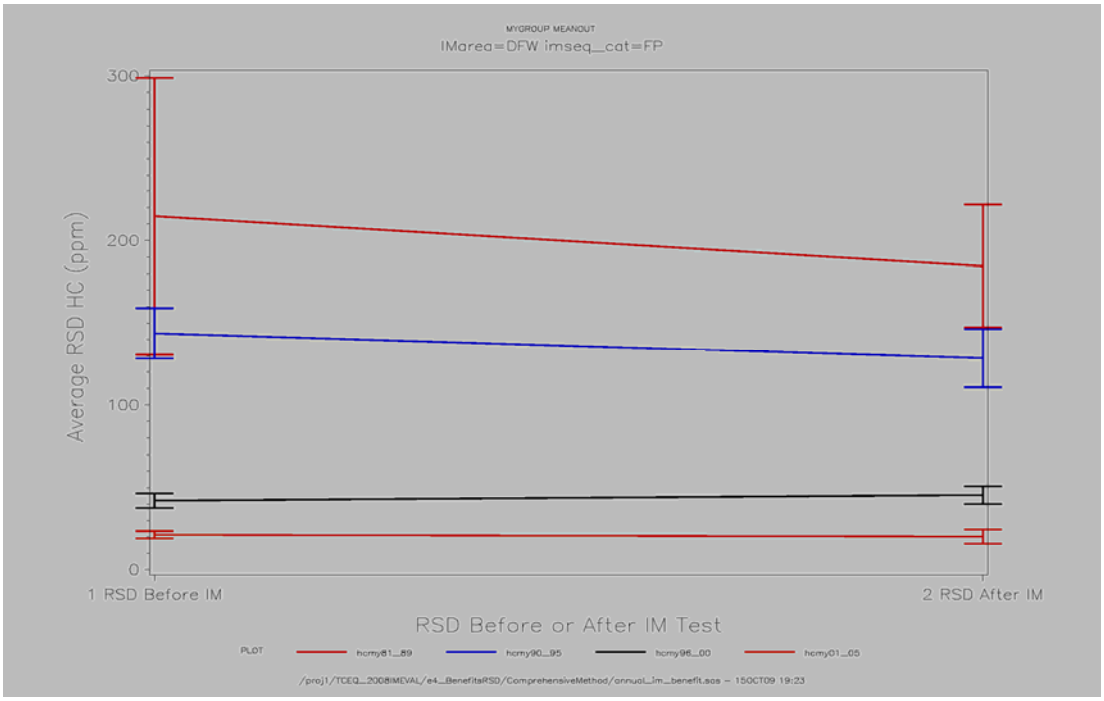


Figure 5-15. Average RS CO by Model Year Group Before and After I/M Test for HGB Vehicles with I/M Sequence Category = FP

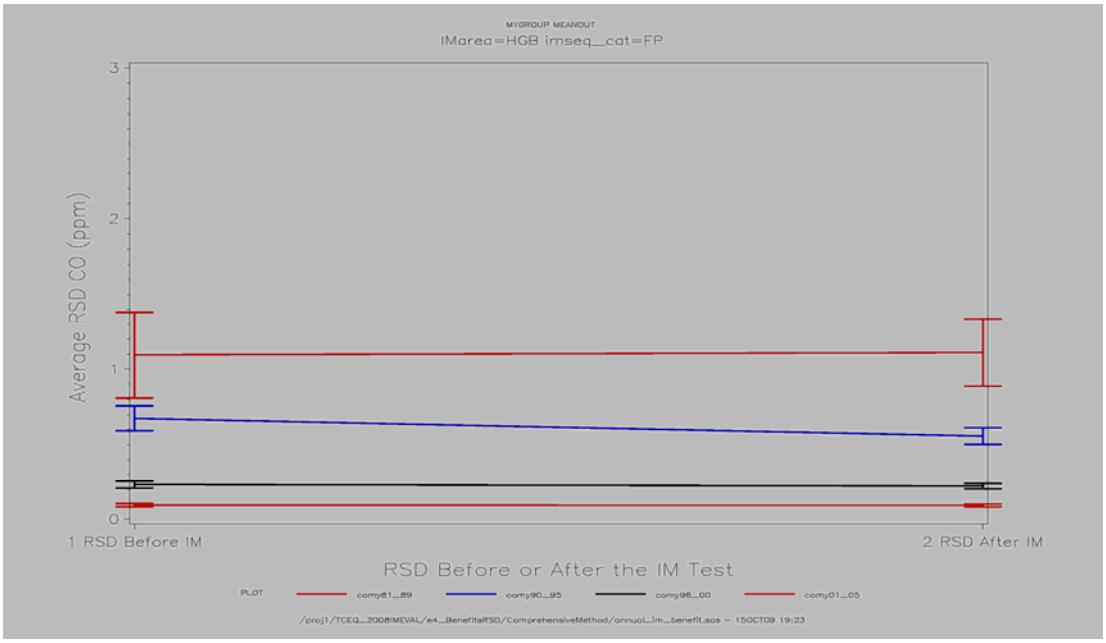


Figure 5-16. Average RS CO by Model Year Group Before and After I/M Test for DFW Vehicles with I/M Sequence Category = FP

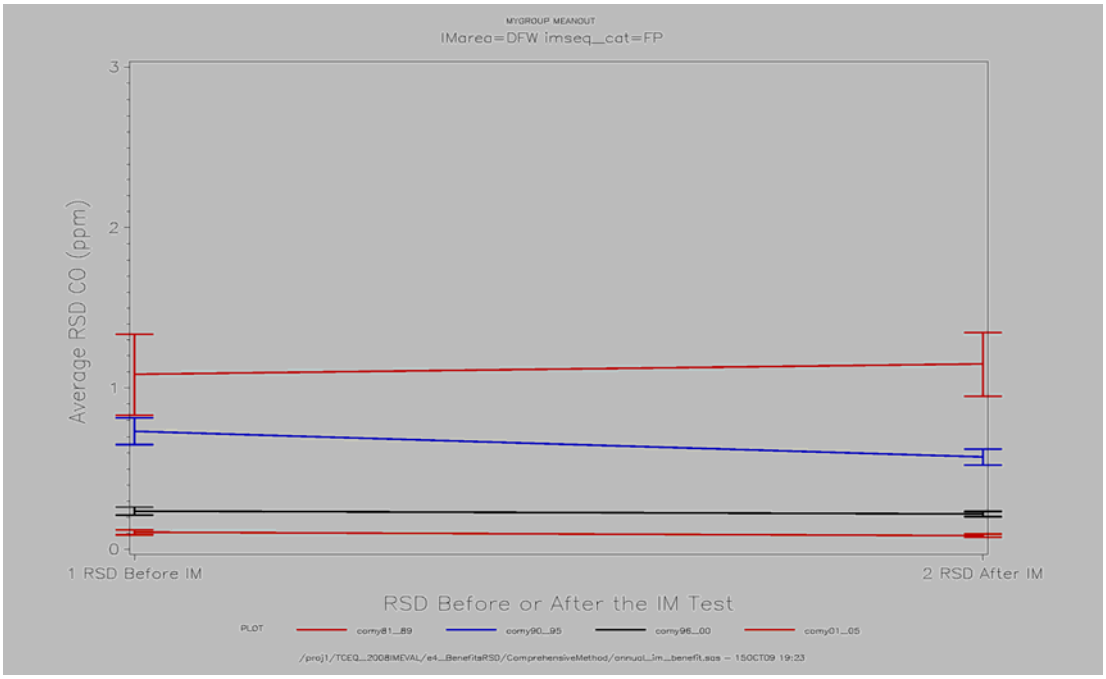


Figure 5-17. Average RS NOx by Model Year Group Before and After I/M Test for HGB Vehicles with I/M Sequence Category = FP

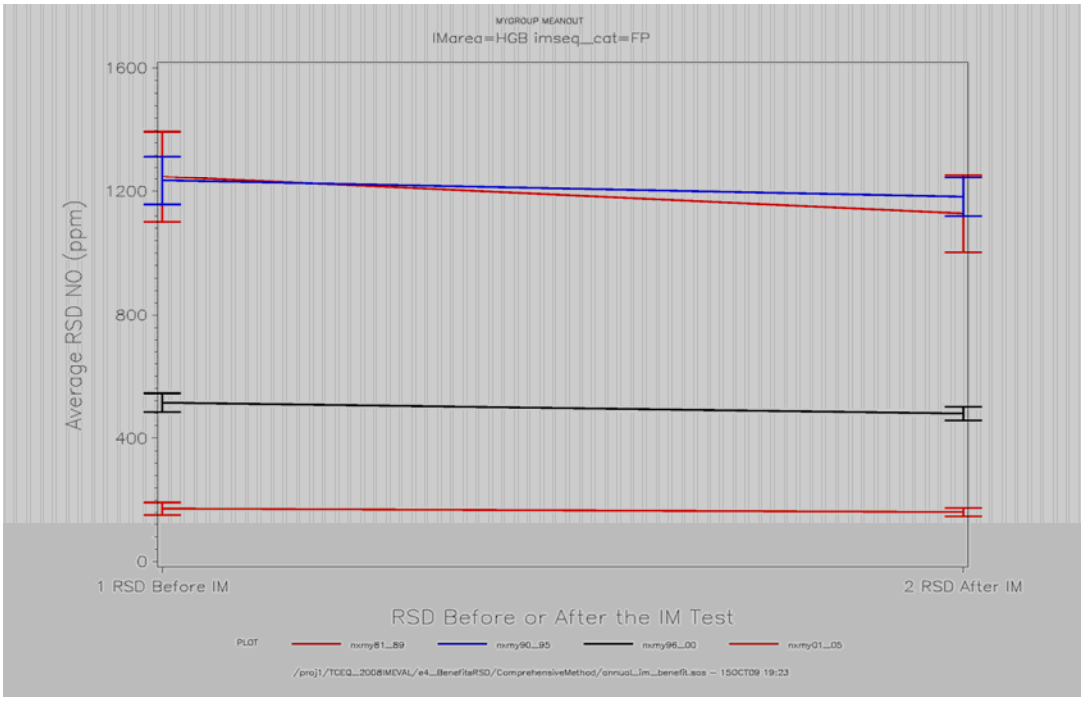


Figure 5-18. Average RS NOx by Model Year Group Before and After I/M Test for DFW Vehicles with I/M Sequence Category = FP

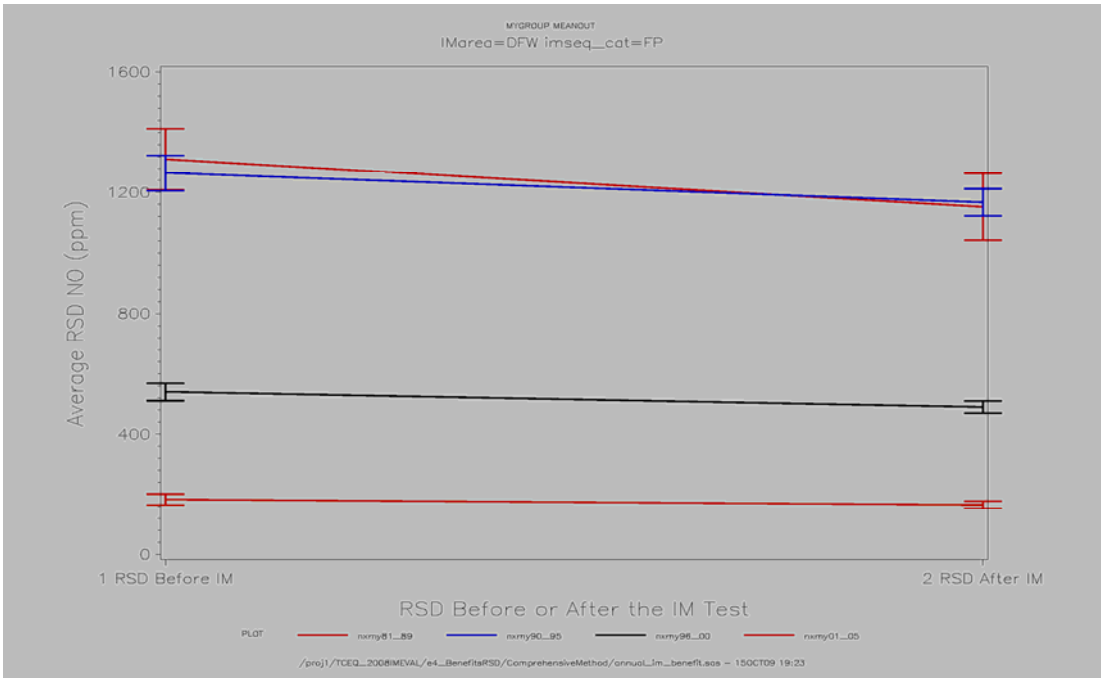


Figure 5-19. Average RS HC by Model Year Group Before and After I/M Test for HGB Vehicles with I/M Sequence Category = 1P

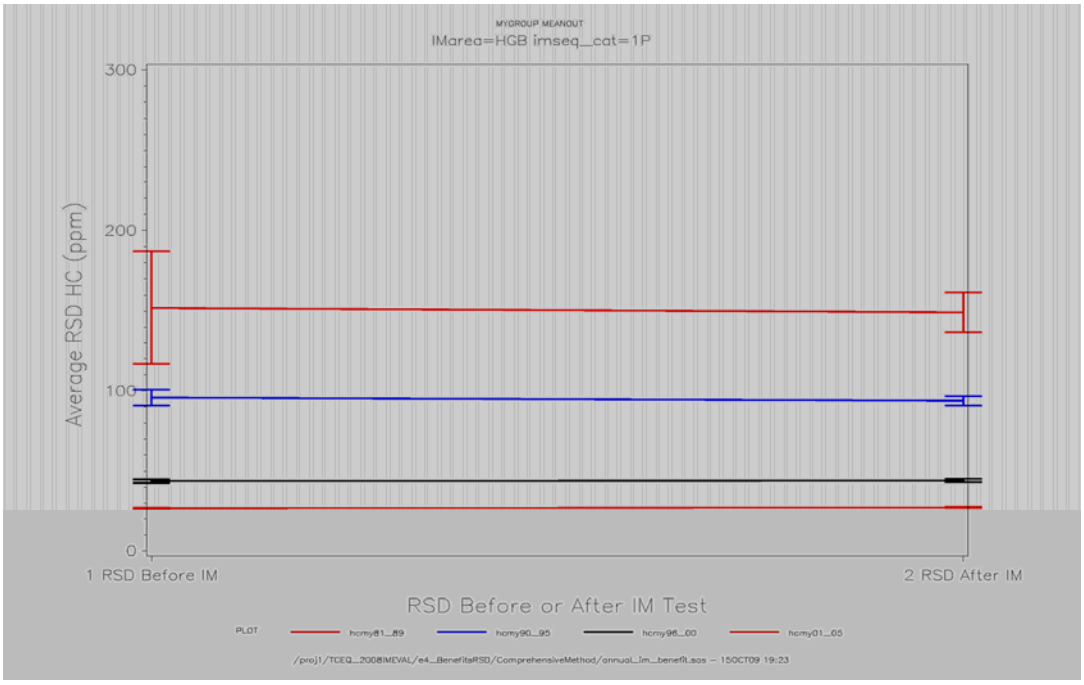


Figure 5-20. Average RS HC by Model Year Group Before and After I/M Test for DFW Vehicles with I/M Sequence Category = 1P

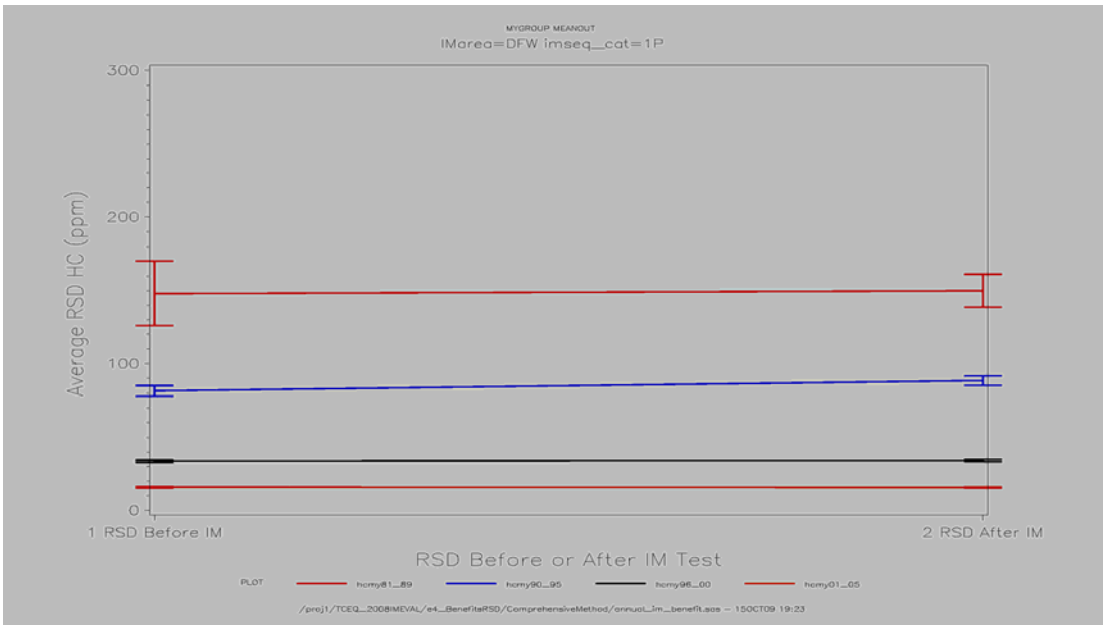


Figure 5-21. Average RS CO by Model Year Group Before and After I/M Test for HGB Vehicles with I/M Sequence Category = 1P

