FINAL

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

Prepared for:

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Prepared by:

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EVALUATION OF THE TEXAS VEHICLE EMISSIONS INSPECTION AND MAINTENANCE PROGRAM IN THE DALLAS-FORT WORTH AND HOUSTON-GALVESTON-BRAZORIA NONATTAINMENT AREAS

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EXECUTIVE SUMMARY

This report documents the evaluation of the Texas Vehicle Emissions Inspection and Maintenance (I/M) program for the 2016 and 2017 biennial period. Eastern Research Group (ERG) performed this evaluation for the Texas Commission on Environmental Quality (TCEQ) using the Texas Information Management System (TIMS) database data and Remote Sensing (RS) data from January 1, 2016 through December 31, 2017.

This evaluation generally follows the United States Environmental Protection Agency (EPA) draft guidance on using in-program data for the evaluation of the Texas I/M program performance [EPA, 2001][1] and the EPA guidance on the use of RS for the evaluation of I/M program performance [EPA, 2004]. This study focuses on program coverage, the inspection process, and the repair process. Additionally, program benefits were estimated on an annual basis. However, because of the increasingly lower tailpipe test volumes, which are now less than 3 percent of the overall test volume, some analyses that were completed in previous program evaluation reports are not presented in this report.

Overall, the results for the Texas I/M program were positive. However, in the course of performing this evaluation a few areas were found where improvements could be made. Additionally, some of these suggestions will be helpful for future biennial evaluations will make the results more reflective of overall 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.

A. COVERAGE

The results of the coverage analysis using out-of-program data remote sensing data revealed a consistent, high rate of participation in the Texas I/M program.

Participation Rates (Section II.A) – The program participation rates were estimated 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 Dallas-Fort Worth (DFW) program area, the participation rate was 91.5 percent in 2016 and 93.4 percent in 2017. In the Houston-Galveston-Brazoria (HGB) program area, the participation rates were 91.6 percent and 94.4 percent, respectively. The overall program participation rates were 93.0 percent in 2016 and 95.2 percent in 2017.

B. INSPECTION

Appropriateness of Major TIMS Fields (Section III.A) – The TIMS was used to document the Texas 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

[1] Citations for references are given in Section 7.

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 oxides of nitrogen[2] (NO_x) and Two-Speed Idle (TSI) HC and CO were typical for vehicle emissions data, as the distributions were all positively skewed (that is, most observations were at low emissions concentrations), and there is no evidence of large numbers of very high concentration values. The shapes of the distributions looked typical for a fleet of modern in-use vehicles. Overall, the figures indicated that no gross errors were being made in measuring and recording tailpipe emissions. Very few out-of-range emission values were found.

Inspection Statistics (Section III.B) – Analysis of the TIMS data indicated that during the evaluation period over 17.9 million ASM, TSI, and On-board Diagnostics (OBD) tests were performed on approximately 9.9 million unique 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. The DFW and HGB program areas had comparable test failure rates. About 4 percent of the OBD tests were fails, about 12 percent of the ASM tests were fails, and about 7 percent of the TSI tests were fails. It is worth noting that the higher percentage of OBD tests in this report versus those seen in the previous studies means that fleet-wide, fewer vehicles are now initially failing, resulting in fewer repairs. This change will impact any fleet-wide comparisons between the results from this report and the earlier studies.

Repeat I/M Failure Patterns (Section III.C) – ERG examined the TIMS data to determine the relative frequencies of the I/M pass/fail patterns during each vehicle's inspection cycle.

- Over 99.5 percent of the test sequences were a verified initial test or an initial test that could reasonably be assumed to be a true initial test, and a final certified test.

Emissions Analyzer Data Quality (Section III.D) – 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, carbon dioxide (CO_2), and oxygen (O_2), gas audit results to validate analyzer accuracy, and comparison of instrument calibrations with inspection

[2] The ASM test measures NO; however, the Texas vehicle inspection record converts this value to estimate a NO_X value.