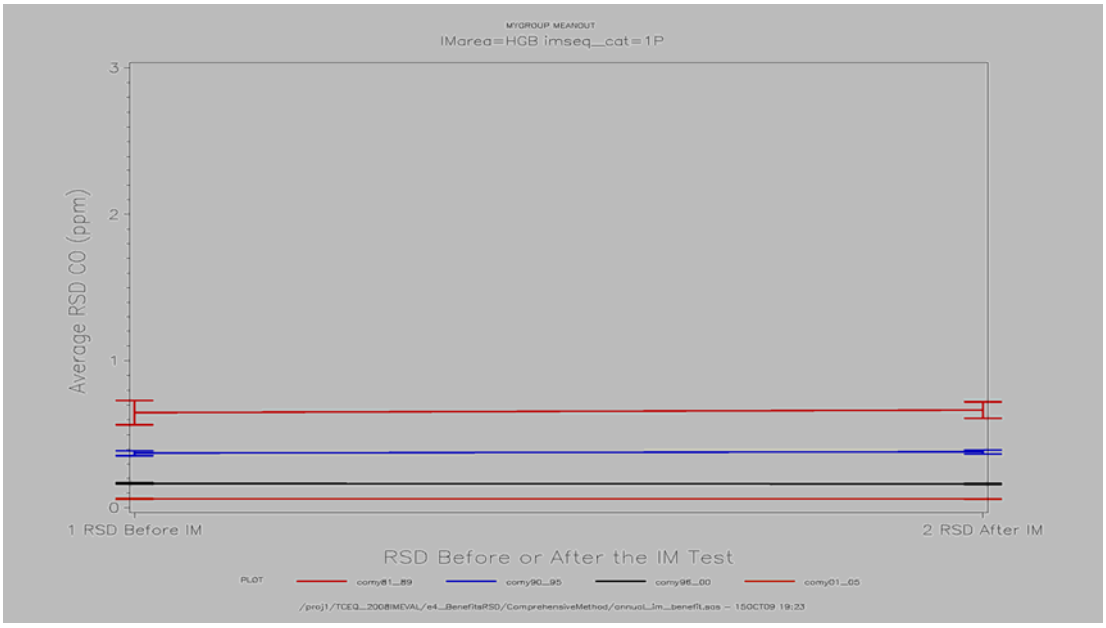


Figure 5-22. Average RS CO by Model Year Group Before and After I/M Test for DFW Vehicles with I/M Sequence Category = 1P

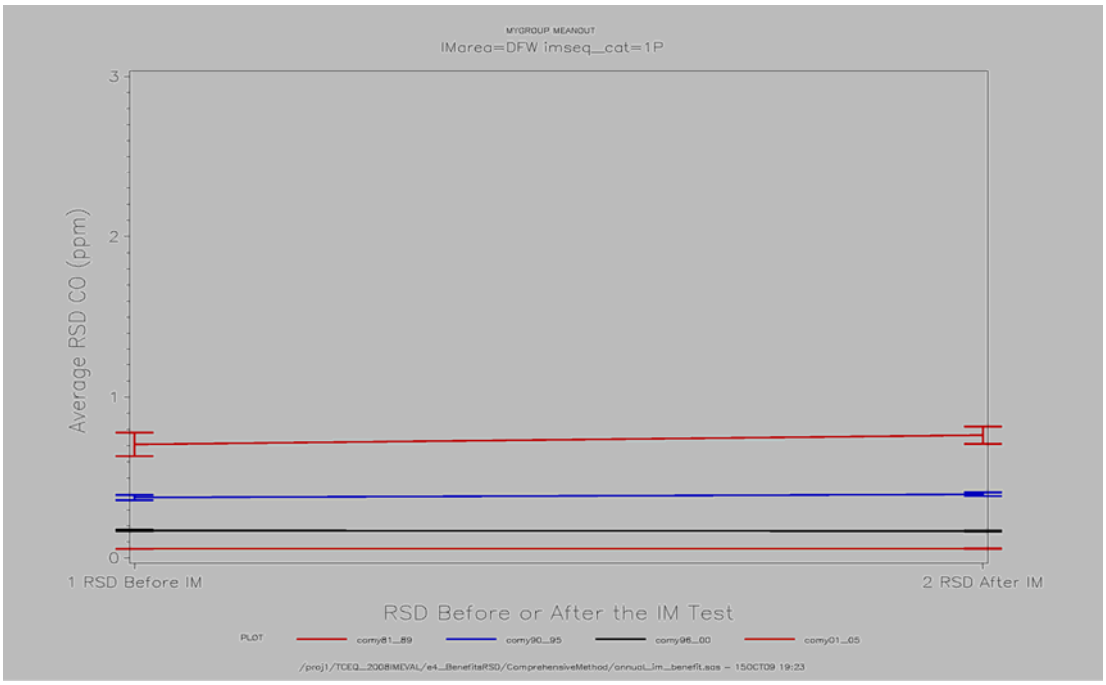


Figure 5-23. Average RS NOx by Model Year Group Before and After I/M Test for HGB Vehicles with I/M Sequence Category = 1P

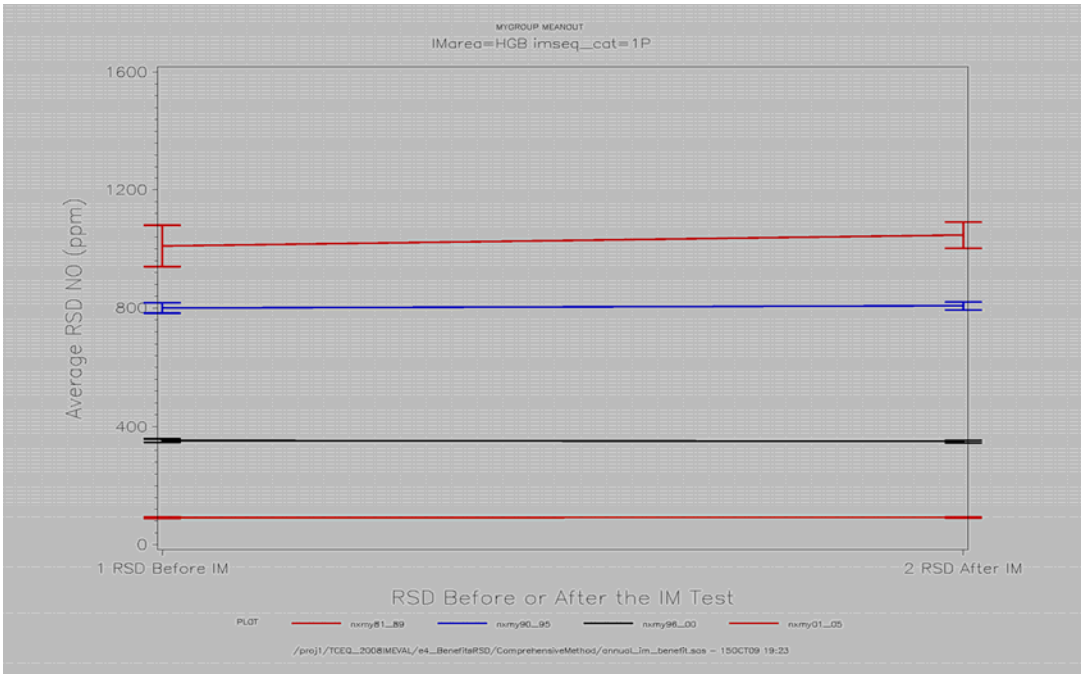
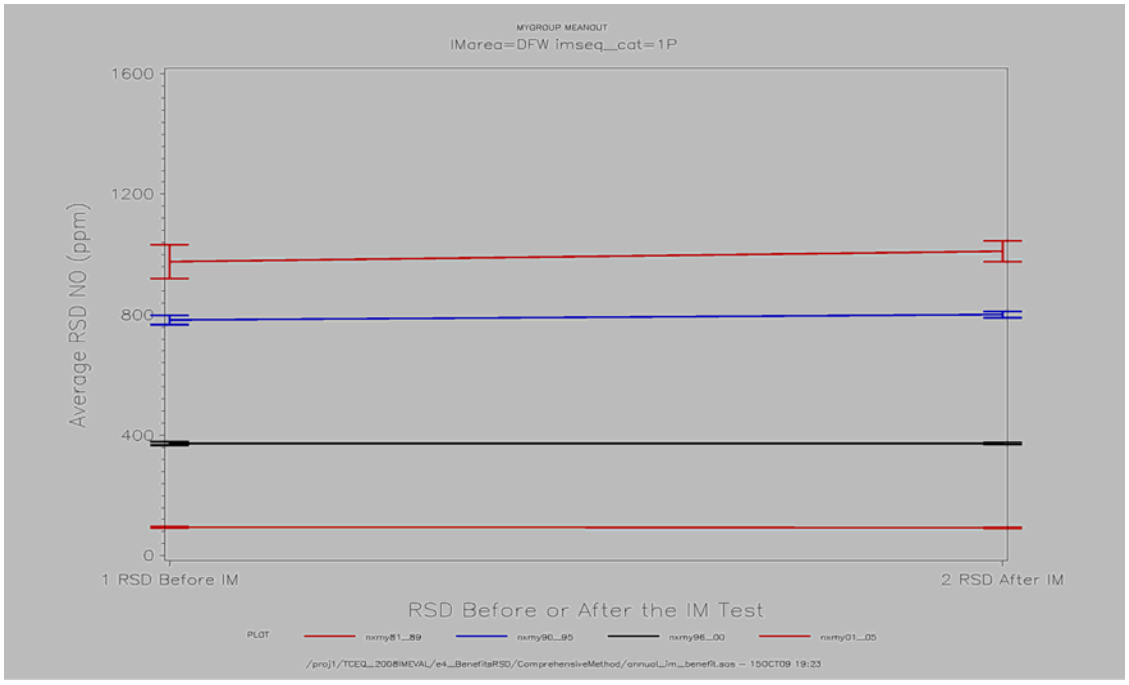


Figure 5-24. Average RS NOx by Model Year Group Before and After I/M Test for DFW Vehicles with I/M Sequence Category = 1P



The RS average concentrations shown in the figures above are tabulated in Tables 5-6 and 5-7. The values in Table 5-6 show that in 20 of the 24 cases the average emissions

decreased for the FP vehicles. The values in Table 5-7 show that for 1P vehicles the emission changes were small. Of the 24 cases, 6 decreased slightly, 7 stayed about the same, and 11 increased.

Table 5-6. RS Averages Before and After an I/M Test for HGB and DFW for I/M Sequence Category = FP

Houston Galveston Brazoria (HGB) Area						
	RS HC (ppm)		**RS CO (%)**		**RS NO (ppm)**	
MY Group	**Before I/M**	**After I/M**	**Before I/M**	**After I/M**	**Before I/M**	**After I/M**
1981-1989	312	167	1.09	1.11	1,395	1,128
1990-1995	148	126	0.68	0.56	1,236	1,183
1996-2000	51	55	0.23	0.22	515	479
2001-2005	31	28	0.09	0.09	173	162
Dallas Fort Worth (DFW) Area						
	RS HC (ppm)		**RS CO (%)**		**RS NO (ppm)**	
MY Group	**Before I/M**	**After I/M**	**Before I/M**	**After I/M**	**Before I/M**	**After I/M**
1981-1989	215	185	1.08	1.15	1,411	1,152
1990-1995	144	129	0.73	0.57	1,264	1,167
1996-2000	42	46	0.24	0.22	540	490
2001-2005	21	20	0.10	0.08	184	166

Table 5-7. RS Averages Before and After an I/M Test for HGB and DFW for I/M Sequence Category = 1P

Houston Galveston Brazoria (HGB) Area						
	RS HC (ppm)		**RS CO (%)**		**RS NO (ppm)**	
MY Group	**Before I/M**	**After I/M**	**Before I/M**	**After I/M**	**Before I/M**	**After I/M**
1981-1989	152	149	0.65	0.67	1,010	1,046
1990-1995	96	94	0.37	0.38	800	807
1996-2000	44	44	0.16	0.16	353	350
2001-2005	27	27	0.06	0.06	91	92
Dallas Fort Worth (DFW) Area						
	RS HC (ppm)		**RS CO (%)**		**RS NO (ppm)**	
MY Group	**Before I/M**	**After I/M**	**Before I/M**	**After I/M**	**Before I/M**	**After I/M**
1981-1989	148	150	0.71	0.76	977	1,011
1990-1995	81	88	0.38	0.40	783	802
1996-2000	34	34	0.17	0.17	374	373
2001-2005	16	15	0.06	0.06	94	92

The results in Tables 5-6 and 5-7 show the difference in average RS concentrations between before and after I/M observations, for different model year groups. To calculate the net overall effect on emissions of the I/M program, these results must be combined. Because RS measurements are primarily taken on freeway on-ramps, the average vehicle that is observed by RS is somewhat newer that the average vehicle in the I/M fleet. This difference is shown in

Table 5-8, which contains the distribution of vehicles among the model year groups for the RS measurements -matched-to-I/M fleet, and for the I/M fleet. The fact that this difference exists, i.e. that the RS measurements-matched-to-I/M fleet is somewhat newer than the I/M fleet, should be kept in mind when considering overall fleet results.

Table 5-8. Model Year Distributions for RS-Matched-to-I/M Fleet and I/M Tested Fleet

Model Year Group	Dallas Fort Worth (DFW) Area				Houston Galveston Brazoria (HGB) Area			
	RS-Matched-to-I/M Fleet		I/M Tested Fleet		RS-Matched-to-I/M Fleet		I/M Tested Fleet	
	Number	%	Number	%	Number	%	Number	%
1981-1989	18,558	1.3	206,664	3.0	14,008	1.1	155,030	2.7
1990-1995	141,183	9.8	990,955	14.4	113,884	8.7	808,598	14.0
1996-2000	448,876	31.3	2,255,263	32.8	394,992	30.1	1,893,985	32.9
2001-2005	827,477	57.6	3,423,402	49.8	789,667	60.2	2,899,309	50.4
Total	1,436,094	100.0	6,876,284	100.0	1,312,551	100.0	5,756,922	100.0

The overall fleet results for the annual I/M benefit are shown in Table 5-9. The first block of data shows only a very slight drop in the RS averages from before to after an I/M test for the entire RS matched I/M fleet. However, as discussed above, the RS averages do drop for the vehicles that do actually receive a failing test and then a repair to pass the final I/M test. This suggests that the I/M program is causing an I/M benefit for those vehicles even though the emissions do not drop for the entire dataset. It is very possible that in the absence of the I/M program, annual fleet emissions would increase by much larger amounts.

Table 5-9. RS Average Concentrations to Evaluate the Annual I/M Benefit

I/M Program Area	I/M Sequence Category	Number of Obs, Before+ After	RS HC (ppm)			RS CO (%)			RS NO (ppm)		
			Before I/M	After I/M	Change (%)	Before I/M	After I/M	Change (%)	Before I/M	After I/M	Change (%)
DFW + HGB	1P + FP	798,516	34	36	5	0.13	0.13	4	251	262	4
DFW + HGB	1P	764,352	33	35	5	0.12	0.13	5	238	251	5
	FP	34,164	62	59	-4	0.29	0.26	-8	542	518	-4
DFW	1P + FP	409,762	30	32	7	0.13	0.14	6	260	274	5
HGB	1P + FP	388,754	39	40	2	0.13	0.13	3	241	250	4
DFW	1P	392,184	28	30	7	0.13	0.13	7	247	263	6
	FP	17,578	59	58	-1	0.31	0.27	-10	569	536	-6
HGB	1P	372,168	38	39	3	0.12	0.12	3	229	239	4
	FP	16,586	65	60	-8	0.27	0.25	-5	512	498	-3

5.3 Estimate of the Total I/M Benefit from RS Data

The Total I/M Benefit is the difference in emissions between the I/M fleet and a hypothetical fleet with the same characteristics and driving environment, but a fleet whose vehicles have never been in an I/M program. According to EPA's Reference method [Reference 2], the Total I/M Benefit can be calculated using RS data. This calculation can be done by comparing RS emissions for vehicles registered in an I/M area with vehicles registered in non-I/M areas. The Total I/M Benefit is the difference in emissions between the I/M fleet and the non-I/M fleet.

Currently, the RS measurements in Texas are routinely taken only in the county areas that have I/M programs. However, in the fall of 2008, a study involving the collection of remote sensing data was conducted in the San Antonio area. For this study, the San Antonio RS data were used as the non-I/M fleet, against which the RS data from the DFW and HGB I/M area RS data were compared.

Preparation of RS data - In this task, ERG used the RS data collected in the HGB area, the DFW area, and the SAN area, to evaluate the Total I/M Benefit. The DFW and HGB RS data provided by DPS started out with about 12 million records. The DFW and HGB records span several years, but it is preferable to compare RS results that were taking under similar climactic conditions and at similar times. The San Antonio RS data were collected only in October and November of 2008. For HGB and DFW, the RS dataset ends in late summer of 2008, so October and November of 2007 were used for this analysis. Selecting only October and

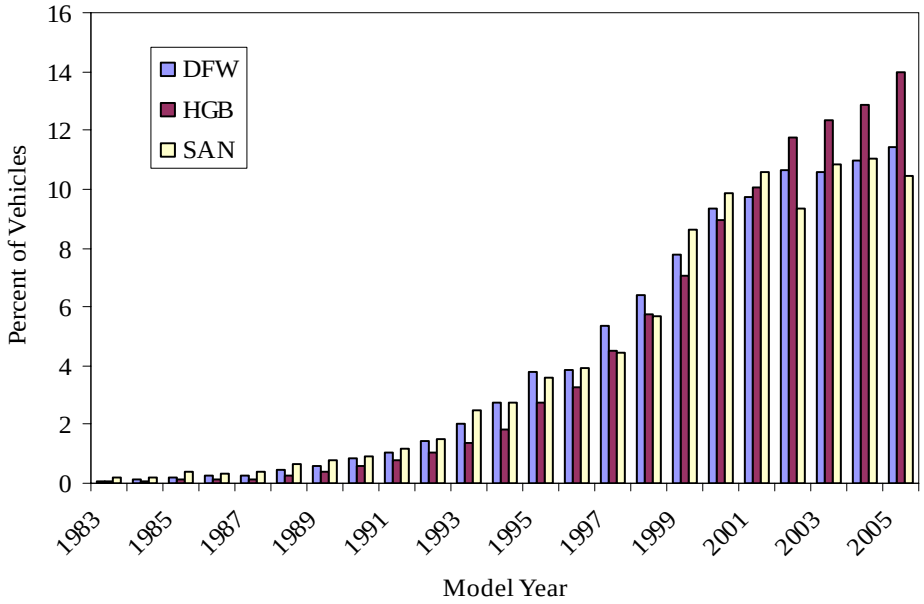
November 2007 from the DFW and HGB RS data left 1.3 million records in the dataset. For all of the analyses with the out-of-program (RS) data, the vehicle license plate was a crucial variable. The license plate is used to determine the county of registration for the vehicle, and vehicle information such as model year. Therefore any records that had missing license plate information were removed. This left 1.1 million records in the RS dataset.

When the RS data were collected, each vehicle was matched by plate with the current Texas registration data to determine the county in which the vehicle was registered. This registration county information was included in the RS data fields. For about one quarter of the RS data, this registration county name was listed as "UNKNOWN." The county of registration is essential to determining whether or not the vehicle was subject to an I/M program when the RS readings were taken. The Texas registration data provided for this project could have been used to match these RS vehicles by plate to get the registration county. However, the registration records provided to ERG for this project were a snapshot of the registration data taken at a point in time after all the RS data were recorded. Matching to this registration database would have caused errors in assigning registration counties to vehicles at the time of their RS measurements. Therefore, RS records with an "UNKNOWN" registration county or a registration county outside the DFW, HGB, or SAN areas were deleted from the dataset. RS records collected in areas other than DFW, HGB, or SAN were also deleted from the dataset (regular RS records are collected in all I/M areas within the state of Texas including the El Paso, Williamson, and Travis counties). Therefore, only RS data collected in HGB, DFW, and SAN, for vehicles registered in HGB, DFW, or SAN, were kept in the dataset. This left about 700,000 RS records: 372,000 records collected in the HGB area, 300,000 records collected in the DFW area, and 21,000 records collected in the SAN area.

The RS records provided to ERG by DPS were already checked for validity by the RS data collection contractor. Therefore, there was no check made for the validity of the values within each of the RS data fields with the exception of the missing variable information discussed above. ERG did, however, calculate the vehicle specific power (VSP) for each vehicle using the RS speed, acceleration, and the slope at the RS site. The slope for the RS site was not included in the RS data. These data were provided separately by DPS. Once the sites and slopes were matched to the RS records and the VSP calculations were done, a VSP filter was applied. Any records with a VSP outside the range of 5-25 kW/Mg were removed from the dataset. This left 580,000 records: 315,000 for the HGB area, 242,000 for the DFW area, and 18,000 for the SAN area.

Comparison of Fleets – The model year distribution of the fleet observed by RS in each of the three areas is shown in Figure 5-25. It can be seen from the figure that the HGB fleet contained the largest proportion of new vehicles, while the SAN fleet had a slightly larger proportion of the very oldest model year vehicles.

Figure 5-25. Model Year Distribution of SAN, DFW and HGB Fleets



Calculation of Total I/M Benefit – To determine the total benefit of the DFW and HGB I/M programs, the measured RS emission levels from the DFW and HGB areas were compared to RS emissions levels from the SAN area (which does not operate an I/M program). A first comparison was made by plotting the mean RS emissions concentrations from each area, stratified by model year. These plots are shown in Figures 5-26, 5-27, and 5-28, for HC, CO, and NO, respectively. It can be seen from the plots that for all three pollutants, for almost all model years, the mean RS emissions in SAN were substantially higher than those in DFW or HGB. The figures also show that RS emissions levels in DFW and HGB were very similar, so for the rest of this section, they will be combined into a single "I/M Area" group, for comparison to the San Antonio "Non-I/M Area" group.

Figure 5-26. Mean RS HC Emissions by Area and Model Year

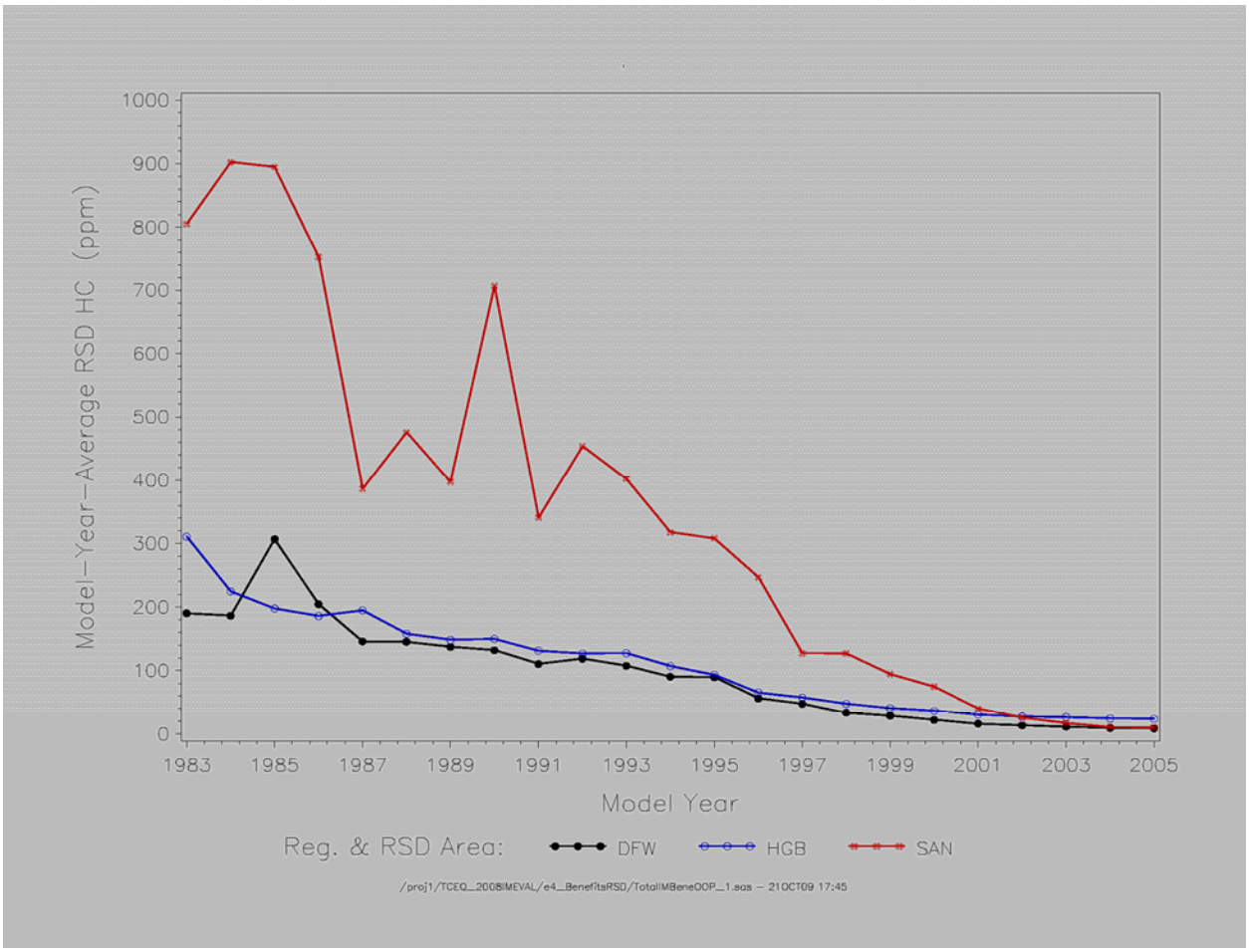


Figure 5-27. Mean RS CO Emissions by Area and Model Year

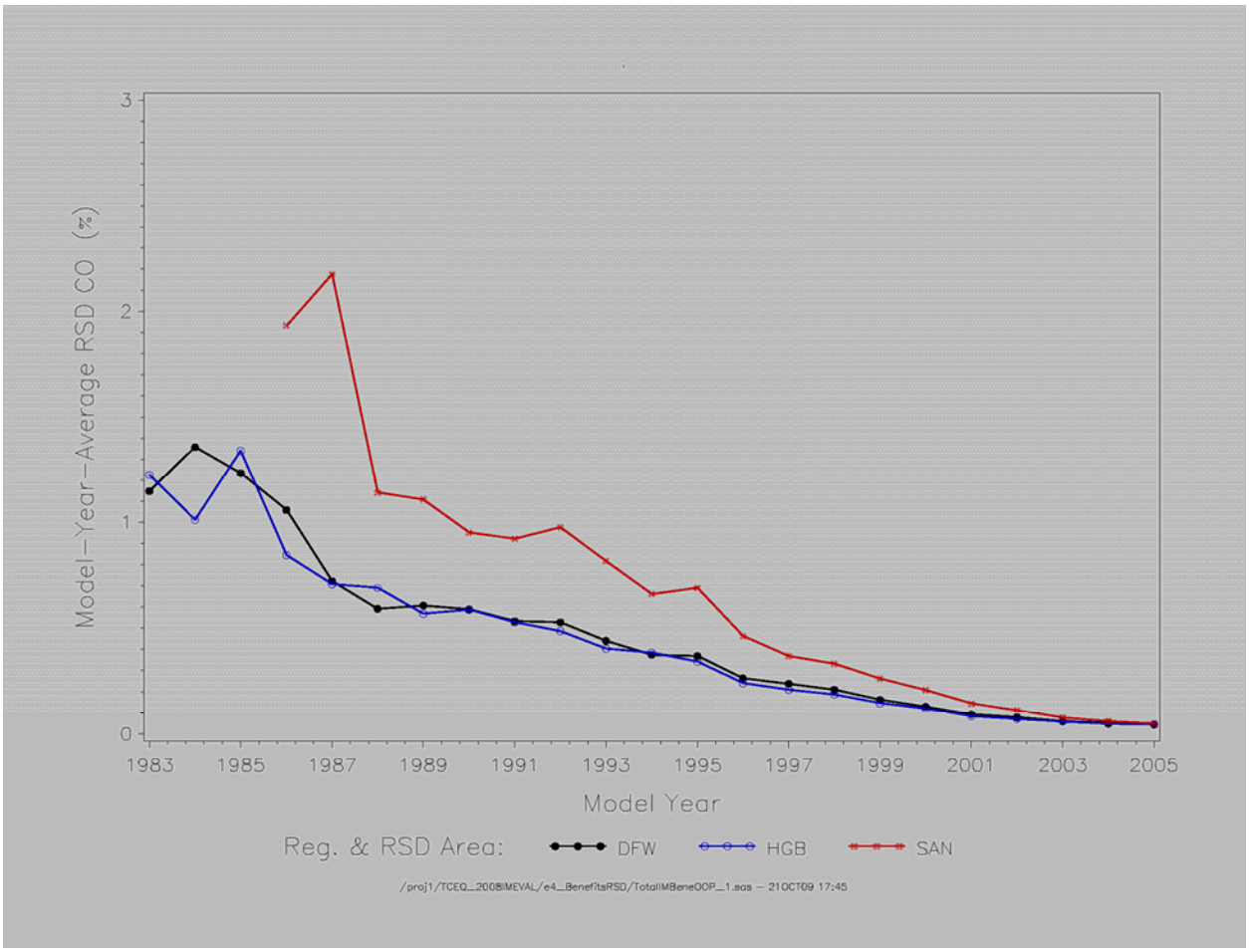
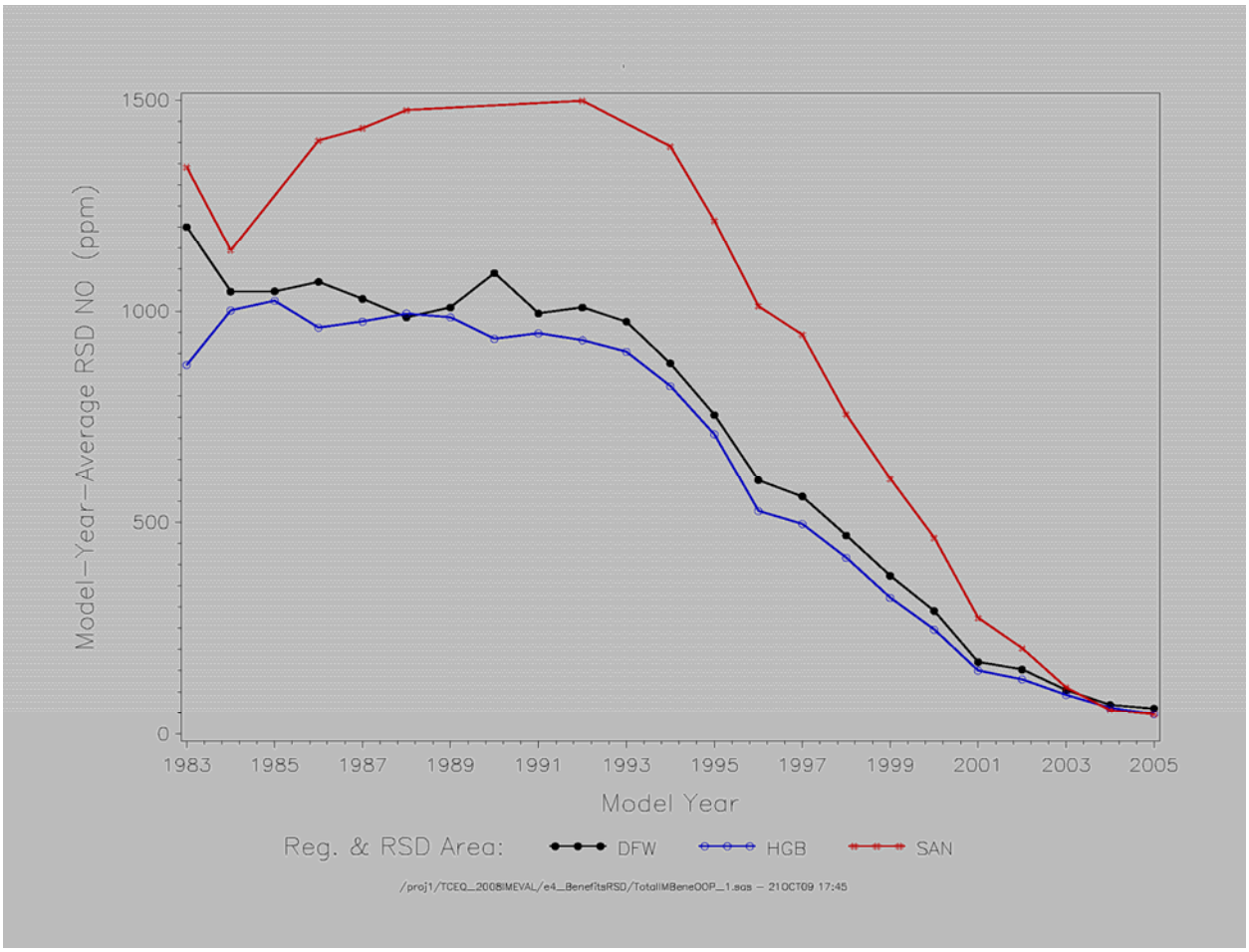


Figure 5-28. Mean RS NO Emissions by Area and Model Year



The difference in emissions between the I/M Areas and the Non-I/M Area are shown again in Figure 5-29, as the percent difference between the two areas. For the very newest model years, very small differences in mean RS emissions concentrations are amplified into percent changes that appear to be large. However, the means for the newest model years are so low that they may be influenced by even small amounts of bias that are sometimes present in remote sensing instrumentation; the differences may or may not represent actual differences in emissions of new vehicles in the different areas. However, for the remainder of model years, where the mean concentrations are larger, it would appear that the I/M program in the DFW and HGB areas has had a substantial effect on reducing RS emissions concentrations to levels some 30 to 70% below the RS emissions of the Non-I/M Area fleet.

In order to quantify the Total I/M Benefit, the mean RS HC, CO and NOx emission concentration levels were calculated separately for the I/M areas and the non-I/M area for each model year. These results are shown below in Table 5-10.

Figure 5-29. Percent Difference Between Non-I/M Area and I/M Area RS Concentration Levels

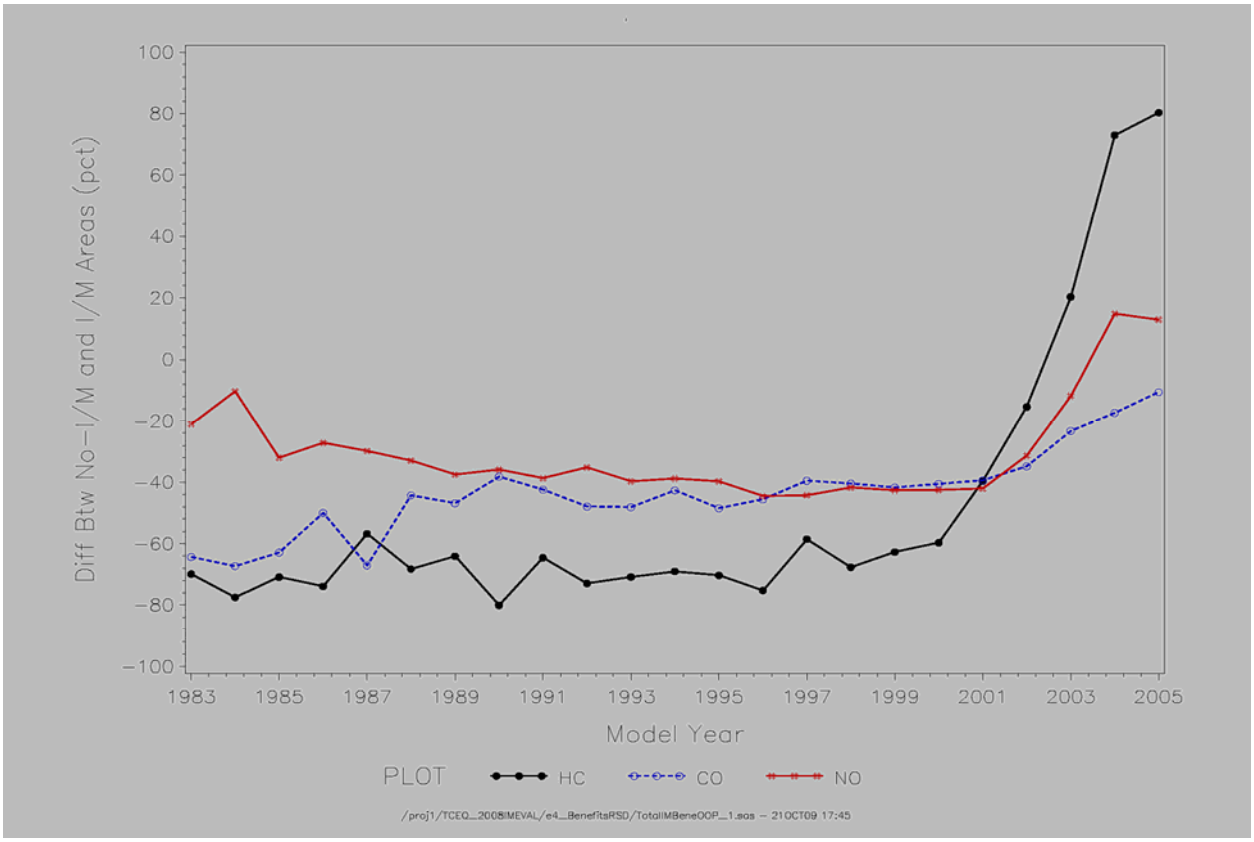


Table 5-10. Mean RS Emissions Concentration Levels and Changes in I/M Areas vs. Non-I/M Area

	Number of Obs.		HC			CO			NOx		
Model Year	Non-I/M Area (San Antonio)	I/M Areas (DFW & HGB)	Mean, Non-I/M Area (ppm)	Mean, I/M Areas (ppm)	Change from Non-I/M to I/M	Mean, Non-I/M Area (ppm)	Mean, I/M Areas (ppm)	Change from Non-I/M to I/M	Mean, Non-I/M Area (ppm)	Mean, I/M Areas (ppm)	Change from Non-I/M to I/M
1983	33	319	805	242	-70	3.31	1.18	-64	1341	1059	-21
1984	38	609	902	203	-77	3.68	1.20	-67	1145	1027	-10
1985	71	760	895	261	-71	3.44	1.28	-63	1526	1038	-32
1986	62	1,034	753	197	-74	1.93	0.97	-50	1404	1024	-27
1987	70	1,193	386	167	-57	2.18	0.72	-67	1434	1006	-30
1988	118	1,918	476	151	-68	1.14	0.64	-44	1476	990	-33
1989	141	2,668	397	143	-64	1.11	0.59	-47	1598	998	-38
1990	164	3,970	707	141	-80	0.95	0.59	-38	1582	1015	-36
1991	217	5,002	341	121	-65	0.92	0.53	-42	1586	972	-39
1992	271	6,742	454	123	-73	0.98	0.51	-48	1498	972	-35
1993	456	9,121	402	117	-71	0.82	0.42	-48	1562	942	-40
1994	495	12,515	317	98	-69	0.66	0.38	-43	1390	852	-39
1995	654	17,760	308	91	-70	0.69	0.36	-48	1215	732	-40
1996	709	19,617	247	61	-75	0.46	0.25	-46	1012	561	-45
1997	805	27,152	127	53	-59	0.37	0.22	-40	945	527	-44
1998	1,037	33,598	127	41	-68	0.33	0.20	-40	756	440	-42
1999	1,572	40,993	95	35	-63	0.26	0.15	-42	602	345	-43
2000	1,791	50,737	75	30	-60	0.21	0.12	-41	463	266	-42
2001	1,924	55,195	40	24	-40	0.14	0.09	-39	274	159	-42
2002	1,699	62,825	26	22	-15	0.11	0.07	-35	202	139	-31
2003	1,974	64,559	17	20	20	0.08	0.06	-23	110	97	-12
2004	2,008	67,095	11	18	73	0.06	0.05	-17	56	65	15
2005	1,897	71,559	10	18	80	0.05	0.04	-11	46	52	13

6.0 Measures for Evaluating Station Performance

In for an I/M program to function as it was designed to do, it is critical that each I/M inspection station follow the procedures and regulations that have been created to ensure that inspections are consistently performed properly. In this section, data from the TIMS database are used to explore a range of ways in which individual I/M stations and inspectors may be circumventing procedures or regulations – in other words, cheating. The offenses can be broken into two different levels: 1) errors of commission: intentional breaking of rules to manipulate inspection results, and 2) errors of omission: failure to routinely follow regulated procedures. The specific actions that will be investigated here include:

- Errors of Commission:
  - OBD Fraud Checks (Section 6.1)
    - VIN from vehicle doesn't match OBD-downloaded VIN (6.1.1)
    - Power Control Module (PCM), Parameter ID (PID), VIN, and/or readiness status changes between inspections (6.1.2)
  - Tailpipe Inspection Manipulation (Section 6.2)
    - Clean-piping: a passing retest follows a failed inspection within only a few minutes (6.2.1)
    - Switching vehicle from ASM to TSI in order to pass inspection (6.2.2)
    - Switching from LD (<8,500 GVWR) to HD (>8,500 GVWR) in order to pass inspection (6.2.3)
    - Stations with a very high or very low ASM or OBD fail rate (6.2.4)
- Errors of Omission:
  - Use of analyzers of less-than-optimal functionality (Section 6.3)
    - Performing inspections on analyzers with a high degree of drift (6.3.1)
    - Performing inspections right before failing a span gas audit (6.3.2)
    - Performing only one of the four calibrations that are required every 72-hours, instead of all four (6.3.3)
  - Data entry issues (Section 6.4)
    - Consistently entering repair type as "Misc" (6.4.1)
    - Consistently entering repair cost as $0 (6.4.2)
    - VIN Check digit errors (6.4.3)
    - Anomalous inspection sequences (other than 1P or FP) (6.4.4)
  - Anomalous test results (Section 6.5)
    - ASM or TSI Inspection results with greater than 16% CO_2 (6.5.1)
    - ASM or TSI Inspection results with greater than 20.5% O_2 (6.5.2)
    - ASM or TSI inspections with high DCF values (6.5.3)

Obviously, many stations will have the occasional inspection where the analyzer had drifted just before a calibration, or the VIN was accidentally entered incorrectly and didn't match the downloaded OBD VIN, etc. However, the goal of this section is to identify those stations

where these events are frequent, suggesting that their occurrence is not accidental and these events are much more common than at other stations.

A percentile rank will be assigned to each station for its performance on each bullet the above list. Using a ranking of the stations for each measure permits the comparison of one measure to another measure even if the two have different types of results. The final result will be a compilation of the ranks for each station on each of the measures of errors of commission and each of the measures of omission. These compiled ranks will be discussed in Section 6.6.

A short list of inspection stations that are operated by the state was provided by TxDOT. These stations were excluded from all of the analysis in this section, as they tended to exhibit a substantially different range of results than the majority of stations, skewing the distribution of the results. These stations were: 1G25792, 4G25799, 2G34721, 1G34843, 6G20541, 6G36011, and 2G25739.

6.1 OBD Data Checks for Evidence of Station Fraud

"Clean-piping" is a term used to describe a type of vehicle emissions test fraud in which an inspector substitutes a vehicle with passing emission rates in place of a vehicle with high emission rates in order to achieve a pass record for the high-emitting vehicle. Historically, this has been identified through the use of covert audits, notifications by motorists, and analysis of vehicle emission result trends. For a vehicle receiving an OBD inspection, the analogous practice is typically referred to as "clean-scanning," where a vehicle with no MIL illumination is substituted in place of a vehicle with MIL illumination and stored DTCs in an attempt to receive a passing test result. Although identification of emission results trends is not possible with OBD tests, information downloaded from the OBD system during an inspection may be used to identify possible clean-scanning activities.

6.1.1 Comparison of Inspector-Entered VIN to Vehicle-Downloaded OBD VIN

For OBD vehicles, a comparison of the inspector-entered VIN against the vehicle-downloaded VIN via the OBD connection can help verify that all OBD inspections are performed on the correct vehicle. Both the inspector-entered VIN and the vehicle-downloaded VIN are recorded in each vehicle inspection record of the Texas TIMS.

For this analysis, all test records where no OBD VIN was present were excluded. This reduced the dataset from 13,614,382 records to 5,733,777 records. For each of these remaining records, the OBD-downloaded VINs were compared with VINs entered (either via keyboard or barcode scan) during the vehicle inspection. Approximately 6% of these records (345,546

records) were found to have VIN to VIN discrepancies. Manual investigation of these records showed a number of the OBD VINs or entered VINs were invalid (e.g., 104,182 VINs were less than 17 characters in length), and some mismatches were also due to VIN errors in the vehicle test record. An investigation of the VIN discrepancies, shown in Table 6-1, revealed that vehicles from the early years of OBD (1996-1999) had very high rates of discrepancies, with as many as 96% of vehicle records containing a discrepancy. Rates were very low for the later model years, in part due to EPA's requirement in 2005 for the OBD system to log the eVIN. However, it should be noted that the vehicles that benefit from clean-scanning are those that fail an inspection and that group would likely be dominated by the early model-year vehicles, rather than the newer vehicles.

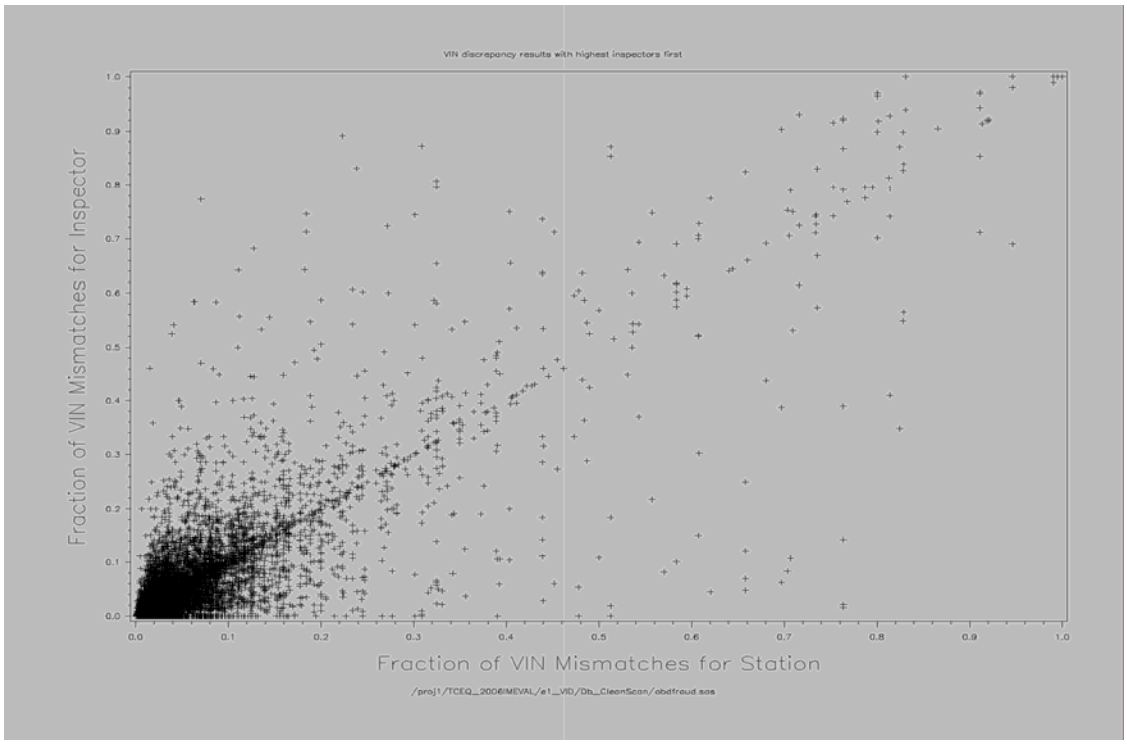
Table 6-1. Rates of OBD-Downloaded and Inspector-Entered VIN Discrepancies, by Model Year

Model Year	Number of OBD Inspections with VIN Mismatch	Percent of OBD Inspections with VIN Mismatch	Total Inspections
1996	13,202	96.06	13,744
1997	14,754	94.31	15,644
1998	14,206	92.53	15,353
1999	16,137	78.32	20,604
2000	61,109	26.67	229,112
2001	51,709	8.89	581,565
2002	51,932	7.68	675,910
2003	48,887	6.60	740,555
2004	31,090	3.59	865,821
2005	22,013	1.64	1,342,521
2006	13,610	1.57	868,050
2007	5,766	1.70	338,659
2008	1,055	4.26	24,794
2009	72	4.98	1,445

The rate at which VIN discrepancies were recorded was calculated for each station that performed OBD inspections, and for each inspector. The results of this comparison are shown graphically in Figure 6-1. The horizontal axis shows the fraction of OBD inspections that contained a VIN discrepancy for each station, while the vertical axis shows the fraction of OBD inspections with a VIN discrepancy for each inspector. To reduce errors due to small sample size, stations that performed fewer than 100 inspections or inspectors that performed fewer than 100 inspections were excluded from the plot. The large cluster of points at the bottom left corner of the plot includes most stations and inspections: these had a near-zero rate of VIN discrepancies. The points closer to 1 on the horizontal or vertical axis indicate stations or inspectors that almost always produced OBD records with a VIN discrepancy. These very-high

rates could result from practices other than clean-scanning, such as consistently sloppy data entry.

Figure 6-1. Rates of OBD-Downloaded and Inspector-Entered VIN Discrepancies, by Station and Inspector



One additional factor that was calculated for each station was the number of times the same VIN was downloaded in different OBD inspections. If clean-scanning is taking place, there is a good chance that the "clean" vehicle would be used repeatedly and its VIN would be downloaded numerous times, whereas VIN typos would vary with each inspection. This turned out to be a revealing investigation, as it was found that some stations did OBD inspections on the same downloaded-VIN more than a thousand times.

These VIN mismatch findings were condensed into a rank for each station, based on the fraction of inspections that revealed a disagreement between the entered VIN and the downloaded VIN. Stations that performed fewer than 100 OBD inspections over the two year period were again excluded from the results, due to the possibility of spurious results from the small sample size. As an example of the findings, the VIN mismatch rates for the 10 worst offending stations are listed below in Table 6-2. The table shows the rate at which there was a disagreement between the entered VIN and the downloaded OBD VIN, out of all inspections at that station that included a 17-digit VIN in both fields. The stations in the first three rows of the

table actually had a mismatch rate of 1.0, meaning all inspections at that station had a VIN mismatch when both the OBD downloaded and the inspector entered VIN were present. The table also shows the maximum number of times a single VIN was tested at each station.

Table 6-2. Stations with Highest and Lowest Rates of OBD and Entered VIN Mismatches

Station ID	Percent of Inspections Where VIN Did Not Match	Total Number of Inspections Performed at Station	Maximum Number of Tests on a Single VIN	Percentile Rank for Station
Ten worst stations:				
1P39272	100%	231	232	100.00
1P37432	99%	375	155	99.97
1P36597	99%	638	588	99.94
2P36491	92%	1,090	155	99.92
1P38855	92%	124	79	99.89
1P34167	91%	486	189	99.86
1P37231	91%	1,689	993	99.83
1P37411	87%	231	193	99.80
1P37724	83%	206	170	99.78
1P36692	83%	330	200	99.75
Ten best stations:				
1F21586	0%	220	3	0.03
1F22112	0%	120	4	0.06
1F30514	0%	263	4	0.08
1G18052	0%	344	5	0.11
1G20385	0%	262	4	0.14
1G20713	0%	161	6	0.17
1G20725	0%	186	4	0.20
1G25608	0%	138	5	0.22
1G26849	0%	104	3	0.25
1P29502	0%	354	2	0.28

6.1.2 Comparison of Vehicle-Specific Information Between the First Test and Subsequent Tests

The purpose of this analysis was to compare OBD-downloaded information for a given vehicle on its first inspection, to OBD-downloaded information on retests of that same vehicle. Certain types of OBD information may be combined to create unique “electronic profiles” for each vehicle, and the electronic profile should be the same at the initial inspection and at subsequent inspections. If the electronic profile changes from one inspection to the next, inspection fraud may be suspected. For this analysis, only those vehicle inspection cycles that included an initial test and at least one retest were used, reducing the dataset from 13,614,336

OBD inspections, to 1,710,683 inspections. This includes 819,360 initial inspections, and 891,323 retests.

Three variables were used to create the first "electronic profile" for each vehicle: the OBD-downloaded VIN, the PCM ID, and the PID Count. The downloaded values for these three variables from all OBD tests conducted over the two-year audit period are summarized below:

- OBD VIN: OBD-downloaded VINs (valid or invalid) were only available in 31% of the 1,710,683 test records. The OBD VIN or the manually entered VIN was null in the remaining 69% of the OBD test records. Because of this, use of the OBD VIN in itself would not be sufficient to positively identify clean-scanning.

- PCM Module ID: PCM Module ID was available in approximately 95% of the 1,710,683 test records. 96 unique PCM Module IDs were seen, but 65% of all PCM Module IDs had a value of "10". Five other PCM Module IDs each comprised an additional 2 to 4% of the test records, and the remaining test records were distributed among the other 90 PCM Module IDs. Because of this, as with the OBD VIN, use of PCM Module ID alone would not be sufficient to positively identify clean-scanning (a substituted vehicle could easily have a value of "10" or one of the other five common PCM Module IDs).

- PID Count: 102 unique PID Count values were seen, and approximately 95% of all OBD test records contained a value for PID Count. Seven PID Count values were seen in 64% of all OBD test records, while the remaining test records contained one of the remaining 93 PID Count values.

- When the PCM Module ID and PID Count are looked at in combination, the three most common combinations comprise 14, 13, and 12% of inspections, with 822 combinations making up the remainder of inspections. Thus the combination of PCM Module ID and PID Count is highly variable and may be a good indicator of a different vehicle being substituted for the test.

The second electronic profile that was created was an "enabled profile". For this, OBD monitors were identified that are commonly found to be both "monitored" and "not monitored," depending on the make/model/model year of vehicle being inspected. For example, very few vehicles have monitored positive crankcase ventilation or air conditioning systems, so these would be poor indicators of potential clean-scanning since the monitored status is almost surely the same for two different vehicles. Similarly, catalysts and oxygen sensors are almost always monitored, so these too would be poor indicators of potential clean-scanning. Again, two different vehicles will likely both have these monitored. As shown below, EGR systems, evap systems, and to a lesser extent heated oxygen sensor systems and secondary air injection systems

were seen to have significant percentages of vehicles with both "monitored" and "not monitored" status:

- EGR systems: 36% not monitored, 64% monitored
- evap systems: 14% not monitored, 86% monitored
- heated O_2 systems: 3% not monitored, 97% monitored
- secondary air systems: 93% not monitored, 7% monitored
- When the status of the four monitors is looked at together, two combinations of monitor status dominated the dataset, with 51% and 27% of vehicles. Smaller numbers of vehicles comprised the remaining 14 combinations and 22% of vehicles. Since the combined monitored status of these four monitors could provide a distinguishing and characteristic profile from vehicle to vehicle, these four monitors were used for this analysis.

An electronic profile and a monitored-status profile were created for each vehicle, for its initial inspection and for any re-inspections. Any tests where either profile differed from inspection to inspection were flagged. Tests where both the electronic profile and the monitored-status profiles changed would be an indicator that a different vehicle was being substituted for the test. Note that for any individual vehicle, these downloaded values may vary among analyzer manufacturers (in particular the PCM Module ID and the PID Count), so the analysis was based on vehicle/analyzer combinations. All inspections where the initial inspection took place on a different type of analyzer than that used for the retest inspection were excluded from the analysis.

Occasionally, analyzer hardware upgrades or software updates could result in OBD system PID count mismatches between multiple tests on the same vehicle, and the OBD-downloaded VIN could be mismatched on multiple tests from the same vehicle in extremely rare instances where the PCM on the vehicle was improperly reprogrammed in an attempt to repair the vehicle. An assessment of the likelihood of fraud is provided for each of the scenarios listed below. It is also worthwhile to note that since each vehicle's OBD system "profile" was assigned based on the information collected during the vehicle's first test, this analysis would not identify any tests where a vehicle was substituted, i.e., clean-scanned, during the initial inspection.

As described above, the dataset included 819,360 initial inspections and 891,323 retests. Of those retests, 95,877 took place on a different type of analyzer than that of the initial test, and

were excluded from the results. This left 795,446 retests for analysis. The results of the analysis were:

- 630,177 (79.2% of the 795,446-record dataset) tests had matches for both the electronic profile and the readiness profile between initial test and subsequent retests on the same analyzer. These tests very likely indicate compliant testing.

- 28,032 (3.5% of the 795,446 record dataset) tests had a mismatch for both the electronic profile info and the readiness profile, between the initial test and at least one retest on the same analyzer. Test pairs where both computer ID information and readiness profile differ are likely to be performed on two different vehicles (i.e., an indication of clean-scanning).

- 134,867 (16.9% of the 795,446 record dataset) tests had an electronic profile mismatch info between the initial test and at least one retest on the same analyzer, but the "readiness profile" matched between the initial test and all subsequent retests on the same analyzer. Since the computer ID serves as a unique identifier for any vehicle, this information should always match for retests on the same vehicle. A mismatch could occur only in the following scenarios:

  - if another vehicle was substituted for a retest (clean-scanning)
  - if an anomaly in the analyzer software interpreted the computer ID info two different ways on subsequent retests for the same vehicle
  - if a vehicle repair was performed in which the vehicle's PCM was re-programmed with new ID info as a part of a repair

  Although the last two scenarios are unlikely, it was not possible to quantify the likelihood of this occurring in this analysis. It is possible for two different vehicles to have common readiness profiles, so a readiness profile match does not confirm that clean-scanning did not occur. Therefore, this scenario (computer ID mismatch) is felt to be a good indicator of clean-scanning.

- 2,370 (0.3% of the 795,446 record dataset) tests had a "readiness profile" mismatch between the initial test and at least one retest on the same analyzer, but the electronic profile matched between the initial test and all subsequent retests on the same analyzer. This scenario is difficult to interpret, since the readiness profile is based on "monitored vs. unmonitored" status of various systems, as opposed to ready/not ready status, and therefore should never change for a vehicle despite the vehicle's state of readiness. Similarly, the computer ID information should be static for any one vehicle except for the case when PCM reprogramming is part of the repair process. Because of the contradictory results, the scenario of a readiness profile mismatch with a computer ID info match is not considered to be a strong indicator of non-compliant testing.

A summary of this information is provided in Table 6-3.

Table 6-3. Percentages of Tests with Various OBD Fraud Indicators

Retest Match Scenario	Retest-only Dataset (795,446 tests total)
All match (compliant)	79.2 %
Readiness mismatch (ambiguous)	0.3 %
PCM ID info mismatch (fraud likely)	16.9 %
Both mismatch (fraud very likely)	3.5 %
Estimated % of clean-scanning	4% to 21%

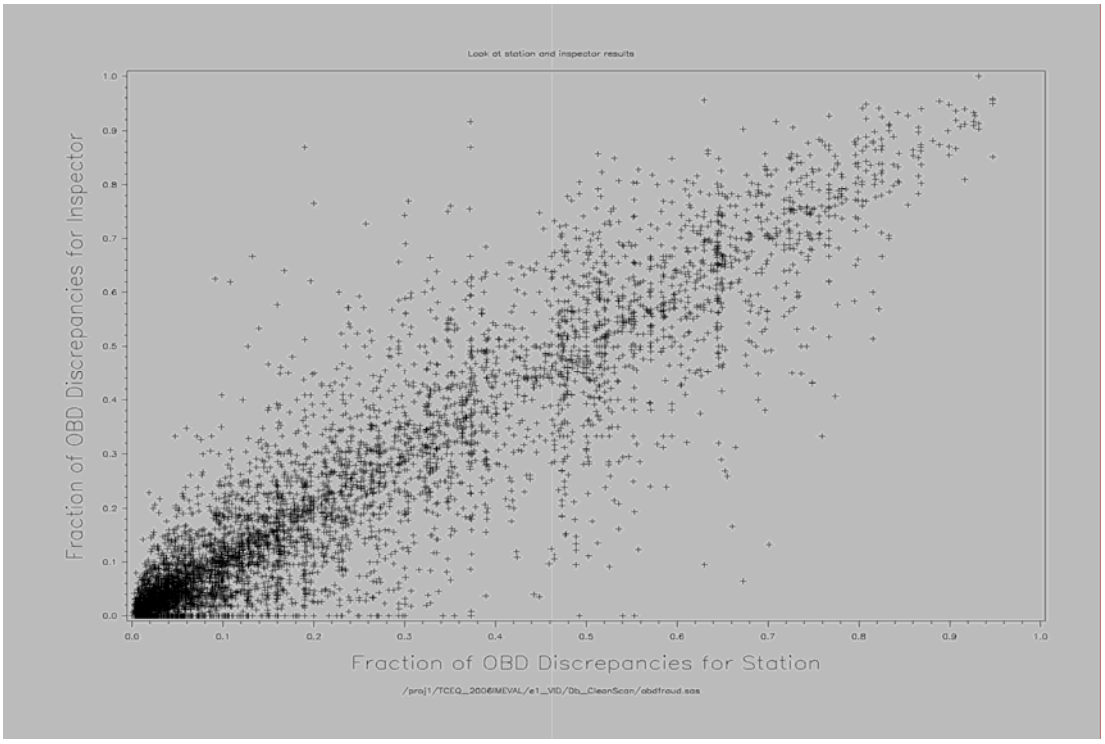
Next, using the complete dataset, which includes tests classified as initial tests, the following general statistics were seen for stations and inspectors with computer ID information or "readiness profile" mismatches.

- Over the two-year audit period, 91% of the 4,063 inspection stations had at least one test record with either a readiness profile or computer ID information mismatch between an initial test and a subsequent test for the same vehicle (tested using the same analyzer as the initial test). The maximum number of mismatch retest records for any one station was 1,812 records over the two-year period, and another 20 stations had more than 600 records with a mismatch. Some stations had mismatch rates as high as 94%.

- Over the two-year audit period, 56% of the 23,421 inspectors had at least one test record with either a readiness profile or computer ID information mismatch between an initial test and a subsequent test on the same vehicle using the same analyzer. The maximum number of mismatch retest records for any one inspector was 878 records over the two-year period, while an additional 13 inspectors had more than 400 mismatch retest records. Inspector mismatch rates as high as 96% were seen.

The distribution of station and inspector mismatch rates is shown in Figure 6-2. The horizontal axis shows the fraction of retest records that contained an electronic profile or readiness profile mismatch, for each station. The vertical axis shows the fraction for each inspector. The large concentration of data points in the lower left corner are stations and inspectors that produced retest records that rarely had a mismatch when compared to the information from the initial inspection. In contrast, the stations/inspectors in the upper right-hand portion of the chart are those that are most likely to be clean-scanning.

Figure 6-2. Rates of Re-Test Discrepancies in OBD Computer and Readiness Information, by Station and Inspector



These results were condensed into a rank for each station, based on the fraction of retest inspections performed at that station that included both an electronic profile mismatch and a readiness profile mismatch. Stations with fewer than 100 OBD retest inspections over the two year period were excluded from the results, due to the possibility of spurious results from the small sample size. The 10 stations with the highest rates of profile mismatches and for comparison, the 10 stations with the lowest rates of profile mismatches are listed in Table 6-4. Some electronic profile and/or readiness mismatches are to be expected, and as mentioned above, more than 90% of stations had at least on case of a mismatch. However, most of those stations had only one or a few mismatches. Overall, about 3.5% of retest inspections resulted in a readiness profile and electronic profile mismatch. When stations with a mismatch in as many as 72% of their inspections are seen, one can start to suspect that something beyond the expected occasional difference is taking place.

Table 6-4. Stations with Highest and Lowest Percents of Electronic Profile and Readiness Profile Mismatches

Station ID	Percent of Re-inspections with BOTH Electronic & Readiness Mismatch	Number of Re-inspections at Station	Percentile Rank for Station
Ten worst stations:			
1P38422	72%	111	100.00
1P36516	67%	117	99.95
2P30412	66%	391	99.90
2P38458	64%	117	99.86
1P32898	63%	103	99.81
1P37414	61%	129	99.76
2P38077	61%	234	99.71
1P36321	61%	137	99.66
1P35785	61%	190	99.62
1P36419	60%	181	99.57
Ten best stations:			
1G20029	0%	210	0.05
1G20214	0%	174	0.10
1P00282	0%	312	0.14
1P00544	0%	170	0.19
1P00561	0%	106	0.24
1P00841	0%	549	0.29
1P01111	0%	100	0.34
1P01700	0%	838	0.38
1P01916	0%	145	0.43
1P02082	0%	172	0.48

6.2 Tailpipe Inspection Data Checks for Fraud

Unlike OBD inspections, tailpipe emissions inspections do not include the download of vehicle-specific information that remains unchanged from an initial inspection to a re-inspection. However, several different types of inspection results have been identified that may provide good indicators that tailpipe emissions inspection fraud may be occurring at a given station. Several of these are extremely uncommon in the TIMS dataset as a whole, but are relatively common for a handful of stations.

- Sometimes a failing inspection is followed by a passing inspection only a few minutes later. This could indicate the occasional easy repair when it happens once or twice for each station, but when it occurs a large number of times at only a few stations, it is more likely to indicate clean-piping.
- Occasionally a vehicle receives an initial inspection that is an ASM test, and a retest inspection that is a TSI test. When such switches occur a large number of times at a single station, and when the test results also show that most of the ASM

tests were failed for high NOx levels (NOx is not measured in a TSI test), it is likely to indicate a version of inspection fraud.

- Similarly, an initial failed inspection of a light-duty vehicle (GVWR<8,500 lbs) is sometimes followed by a passed inspection of that vehicle as a heavy-duty vehicle. Cutpoints are higher for HD vehicles, making the inspection easier to pass. This happens very infrequently in the dataset as a whole, but much more frequently at some stations.
- The overall failure rate at a station can be used as an indicator of whether fraud is occurring. Unusually high or unusually low failure rates may both be a cause for concern. This factor can be difficult to analyze, since it is known that different areas with a different type of fleet (or a different socio-economic status) often have real differences in failure rates.

Each of these factors is discussed in more detail in the following sections, and a ranking is assigned to each station, for each factor.

6.2.1 Short Time Interval Between Inspections

For inspection cycles that begin with a failing inspection, a retest (or retests) usually follows a day or several days after the initial failed inspection. Presumably, repairs are performed during that interval between inspections. However, some failing inspections are followed by a passing inspection within minutes, leading one to wonder how the vehicle was successfully repaired so quickly, or if instead clean-piping occurred for the passing retest. The dataset shows that many stations have one or a few cases of a passing retest following a failing initial test within a short time. These occasional cases may be the real result of a simple fix: a reconnection of a loose line or wire or other simple change. Some vehicles which failed with emissions levels very near the cutpoints might also be retested after no repairs, and pass due to the I/M test variability. However, some stations show a much more frequent occurrence of initial inspections being quickly followed by passing inspections when compared to the majority of stations. In these cases, there may be cause for a suspicion of inspection fraud.

For this analysis, any inspections that were aborted or had dilution problems were deleted from the dataset, and only TSI or ASM inspections were considered. This left 3.2 million observations in the dataset. In addition, only time differences on retest inspections that were conducted at the same inspection station as the initial inspection were used. This resulted in a dataset of about 310,000 retest observations.

The distribution of the number of times that a failed initial inspection was followed by a passing retest within 15 minutes at a given station over a 2.5 year period is listed in Table 6-5. The table shows that this happened 28 times at the station with the highest frequency of

occurrences, while for most of the 2,700 stations that performed tailpipe inspections, it did not ever happen.

Table 6-5. Number of Close-in-Time Retests per Station

Number of Close-In-Time Retests	Number of Stations	Percent of Stations
28	1	0.0
20	1	0.0
18	1	0.0
16	1	0.0
13	2	0.1
12	2	0.1
11	3	0.1
10	2	0.1
9	2	0.1
8	2	0.1
7	1	0.0
6	4	0.2
5	18	0.7
4	23	0.9
3	47	1.8
2	125	4.7
1	329	12.4
0	2,094	78.8
Total	**2,658**	**100.0**

The ten stations with the highest rate of close-in-time retests are listed in Table 6-6. The percentage was calculated from the number of close-in-time retests and the total number of retests, at that station. Stations that performed fewer than 100 retest inspections over the 2.5 year period are excluded from the results.

Table 6-6. Percent of Close-In-Time Retest Inspections for 10 Worst Stations

Station ID	Percent of Close-In-Time Retests	Number of Close-In-Time Retests	Total Number of Retest Inspections	Percentile Rank for Station
2P29931	5.0	6	119	100.00
2P35722	4.3	18	420	99.91
1P33553	4.2	11	260	99.82
1P30200	3.9	6	153	99.72
1P01700	3.5	16	455	99.63
2P36479	3.4	5	145	99.54
1P31418	3.4	12	353	99.45
1P27747	3.1	10	319	99.35
2P33265	3.1	5	161	99.26
2P30227	3.1	7	226	99.17

6.2.2 Changing from ASM to TSI Inspection to Pass

Given that the overall failure rate for the TSI inspection is much lower than that for the ASM inspection, and that the TSI inspection does not measure NOx, while the ASM inspection does measure NOx, ERG investigated whether switching from an ASM inspection to a TSI inspection was ever used to manipulate emissions inspection results.

For this analysis, any inspections that were aborted or had dilution problems were deleted from the dataset, and only TSI or ASM inspections were considered. This left 3.2 million observations in the dataset. Only inspection cycles where the initial inspection and the retest inspection were conducted at the same station were used. This left about 310,000 retests in the dataset.

Overall, it was found that for ASM inspections that were failed for HC and/or CO, but where NOx was passed, 1.0% of retests were TSI instead of ASM. For ASM inspections that included a NOx failure, 1.4% of retests were TSI instead of ASM. This indicates that some intentional test-type switching is taking place to avoid the stricter ASM standards. Table 6-7 shows the frequency and percentage of stations switching to a TSI inspection, which was passed, following a failed ASM initial inspection that included a failure for NOx. Stations that performed fewer than 100 retest inspections were excluded from the results. The table shows that this happened 98 times at the station with the highest frequency of occurrences. The stations in Table 6-7 had rates of 8-20% of all retests being switches from ASM to TSI inspections.

Table 6-7. Percent of Retest Inspections Switched from ASM to TSI for 10 Worst Stations

Station ID	Percent of Retests Switched from ASM to TSI	Number of Switched Retests	Total Number of Retest Inspections	Percentile Rank for Station
1P36369	19.6	44	224	100.00
2P33265	11.2	18	161	99.91
1P02394	11.1	48	434	99.82
1P35240	10.9	14	129	99.72
1P34161	9.7	25	258	99.63
1P31964	9.7	12	124	99.54
2P35706	8.9	9	101	99.45
1P34177	8.9	98	1,103	99.35
1P34344	8.1	10	124	99.26
2P35722	7.9	33	420	99.17

6.2.3 Changing from Vehicle Type from Light Duty to Heavy Duty to Pass Vehicle

Given that inspection standards are less stringent for heavy-duty vehicles than for light-duty vehicles, ERG investigated whether switching a vehicle from having a light-duty GVWR (less than 8,500 lbs) to a heavy-duty GVWR was ever used to manipulate emissions inspection results. The vehicle GVWR is an inspector-entered field in the inspection record.

For this analysis, any inspections that were aborted or had dilution problems were deleted from the dataset, and OBD, TSI and ASM inspections were considered. This resulted in a dataset of 18 million inspection records. Only inspection cycles where the initial inspection and the retest inspection were conducted at the same station were used. This left 1.1 million retest inspections in the dataset.

Overall, it was found that only 0.2% of inspections that were initially failed as a light-duty vehicle were followed by a passing retest as a heavy-duty vehicle. However, these inspections were clustered at a handful of stations, shown below in Table 6-8. The table shows the ten inspection stations with the highest frequency of retests that involved a vehicle that failed as a light-duty vehicle on the initial inspection, followed by a passed retest of the same vehicle as a heavy-duty vehicle. At the first station on the list, fully 17.8% of vehicles that failed as a light-duty vehicle were switched to a heavy-duty vehicle, and passed.

Table 6-8. Percent of Retest Inspections Switched from Light-Duty to Heavy-Duty, for 10 Worst Stations

Station ID	Percent of Retests Switched from LD to HD	Number of Switched Retests	Total Number of Retest Inspections	Percentile Rank for Station
2P00289	17.8	46	258	100.00
1P30191	10.5	19	181	99.96
2P12339	6.2	109	1,760	99.91
1P32094	4.6	17	372	99.87
2P35798	4.0	88	2,219	99.83
1P06692	3.9	7	178	99.78
1P30479	3.8	6	156	99.74
1P38060	3.6	6	167	99.70
2P35711	3.1	28	891	99.65
2P27092	3.0	57	1,911	99.61

6.2.4 Pass/Fail Outliers

Stations can also be evaluated based upon the percentage of vehicles that they pass or fail. Extremely high rates of either passing or failing vehicles may warrant further scrutiny by TxDOT. Since typical pass/fail rates vary widely among inspection types (OBD, ASM, and TSI), this analysis was done separately for OBD and ASM inspections, resulting in two separate percentile rankings for each station. TSI inspections are performed much less frequently than OBD or ASM inspections; therefore, they were not included in this analysis.

It is recognized that differences in inspection failure rates among stations are often due to factors other than fraud. For instance, the age and maintenance level of the fleet tested at each station may vary widely. However, evaluation of the fleet quality and/or socio-economic status of the area each station is beyond the scope of this evaluation, and only overall pass/fail rates for each station are considered here.

Since it was necessary to identify both very low and very high failure rates, the stations were divided into two groups: stations with a failure rate that was above the mean failure rate over all stations, and stations with a failure rate that was below the mean failure rate over all stations. The stations with a failure rate that was above the mean were ranked with the 0% rank for the station at the mean and the 100% rank for the station with the highest failure rate. The stations with a failure rate that was below the mean were ranked with the 0% rank for the station at the mean, and the 100% rank for the station with the lowest failure rate. Thus each station gets one rank, either for being high or being low. The highest failure rate stations are listed in Table 6-9, with failure rates for OBD and ASM inspections listed separately. The lowest failure

rate stations are listed in Table 6-10, with failure rates for OBD and ASM inspections listed separately. Stations with fewer than 100 inspections are excluded from the results.

Table 6-9. Stations with Highest Failure Rates, OBD and ASM

Station ID	Failure Rate	Number of Failed Inspections	Total Number of Inspections	Percentile Rank for Station
OBD Inspection Results:				
1P32516	29.1	133	457	100.00
2P33175	28.3	52	184	99.94
2P32154	26.7	677	2,535	99.87
1P38476	25.9	36	139	99.81
1P36428	25.4	154	606	99.74
1P39107	23.8	39	164	99.68
1P25236	23.4	140	598	99.62
2P35398	23.1	101	438	99.55
2P33739	22.5	138	612	99.49
1P38485	22.2	39	176	99.42
ASM Inspection Results:				
2P12419	39.7	416	1,049	100.00
1P35322	39.0	122	313	99.92
1P38482	35.1	115	328	99.83
1P25236	34.4	62	180	99.75
1P36024	34.3	37	108	99.66
2P35064	34.2	88	257	99.58
2P26692	32.3	484	1,499	99.49
1P38135	32.1	44	137	99.41
2P01387	30.0	304	1,014	99.33
2P06842	29.7	105	354	99.24

Table 6-10. Stations with Lowest Failure Rates, OBD and ASM

Station ID	Failure Rate	Number of Failed Inspections	Total Number of Inspections	Percentile Rank for Station
OBD Inspection Results:				
2P39012	0.0	0	170	100.00
2P19662	0.0	0	180	99.96
2P09450	0.0	0	987	99.91
1P39025	0.0	0	1,273	99.87
1P38865	0.0	0	389	99.83
1P38796	0.0	0	419	99.79
1P37411	0.0	0	1,924	99.74
1P36166	0.0	0	143	99.70
1P32096	0.0	0	145	99.66
1P37006	0.1	4	6,260	99.61
ASM Inspection Results:				
1P39272	0.0	0	110	100.00
1P39131	0.0	0	227	99.92
1P39062	0.0	0	391	99.83
1P39053	0.0	0	285	99.75
1P39046	0.0	0	327	99.66
1P39025	0.0	0	791	99.58
1P38846	0.0	0	330	99.49
1P38831	0.0	0	152	99.41
1P38796	0.0	0	275	99.32
1P38673	0.0	0	212	99.24

6.3 Repeated use of Analyzers with Less-Than-Optimal Functionality

The accuracy of vehicle inspection results and the quality of the data that is stored in the TIMS database depends in part on each analyzer being fully functional at all times. Consistently using an analyzer that is out-of-specification reduces the accuracy of inspection results.

6.3.1 High Degree of Drift

In Section 3.4.1, the impact of analyzer drift was evaluated. Analyzers that consistently drift little from calibration to calibration can be expected to produce more accurate measures of vehicle emissions than those that drift greatly. If the difference between the bottle label value and the pre-calibration analyzer reading is very large, then one presumes that some of the emissions measurements made during the previous 72 hours were more inaccurate than necessary. Here, the percentage of the time that analyzers were found to have drifted out of the specification range prior to the calibration was calculated for each station. Stations with fewer than 40 calibration events in the dataset were excluded from the results. An analyzer was defined as having drifted out of tolerance if any of the gas values (HC, CO, NOx, CO_2, or O_2) at any level (zero, low, or mid span) were measured to be outside of the specified tolerance at the

beginning of the calibration. However, since HC at the zero level was found to be out-of-tolerance in about half of all calibrations, it was not used here because it would not be a useful predictor of poor performance. Using this strict standard, most stations were found to have had at least 1% or more calibrations on initially out-of-tolerance analyzers; however, the worst stations that are shown in Table 6-11 had almost all calibrations on out-of-tolerance analyzers.

Table 6-11. Percent of Calibrations that Began with an Out-of-Tolerance Analyzer

Station ID	Percent of Calibrations that Began with Out-of-Tol Analyzer	Number of Calibrations that Began Out-of-Tol	Total Number of Calibration Events	Percentile Rank for Station
2P25704	100.0	61	61	100.00
1P36071	100.0	40	40	99.96
1P38435	99.1	108	109	99.92
2P05899	99.1	105	106	99.88
2P38252	98.3	118	120	99.84
1P36673	97.7	127	130	99.80
2P32154	96.8	271	280	99.76
1P33944	96.7	263	272	99.72
2P31197	96.7	203	210	99.68
1G20288	96.5	164	170	99.64

6.3.2 Frequently Failing Span Gas Audits

Another time that the accuracy of analyzers is checked is during a span gas audit. Span gas audits were discussed in detail in Section 3.4.3. Here, the audit failure rate for each station was calculated. Stations with fewer than 6 audits in the dataset were excluded from the results. Most stations passed all of their audits. The ten stations with the highest span gas audit failure rates are shown below in Table 6-12.

Table 6-12. Percent of Span Gas Audits that were Failed

Station ID	Percent of Audits that were Failed	Number of Audits that were Failed	Total Number of Audits for Station	Percentile Rank for Station
2P35156	75.0	9	12	100.00
6P37338	70.0	7	10	99.94
6P36354	66.7	6	9	99.89
2P33024	66.7	4	6	99.83
2P29944	63.6	14	22	99.77
1P28981	60.0	6	10	99.72
2P36394	57.1	8	14	99.66
6P31104	56.5	13	23	99.60
2P27143	55.6	5	9	99.54
2P37279	53.8	7	13	99.49

6.3.3 Failure to Perform All Calibrations

Analyzers that are used for emissions inspections are required to undergo several types of calibration every 72-hours. If they do not receive all required calibrations, they are supposed to be locked out from performing I/M inspections until all calibrations are completed and passed. In Section 3.4.4, it was found that some analyzers pass only one calibration type without receiving all calibrations, and then proceed to perform inspections. Additionally, some analyzers receive one or more calibrations but do not pass them, and are allowed to continue performing inspections. Here, those results are examined to identify stations with a higher than average rate of performing incomplete or failed 72-hour calibrations, and then performing I/M inspections. The results for the top ten worst stations are shown in Table 6-13, which gives the percentage of I/M inspections that were performed while the analyzer should have been locked out. Stations with fewer than 100 inspections in the dataset are excluded from the results. While most stations never perform any inspections while the analyzer should have been locked out, the table shows that some stations fail to perform complete analyzer calibrations on a routine basis.

Table 6-13. Percent of Inspections When Analyzer Should Have Been Locked Out

Station ID	Percent of Inspections Performed on Analyzer that should have been locked out	Number of Inspections on Analyzer that should have been locked out	Total Number of Inspections for Station	Percentile Rank for Station
1P31791	79.0	6,877	8,704	100.00
1P36679	71.2	825	1,158	99.96
1P30606	67.2	2,447	3,644	99.92
1P36986	59.6	2,606	4,375	99.89
1P37432	56.4	75	133	99.85
1P34349	55.2	1,491	2,701	99.81
1P32630	55.2	999	1,811	99.77
1P36147	53.4	63	118	99.74
1P30749	49.9	3,324	6,662	99.70
1P35809	48.9	531	1,087	99.66

6.4 Data Entry Issues

Several VID fields are subject to manual data entry by inspectors during the inspection process. Consistently unusual data entry patterns can be detected at certain stations when the data are analyzed. This section presents the analysis results for several data entry metrics.

6.4.1 Consistently Entering Repair Type as "Misc"

Repairs performed are categorized by inspectors into five different types: fuel system, ignition/electrical system, emissions system, engine-mechanical, and miscellaneous repairs. Miscellaneous repairs accounted for approximately one-third of the repairs recorded in the TIMS during the most recent analysis period. At certain stations, miscellaneous repairs account for much more than that. A summary of stations with a high percentage of miscellaneous repairs is presented in Table 6-14.

Table 6-14. Miscellaneous Repair Percentage (Stations > 500 repairs)

STATION_ID	NON-MISC	MISC	TOTAL	MISC %
1P00576	1	611	612	99.8
1P37169	1	525	526	99.8
1P33468	4	628	632	99.4
1P36641	9	1012	1021	99.1
2P35275	7	520	527	98.7
1P31462	16	1088	1104	98.6
1P30749	20	1213	1233	98.4
1P17052	9	513	522	98.3
6P18784	17	881	898	98.1
1P34877	14	568	582	97.6
2P03448	18	720	738	97.6
2P12877	25	881	906	97.2
6P30624	16	502	518	96.9
1P34773	28	872	900	96.9
1P18013	21	609	630	96.7
2P31289	31	470	501	93.8
1P31940	38	548	586	93.5
2P27849	51	702	753	93.2
1P37118	64	867	931	93.1
1P25039	46	588	634	92.7
2P09687	41	472	513	92.0
1P34602	64	593	657	90.3
1P33819	67	602	669	90.0

6.4.2 Consistently Entering Repair Cost as $0

Repairs performed must also be recorded with an associated repair cost. Repairs recorded with a cost of $0 accounted for approximately one-third of the values in the TIMS during the most recent analysis period. At certain stations, zero-cost repairs account for much more than that. A summary of stations with a high percentage of zero-cost repairs is presented in Table 6-15 below.

Table 6-15. Zero-Cost Repair Percentage (Stations > 500 repairs)

STATION_ID	NON-ZERO	ZERO	TOTAL	ZERO %
1P31959	0	1322	1322	100.0
1P32390	0	593	593	100.0
1P34877	0	582	582	100.0
1P37169	0	526	526	100.0
1P00576	1	611	612	99.8
1P31834	1	558	559	99.8
1P17052	1	521	522	99.8
1P36419	1	509	510	99.8
1P31462	3	1100	1103	99.7
1P36641	3	1018	1021	99.7
1P18013	2	626	628	99.7
1P02394	3	767	770	99.6
1P37118	4	919	923	99.6
2P27688	3	540	543	99.4
6P16109	6	517	523	98.9
6P30624	6	510	516	98.8
1P32561	9	555	564	98.4
2P19569	20	1188	1208	98.3
6P11407	11	499	510	97.8
1P30749	27	1206	1233	97.8
2P35275	12	515	527	97.7
1P28981	16	508	524	96.9
1P08007	33	865	898	96.3
1P33772	38	873	911	95.8
1P33819	32	616	648	95.1
1P31940	32	539	571	94.4
1P30083	31	471	502	93.8
2P30537	40	600	640	93.8
1P32986	59	800	859	93.1
1P34773	64	836	900	92.9
2P03448	53	685	738	92.8
6P27010	67	791	858	92.2
2P09674	91	989	1080	91.6
2P22683	82	872	954	91.4
1P34403	88	857	945	90.7

6.4.3 VIN Check Digit Errors

For each vehicle inspected at a station, the VIN must be recorded. For approximately 1.5% of the VINs on record, the VIN either has a bad check digit or an illegal character in the VIN. Some stations report an unusually high percentage of incorrect VINs. A summary of stations with a VIN check digit errors is presented in Table 6-16 below.

Table 6-16. Check Digit Error Percentage (Stations > 100 inspections)

STATION_ID	CHKDGT_OK	CHKDGT_BAD	TOTAL	CHKDGT_BAD %
2P37037	41	123	164	75.0
1P38883	129	196	325	60.3
1P38893	49	73	122	59.8
1P39309	53	64	117	54.7
1P39053	181	177	358	49.4
1P39062	229	221	450	49.1
1P39272	117	108	225	48.0
1P38554	118	108	226	47.8
1P39131	125	106	231	45.9
1P39014	65	54	119	45.4
1P38336	1049	849	1898	44.7
1P38865	110	79	189	41.8
1P39046	172	113	285	39.6
1P38850	162	91	253	36.0
2P35798	21818	11897	33715	35.3
1P39035	251	131	382	34.3
1P37993	542	280	822	34.1
1P37940	500	251	751	33.4
1P37977	1142	541	1683	32.1
1P38698	488	227	715	31.7
1P39282	70	32	102	31.4
1P37775	993	444	1437	30.9
1P38683	781	349	1130	30.9
1P39013	90	40	130	30.8

6.4.4 Anomalous Inspection Sequences (other than 1P or FP)

Each vehicle that participates in the I/M program produces a brief history when it is inspected, repaired, and retested. 99% of the vehicles that participate in the program have a repair sequence of either pass (P) or fail-pass (FP). The remaining portion of the fleet, less than one percent, consists of vehicles with histories that contain multiple passes or fails. Table 6-17 below lists stations that were in contact at some point with vehicles that had anomalous inspection sequences.

Table 6-17. Anomalous Inspection Sequence Percentage (Stations > 100 repairs)

STATION_ID	SEQ_OK	SEQ_BAD	TOTAL	SEQ_BAD %
1P38854	97	12	109	11.0
2P28928	1256	154	1410	10.9
2P36912	549	67	616	10.9
2P39198	150	17	167	10.2
2P39085	163	18	181	9.9
1P39332	163	17	180	9.4
2P39191	285	29	314	9.2
2P38297	1536	153	1689	9.1
1P39020	105	10	115	8.7
2P37651	279	25	304	8.2
2P34123	1033	91	1124	8.1
2P39253	125	11	136	8.1
2P38259	114	10	124	8.1
2P35802	126	11	137	8.0
2P38298	532	46	578	8.0
1P39304	198	17	215	7.9
2P32154	3029	258	3287	7.8
2P37271	654	55	709	7.8
2P36242	418	35	453	7.7
2P35795	174	14	188	7.4
1P39273	103	8	111	7.2
1P38647	416	32	448	7.1
2P36914	899	69	968	7.1

6.5 Anomalous Test Results

In Section 3.4.2, several types of tailpipe inspection results displayed emissions concentrations that are not consistent with those expected for stoichiometric combustion. These include CO_2 levels higher than 16%, O_2 levels near ambient concentrations, and high dilution correction factors. In this section the rate of each of these anomalies by station is investigated.

6.5.1 Tailpipe Inspections with CO_2 Greater Than 16%

Table 6-18 presents stations with a high percentage of vehicles whose ASM or TSI tests produced CO_2 readings greater than 16%, outside the normal combustion range. Stations that performed fewer than 100 inspections are excluded from the table.

Table 6-18. Percent of Inspections with CO_2 Greater Than 16%

Station ID	Percent of Inspections with CO_2 Greater Than 16%	Number of Inspections with CO_2 Greater Than 16%	Total Number of Inspections for Station	Percentile Rank for Station
2P34817	76.6	528	689	100.00
2P36490	71.3	438	614	99.96
2P33971	70.7	1,390	1,965	99.92
2P26640	68.7	2,844	4,142	99.88
2P34625	64.0	786	1,229	99.84
2P33880	58.9	245	416	99.79
2P32603	57.7	1,141	1,976	99.75
2P35953	56.3	731	1,298	99.71
2P38072	54.6	625	1,145	99.67
2P36234	49.6	323	651	99.63

6.5.2 Tailpipe Inspections with O_2 Greater than 20.5%

Table 6-19 presents stations with a high percentage of vehicles whose ASM or TSI tests produced CO_2 readings greater than 20.5%, which is outside the normal combustion range and is very close to the ambient O_2 concentration of 20.9%. Stations that performed fewer than 100 inspections are excluded from the table.

Table 6-19. Percent of Inspections with O_2 Greater Than 16%

Station ID	Percent of Inspections with O_2 Greater Than 20.5%	Number of Inspections with O_2 Greater Than 20.5%	Total Number of Inspections for Station	Percentile Rank for Station
2P37705	100.0	924	924	100.00
2P36917	100.0	555	555	99.96
2P12833	100.0	613	613	99.92
1P39282	100.0	115	115	99.88
1P37415	100.0	1,492	1,492	99.84
1P32361	100.0	426	426	99.79
1P10768	100.0	304	304	99.75
1P01761	100.0	260	260	99.71
1P32646	100.0	2,027	2,028	99.67
2P32162	99.7	614	616	99.63

6.5.3 Tailpipe Inspections with High Dilution Correction Factor Differences

Table 6-20 presents stations with a high rate of inspections where the CO/CO_2-based DCF was out of agreement with the O_2-based DCF. This indicates a problem with the measurement of one or more of the pollutants. Stations that performed fewer than 100

inspections are excluded from the table. It can be seen from the table that the top ten stations had differences between the two DCFs for every inspection. It should be noted that there is overlap between the results in this section and the results in the previous two sections (CO_2 greater than 16% and O_2 greater than 20.5%). Anomalous concentrations are also indicators of problems with the emissions measurements, and are also likely to result in a disagreement between the two DCFs.

Table 6-20. Percent of Inspections with Disagreement Between CO/CO_2 and O_2 DCFs

Station ID	Percent of Inspections with DCF Disagreement	Number of Inspections with DCF Disagreement	Total Number of Inspections for Station	Percentile Rank for Station
2P38823	100.0	139	139	100.00
2P38589	100.0	152	152	99.96
2P37705	100.0	924	924	99.92
2P37144	100.0	119	119	99.88
2P37086	100.0	106	106	99.84
2P36917	100.0	555	555	99.79
2P36903	100.0	141	141	99.75
2P35791	100.0	622	622	99.71
2P34519	100.0	920	920	99.67
2P32059	100.0	531	531	99.63

6.6 Compilation of Percentile Rankings

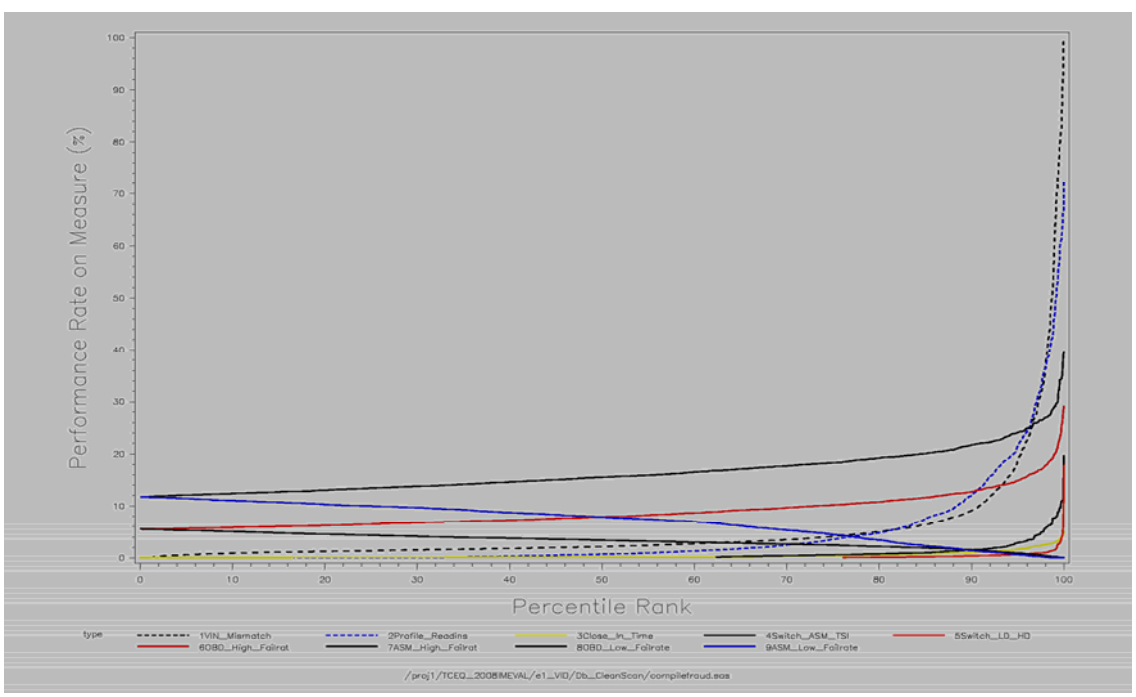
After a separate ranking was assigned for each of the measures of errors of commission, the ranks were used to score the stations and identify the stations with the highest likelihood of either errors of commission, or errors of omission.

Some of the details of the ranking procedure and the resulting ranks make it challenging to combine the ranks for an overall score. First, most stations did not perform enough inspections of one type or another (i.e., OBD retests, ASM inspections, etc.) to receive a rank for all of the measures. Secondly, it is known from the measures listed in the previous sections that the range of results was not the same for each measure. For example, for the OBD VIN mismatch section, about 75% of stations had very low VIN mismatch rates. The remaining 25% had VIN mismatch rates that might be cause for concern, or among the top 25 percentiles in the ranking. In contrast, for the tailpipe inspection being switched from light-duty to heavy-duty in order to pass, at least 95% of stations had reasonably low rates of switching from ASM to TSI, and only the top 5% of stations would lead one to suspect possible fraud. Figure 6-3 below

shows the distribution of the results and the rankings that were created from those results for each of the measures of errors of commission (from sub-sections 6.1 and 6.2).

The green and blue dashed lines for the OBD VIN mismatch and OBD readiness/electronic profile mismatch show that the stations from 0 to the 75th percentile had a very low percentage of mismatches. Above the 75th percentile, the mismatch rate quickly increases. For two of the tailpipe measures, the rate of overly close in time inspections and retests switched from light-duty to HD, the stations below about the 95th percentile had very low results. Above the 95th percentile, the rate of potentially fraudulent results rapidly increases. For the other tailpipe measure, the rate of retests switched from ASM to TSI, the "break" occurred closer to the 90th percentile. The red and purple lines show the rankings for OBD inspection failure rates. For both of those lines, the 0th percentile is the mean failure rate over all stations. The percentiles for the red line increase as the failure rate increases further above the mean, while the percentiles for the purple line increase as the failure rate decreases further below the mean. For both of these, one sees a "break" at about the 90th percentile, where the OBD fail rate starts to change rapidly as the percentile continues to increase. The solid green and blue lines show similar results for the ASM failure rates, except that the "break" for the low ASM failure rates might be closer to the 80th percentile.

Figure 6-3. Distribution of Results and Percentiles for Errors of Commission



At percentiles below the "break" (the percentile above which the results rapidly worsen) in each line on Figure 6-3, it is probably not likely that the station is performing that type of fraudulent activity. At percentiles above the break, there is evidence for suspicion of fraud. Thus, the visual results of the location of the break were used to create an indicator flag for each of the measures. Stations above the break for the given measure were flagged. Then, the total number of flags that each station received was determined. The list of all stations was then sorted by the descending number of flags received, in order to create a final list in order of most-suspicious to least-suspicious. The results for the top 50 most suspicious stations are given in Table 6-21. Table 6-22 gives the results for an additional 50 stations from near the middle of the range of results for comparison purposes.

Some of the first lines in the table show stations that should be investigated (if they haven't already been, as a result of triggers or other audits). For example, the second station, 1P36321, had a very high rate of OBD VIN mismatches, a high rate of OBD readiness and electronic profile mismatches, and then a very low OBD failure rate. This combined result is indicative possible OBD clean-scanning. Some of the lines do not tell as clear a story, such as the first line for station 2P33265, with very high percentiles for each of the tailpipe inspection clean-piping measures, but then a higher than average ASM failure rate. If this table were to be used for identifying stations for enforcement, audits, etc., the user would have to look through the lines and identify the stations with the clearest combination of factors for the type of fraud being considered. The entire table with all stations is available in electronic format.

A similar strategy was used for identifying the stations most likely to need some improvement on proper inspection procedures. The results of errors of omission from the measures in sub-sections 6.3, 6.4, and 6.5 were used here. Figure 6-4 shows the distribution of the results vs. the percentiles for each of the measures. Some of the "break" points are difficult to discern, such as that for the green line, which is for calibrations that began with the analyzer out of tolerance. After consideration of Figure 6-4, the "break" percentiles were assigned at the 80th percentile for analyzers out of tolerance, the 80th percentile for span gas audit failures, the 90th percentile for performing inspections when analyzer is not fully calibrated and should be locked out, the 90th percentile for entering VINs with a bad check digit, the 95th percentile for inspections with unusual pass/fail sequences, the 60th percentile for stations entering repair types as "Misc", the 30th percentile for stations entering repair costs as $0, the 90th percentile for inspections with CO_2 greater than 16%, the 80th percentile for inspections with O_2 greater than 20.5%, and the 70th percentile for inspections with disagreement between the DCFs. It should be noted these percentile flags were determined subjectively and would likely be adjusted over time

as one becomes more familiar with how sensitive each metric is for detecting irregular calibration or test activities.

The results for the top 50 worst-performing stations for errors of omission are listed in Table 6-23. Some of the rows do appear to show a clear picture as the inspectors at some stations having particular trouble entering data accurately and completely, with a high score for VINs with a bad check digit, repair types entered as “Misc”, and repair costs entered as $0. Other stations may have consistent problems with their analyzers, with the analyzer often out of tolerance at the beginning of a calibration, and a high rate of inspections with CO_2 greater than 16% and O_2 greater than 20.5%. Again, the table could be used to identify different types of enforcement that are indicated by the combinations of results on each line.

Table 6-21. Top 50 Most Suspicious Stations for Errors of Commission

Station ID	Sum of Rank Flags	Max Rank for Station	Individual Ranks								
			OBD VIN Mismatch	OBD Profile/ Readiness	Tailpipe Close-In-Time	Switch ASM to TSI	Switch LD to HD	OBD High Fail Rate	ASM High Fail Rate	OBD Low Fail Rate	ASM Low Fail Rate
2P33265	5	99.9	74.5	87.2	99.3	99.9	99.4	96.0	47.7	.	.
1P36321	5	99.7	93.6	99.7	.	.	97.6	.	.	95.4	80.8
1P25057	5	98.3	76.7	76.5	0.0	94.8	97.0	49.2	98.3	.	.
1P32094	4	99.9	99.0	97.9	0.0	97.3	99.9	.	.	79.7	60.5
1P37414	4	99.8	99.4	99.8	.	.	.	.	.	96.0	93.6
1P35240	4	99.7	98.9	97.4	84.9	99.7	99.5	15.0	.	.	69.7
1P36937	4	99.7	99.7	98.3	.	.	30.4	.	.	90.8	91.9
1P36641	4	99.5	99.3	99.5	.	.	29.2	.	.	94.5	90.7
1P32654	4	99.4	93.8	97.4	.	.	.	.	.	99.4	98.9
1P27736	4	99.4	99.4	98.1	.	.	.	.	.	97.6	92.1
1P36809	4	99.3	96.2	99.3	.	.	.	.	.	96.9	93.0
1P37886	4	99.2	99.2	96.9	.	.	.	.	.	93.4	93.3
1P17053	4	99.1	92.1	89.1	99.1	88.7	5.4	80.7	94.4	.	.
1P36998	4	99.1	99.1	96.3	.	.	30.9	.	.	92.1	86.5
1P03175	4	99.0	81.3	82.5	91.7	95.2	99.0	.	48.2	8.0	.
2P37277	4	99.0	26.2	29.7	0.0	94.6	99.0	95.1	94.0	.	.
2P31289	4	98.9	91.4	98.9	.	.	.	.	.	98.5	98.4
1P17445	4	98.7	91.1	85.8	0.0	98.7	6.1	74.3	98.4	.	.
2P36381	4	98.6	83.0	98.6	0.0	56.1	67.4	.	.	97.8	97.1
2P34821	4	98.6	92.7	98.6	0.0	51.3	61.3	.	.	93.2	97.3
2P36489	4	98.5	92.5	98.5	.	.	.	.	.	90.5	90.4
1P37198	4	97.6	97.5	97.0	.	.	97.6	.	.	82.3	88.7
2P03889	4	97.6	83.7	16.0	82.9	91.9	97.6	.	94.3	16.9	.
1P33144	4	97.4	80.8	87.4	81.4	97.4	17.8	75.9	.	.	86.6
1P35506	4	96.7	76.8	93.9	96.7	20.4	80.7	.	.	70.4	80.4
1P37005	4	96.4	92.1	95.4	.	.	96.4	.	.	7.7	95.9
1P36986	4	95.2	95.2	93.5	.	.	30.8	.	.	93.4	91.3
2P35912	4	94.4	90.8	90.2	.	.	.	.	.	91.4	94.4

Station ID	Sum of Rank Flags	Max Rank for Station	Individual Ranks								
			OBD VIN Mismatch	OBD Profile/ Readiness	Tailpipe Close-In-Time	Switch ASM to TSI	Switch LD to HD	OBD High Fail Rate	ASM High Fail Rate	OBD Low Fail Rate	ASM Low Fail Rate
1P00755	4	94.1	94.1	92.4	.	.	0.6	91.5	93.1	.	.
2P31303	4	93.2	92.4	92.1	0.0	93.2	92.8	.	.	62.2	84.6
1P35016	4	92.7	89.7	91.2	.	.	89.1	.	.	91.0	92.7
2P34220	4	92.4	90.8	83.2	0.0	48.9	59.3	.	.	91.5	92.4
1P36369	3	100.0	60.5	71.2	98.4	100.0	96.8	.	79.7	10.9	.
1P38422	3	100.0	99.0	100.0	.	.	.	.	.	38.8	93.4
1P39272	3	100.0	100.0	.	.	.	.	.	.	98.2	100.0
1P36597	3	99.9	99.9	.	.	.	.	.	.	97.1	94.8
1P35322	3	99.9	84.6	.	.	.	98.5	19.8	99.9	.	.
2P12339	3	99.9	56.3	83.3	0.0	95.4	99.9	67.7	28.6	.	.
2P30412	3	99.9	30.9	99.9	.	.	.	.	.	97.9	94.5
2P32154	3	99.9	40.4	79.5	0.0	44.5	55.0	99.9	98.1	.	.
1P37231	3	99.8	99.8	95.9	.	.	88.9	.	.	66.7	86.9
1P32898	3	99.8	.	99.8	.	.	.	.	.	99.6	98.5
1P37411	3	99.8	99.8	.	.	.	.	.	.	99.7	98.6
1P37724	3	99.8	99.8	.	.	.	.	.	.	98.9	98.1
1P25236	3	99.7	.	97.3	.	.	7.4	99.6	99.7	.	.
1P30200	3	99.7	84.9	74.8	99.7	92.8	94.9	.	.	84.5	39.6
1P33861	3	99.7	99.7	98.2	.	.	19.9	.	.	84.6	91.8
1P38060	3	99.7	97.5	86.2	.	.	99.7	64.4	.	.	50.8
1P32428	3	99.7	99.7	97.1	.	.	15.9	.	.	91.7	68.1
2P35711	3	99.7	90.6	68.1	0.0	84.1	99.7	94.9	28.4	.	.

Table 6-22. 50 Mid-Range Stations for Errors of Commission

Station ID	Sum of Rank Flags	Max Rank for Station	Individual Ranks								
			OBD VIN Mismatch	OBD Profile/ Readiness	Tailpipe Close-In-Time	Switch ASM to TSI	Switch LD to HD	OBD High Fail Rate	ASM High Fail Rate	OBD Low Fail Rate	ASM Low Fail Rate
1P25328	0	85.8	6.1	.	.	.	.	.	.	85.8	.
2P12911	0	85.8	56.3	46.8	0.0	34.6	85.8	.	.	59.7	32.3
2P31366	0	85.8	18.2	47.8	69.1	43.0	84.3	.	33.0	85.8	.
1P35164	0	85.8	61.5	70.7	77.5	74.0	85.8	.	25.0	63.0	.
2P12093	0	85.8	37.8	17.5	85.8	32.1	42.1	.	68.4	58.9	.
2P34616	0	85.8	53.7	51.0	76.8	85.8	60.7	.	.	14.8	13.0
1P09847	0	85.8	39.0	60.7	0.0	2.4	3.8	85.8	75.9	.	.
1P06540	0	85.8	62.0	56.0	0.0	73.3	2.6	13.4	85.8	.	.
1P37636	0	85.7	74.1	13.6	.	.	34.2	.	.	85.7	56.4
2P28431	0	85.7	36.1	.	.	.	.	85.7	.	.	.
1P17220	0	85.7	8.0	2.4	0.0	4.3	5.6	.	.	85.7	3.2
1P18119	0	85.6	5.5	.	.	.	.	.	.	85.6	.
2P05071	0	85.6	19.0	16.3	0.0	29.9	85.6	.	.	0.6	35.1
2P34132	0	85.6	38.2	54.5	.	.	59.2	.	.	85.6	29.3
1P36449	0	85.6	.	.	.	.	.	69.6	85.6	.	.
2P35079	0	85.6	13.8	40.2	0.0	52.5	85.6	.	.	19.9	32.8
1P37891	0	85.6	.	.	.	.	.	85.6	.	.	.
1P29799	0	85.5	52.3	62.8	0.0	85.5	12.0	.	63.1	67.7	.
2P36477	0	85.5	11.8	28.4	85.5	56.4	67.7	6.7	66.1	.	.
2P28904	0	85.5	10.1	43.4	0.0	69.4	85.5	.	35.6	23.1	.
1P38443	0	85.5	.	.	.	.	.	.	.	85.5	.
1P29101	0	85.4	38.5	47.9	.	.	11.3	.	.	85.4	66.6
1P39068	0	85.4	.	.	.	.	.	.	85.4	68.5	.
1P37401	0	85.4	13.4	13.1	85.4	26.7	32.8	67.9	.	.	67.8
1P17329	0	85.4	66.0	71.4	0.0	4.6	85.4	.	7.8	34.4	.
2P35591	0	85.3	21.8	26.8	.	.	85.3	.	26.5	6.7	.
2P00329	0	85.3	41.7	15.2	0.0	28.3	37.7	33.8	85.3	.	.
2P28092	0	85.3	8.3	.	.	.	.	.	.	85.3	.

Station ID	Sum of Rank Flags	Max Rank for Station	Individual Ranks								
			OBD VIN Mismatch	OBD Profile/ Readiness	Tailpipe Close-In-Time	Switch ASM to TSI	Switch LD to HD	OBD High Fail Rate	ASM High Fail Rate	OBD Low Fail Rate	ASM Low Fail Rate
2P31641	0	85.3	70.6	37.6	0.0	43.3	53.8	85.3	33.2	.	.
2P03800	0	85.3	12.8	.	.	.	.	.	.	85.3	.
2P37040	0	85.2	25.5	.	.	.	69.7	85.2	74.3	.	.
1P09953	0	85.2	35.4	1.5	85.2	2.6	3.9	.	.	55.8	23.1
1P19102	0	85.2	40.0	.	.	.	.	.	.	85.2	.
1G37403	0	85.2	.	.	.	.	.	85.2	.	.	.
1P36125	0	85.2	64.4	47.0	0.0	22.6	85.2	.	11.3	43.8	.
1P30135	0	85.2	18.0	5.1	0.0	10.4	12.4	.	41.7	85.2	.
1P31110	0	85.1	30.4	5.7	.	.	85.1	.	.	13.4	64.2
2P22627	0	85.1	25.7	.	.	.	.	.	.	85.1	.
2P38466	0	85.1	1.8	.	.	.	.	85.1	.	.	.
1P32692	0	84.9	44.7	.	.	.	.	.	.	84.9	.
1P39274	0	84.9	4.9	.	.	.	.	.	.	84.9	.
1P29983	0	84.9	3.4	.	.	.	.	.	.	84.9	.
1P11977	0	84.8	27.0	54.9	84.8	69.1	5.2	14.6	30.6	.	.
2P33435	0	84.8	26.6	23.5	0.0	81.1	57.3	.	84.8	48.7	.
1P32383	0	84.8	45.7	6.5	0.0	13.1	84.8	.	3.8	18.1	.
2P28901	0	84.8	34.1	60.6	0.0	40.2	49.8	.	.	84.8	57.0
2P29933	0	84.8	26.7	21.7	84.8	69.0	80.1	.	51.9	10.1	.
1P37865	0	84.7	18.0	13.8	.	.	34.6	.	.	84.7	31.1
1P36205	0	84.7	55.8	11.1	0.0	22.8	79.6	84.7	68.5	.	.
2P35482	0	84.7	34.8	43.9	0.0	78.6	84.7	.	.	26.6	9.6

Figure 6-4. Distribution of Results and Percentiles for Errors of Omission

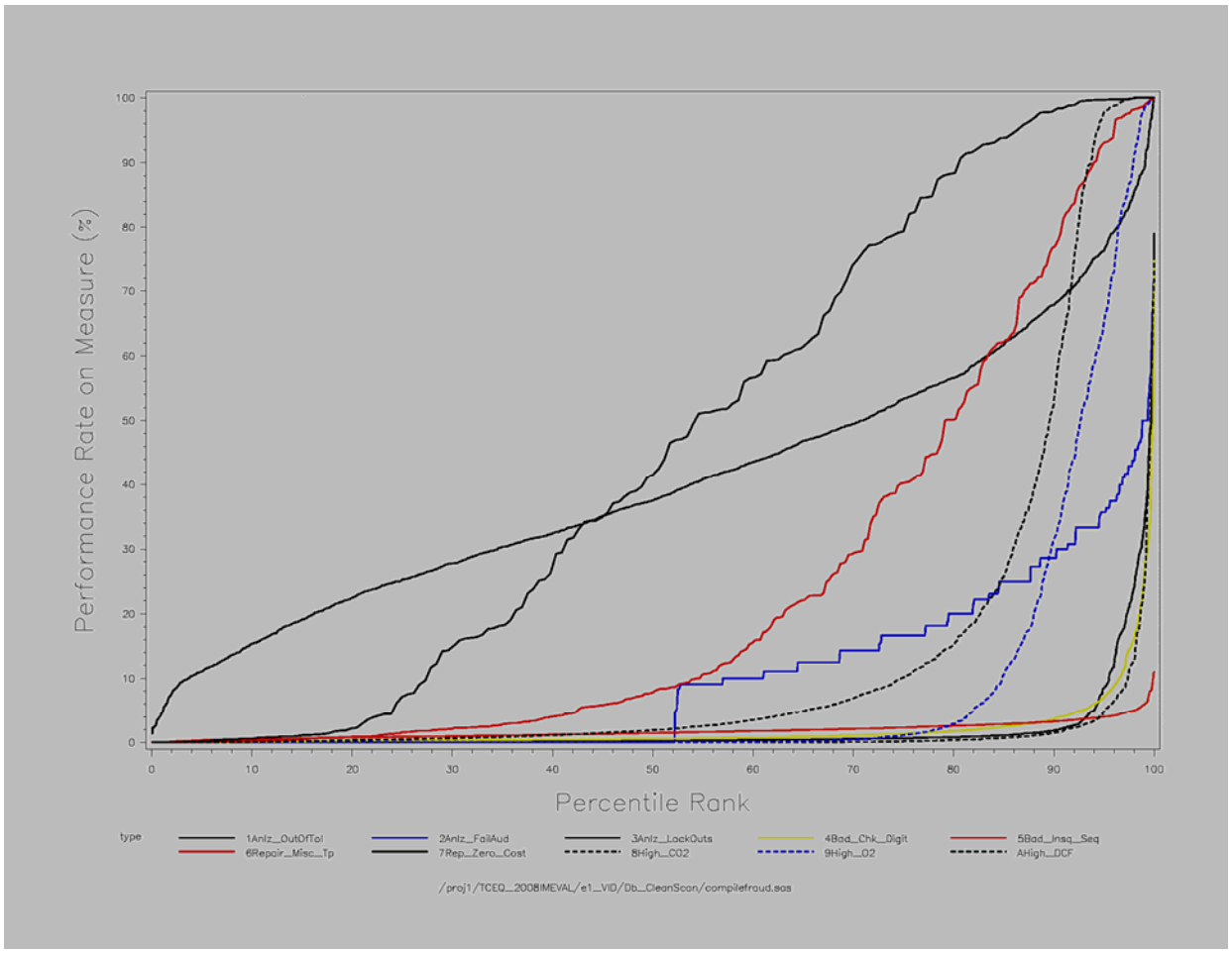


Table 6-23. Top 50 Stations with Errors of Omission

Station ID	Sum of Rank Flags	Max Rank for St.	Individual Ranks									
			Anlz Out of Tol	Anlz Locked Out	Anlz Fail Audits	Bad Chk Digit	Bad P/F Seq	Repair Type "Misc"	Repair Cost $0	CO_2 gt 16%	O_2 gt 20.5%	DCF Disagreement
1P36641	7	99.2	95.9	94.2	59.7	96.3	23.5	99.2	94.9	26.9	86.0	82.1
1P31462	7	99.1	65.2	98.0	92.7	95.1	60.2	98.6	95.5	99.1	61.0	78.6
1P28981	6	99.7	54.9	99.0	99.7	69.4	76.9	17.6	88.1	95.9	84.2	83.4
2P12419	6	99.0	55.3	75.6	99.0	16.4	98.2	65.9	34.1	99.0	67.2	84.5
1P34903	6	98.7	98.7	43.4	82.8	56.2	94.9	38.2	44.3	95.3	83.8	84.4
2P34820	6	96.2	72.4	94.3	87.2	70.7	70.3	84.9	67.6	96.2	75.2	71.2
1P33944	5	99.7	99.7	63.1	98.1	63.2	51.0	12.1	.	95.3	83.9	83.7
1P33468	5	99.5	74.9	87.7	18.2	82.7	69.4	99.5	31.3	94.6	81.2	88.5
1P37775	5	99.4	80.4	95.7	.	99.4	33.3	.	.	98.0	24.9	75.5
1P28634	5	98.9	52.3	98.9	11.1	76.2	58.2	87.6	33.0	96.5	78.9	74.8
2P10911	5	98.9	89.9	76.2	98.9	46.5	66.4	.	.	91.8	84.1	77.1
1P38539	5	98.8	80.8	10.6	.	98.8	3.6	.	.	94.9	95.1	91.8
2P38284	5	98.6	80.7	20.7	.	90.4	98.6	.	.	63.5	88.8	85.5
1P34403	5	98.5	50.4	97.9	20.0	98.5	60.8	93.4	80.7	66.7	73.4	72.3
2P30537	5	97.0	77.7	25.0	38.8	95.7	25.9	89.8	84.7	48.3	89.4	97.0
1P18013	5	96.8	57.5	96.8	6.4	92.2	67.6	96.2	94.3	93.5	4.6	60.8
1P35008	5	95.4	94.9	6.4	95.3	74.6	54.8	.	.	93.6	94.7	95.4
2P12442	5	95.4	57.2	40.8	95.4	30.8	43.7	76.4	58.5	73.4	88.5	89.6
1P35692	5	94.5	53.9	94.5	93.0	93.1	11.0	.	.	22.8	83.1	82.0
1P02394	5	93.8	88.0	25.1	1.8	65.5	69.8	93.7	93.8	76.1	87.0	82.8
6P11286	5	92.3	79.5	92.3	82.0	63.0	80.6	77.5	61.9	90.8	57.5	47.0
1P33054	5	91.0	83.6	66.0	90.7	91.0	46.2	13.7	.	16.5	81.9	72.5
2P30774	5	90.0	86.0	57.1	39.0	26.2	90.0	67.0	65.9	71.0	88.0	84.5
1P00576	4	100.0	52.8	53.2	84.6	94.2	40.9	100.0	97.7	70.8	64.4	16.9
1P31791	4	100.0	42.9	100.0	14.6	89.5	32.6	92.3	79.0	13.7	10.2	72.7
2P35156	4	100.0	95.0	18.0	100.0	77.0	87.3	.	.	55.8	84.7	82.3
2P36490	4	100.0	58.5	80.2	97.7	85.0	93.2	.	.	100.0	83.1	87.9
2P38589	4	100.0	99.6	21.0	.	70.0	62.4	.	.	99.2	97.0	100.0
2P32154	4	99.8	99.8	48.3	40.6	43.1	99.7	28.0	.	50.0	90.7	90.8
2P35953	4	99.7	91.6	61.0	99.3	58.9	90.1	.	.	99.7	64.0	77.2
1P30749	4	99.7	75.8	99.7	58.1	92.7	72.7	98.4	89.2	85.6	59.2	39.5
2P27688	4	99.6	38.6	82.7	36.2	93.7	42.3	4.4	92.6	82.5	98.1	99.6

Station ID	Sum of Rank Flags	Max Rank for St.	Individual Ranks									
			Anlz Out of Tol	Anlz Locked Out	Anlz Fail Audits	Bad Chk Digit	Bad P/F Seq	Repair Type "Misc"	Repair Cost $0	CO_2 gt 16%	O_2 gt 20.5%	DCF Disagreement
2P04038	4	99.6	46.5	26.1	89.2	51.5	99.6	.	.	80.0	87.1	86.7
2P27143	4	99.5	93.6	63.6	99.5	40.4	39.9	.	.	96.0	37.6	70.5
2P25807	4	99.5	87.4	43.1	81.1	39.2	50.1	.	.	99.5	36.4	82.8
2P32062	4	99.3	99.3	81.9	91.2	7.9	78.4	.	.	94.4	65.9	81.8
1P36295	4	99.3	77.3	99.3	66.9	79.6	92.1	14.8	38.1	68.5	80.7	73.2
2P35737	4	99.3	43.5	81.1	94.0	44.3	38.8	.	.	99.3	84.0	78.9
2P28704	4	99.1	78.8	94.6	37.0	74.8	64.3	88.5	15.3	99.1	38.8	73.5
1P38738	4	99.1	96.4	39.6	.	93.3	93.1	.	.	82.6	98.8	99.1
2P35478	4	99.0	99.0	80.1	76.4	34.0	86.4	.	.	98.3	86.5	82.9
1P37893	4	99.0	81.9	9.3	.	99.0	17.0	.	.	32.2	97.4	98.9
1P36937	4	98.9	73.4	98.9	67.2	97.5	14.2	.	.	72.9	82.1	81.8
2P32730	4	98.9	92.5	88.7	95.0	66.6	65.6	.	.	98.9	43.0	83.9
1P02201	4	98.8	98.8	1.0	72.9	79.3	47.0	.	.	97.2	82.5	89.3
2F20441	4	98.7	83.7	64.4	86.3	62.5	6.7	.	.	98.7	71.3	86.6
2P33879	4	98.6	82.8	41.5	98.6	43.3	84.3	.	.	75.2	94.1	91.2
1P35016	4	98.6	48.2	98.6	21.0	96.4	12.6	.	.	20.9	84.0	81.1
2P31367	4	98.5	98.5	89.8	91.8	27.9	33.4	.	.	49.2	84.9	87.0
6P19453	4	98.5	98.5	39.1	84.3	74.5	95.8	.	.	96.1	57.8	66.4

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