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 85.7 percent 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 percent of the Texas I/M inspections performed just before the calibration can be expected to be within the instrument tolerance except for very low values of HC.
- Dilution Correction Factors (DCFs) based on CO/CO_2 compared with DCFs based on O_2 for all inspections in the evaluation period indicated that over 86 percent of the ASM and 83 percent of TSI tests produced measured CO, CO_2, and O_2 values that were consistent with the expected stoichiometric relationship for gasoline combustion.
- The Texas state implementation plan (SIP) requires that each analyzer be audited at least twice per year. The TIMS data indicates that over 94 percent of the analyzers in the state were audited at least twice per year and many of them were audited more times than that. Of the 1,598 analyzer audits performed, 1,427 analyzers received three or more audits.
- 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, 4 percent of all ASM inspections were performed when the dynamometer systems had not successfully passed their calibration check within the 72-hour window, with analyzers made by Worldwide Environmental Products, Inc. (Worldwide) and the Sun Electric (SE) manufactured by Snap-On the most prevalent in this category. Similarly, 0.4 percent of ASM and TSI inspections were performed when the analyzer should have been locked out, and again Worldwide and SE were the most frequent.

OBD Inspection Analyzer Communication Performance (Section III.E) – Overall, OBD communication rates between vehicle computers and program analyzers were greater than 99.9 percent.

TIMS Handling of OBD Codes (Section III.F) – It appears that the OBD inspection logic used in Texas for light-duty gasoline-powered vehicles is in agreement with EPA policies. For the very few cases where this was found not to be true, ERG believes these instances were due solely to a minor oversight such as operator error or analyzers not having the latest software update for a brief period that resulted in a small percentage of errors.

C. REPAIR

Number and Types of Repairs (Section IV.A) – During the evaluation period, analysis of the TIMS data indicated that 179,445 repairs were made to vehicles in order to bring them into compliance with the Texas I/M program. The 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 approximately 23 percent, 9 percent, 25 percent, 2 percent, and 41 percent, respectively.

Repair information is also available through the AirCheckTexas Drive a Clean Machine (DACM) program. Texas created the DACM program under the statutory authority granted in the Low-Income Vehicle Repair Assistance, Retrofit, and Accelerated Vehicle Retirement Program (LIRAP) legislation to enhance the objectives of the Texas I/M program. The DACM program provides financial assistance to low-income vehicle owners to repair or retire vehicles that have failed an emissions test or retire vehicles ten years old or older. For the period covering December 1, 2015 through November 30, 2017, 5,262 vehicle repairs were done at Recognized Emissions Repair Facility (RERF) stations under the DACM program, with 5,025 being made in the DFW and HGB programs.

Emissions Changes Associated with Repairs (Section IV.B) – ERG analyzed the 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 for ASM HC, CO, and NO_x were approximately decreases of 54 percent, 63 percent, and 57 percent, respectively. Note that almost all of these vehicles were fast-pass ASM tests[3], therefore the after-repair emissions concentrations are biased high. However, because repair and emissions degradation begin immediately after certification and continue 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 (Section IV.D) – ERG's analyses indicate approximately 84 percent of OBD tests that initially fail for an illuminated malfunction indicator light (MIL) with stored diagnostic trouble codes (DTCs) eventually receive a passing inspection. However, as also seen in the earlier studies, when evaluating repairs by

[3] Fast-pass refers to a vehicle receiving a passing test prior to the completion of the full test time because its emissions measurements for each pollutant are sufficiently below the test standard to project the vehicle will pass if the test is run for the full test time.

failure category (i.e. evaporative emissions control system, O_2 Sensor, Exhaust Gas Recirculation (EGR) System, air injection system, and catalytic converter), unset readiness monitors were seen to potentially "hide" malfunctions in 2 percent to 39 percent of "repaired" vehicles. This large range is consistent with the findings in previous program evaluation reports and reflects the uncertainty in identifying cases where unset readiness monitors are masking MIL illumination in repaired vehicles.

Average Repair Costs (Section IV.E) – 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 $13.3 million during this evaluation period performing 94,000 repairs so that they would be in compliance with the Texas I/M program. It should be noted that vehicle emissions inspectors hand-enter repair costs, which can lead to transcription errors.

As in the previous studies, a large percentage (53.8 percent) of the repair costs in the TIMS were recorded as zero. Again, with zero repair costs and those over $2,000 removed, the median and mean repair costs ranged from $40-$260 and $94-$353.

D. I/M 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.

Estimate of Annual I/M Benefits from TIMS Data (Section V.A) – ERG calculated the change in emissions concentrations at the time of inspection using the initial and final emissions concentrations of annual inspection sequences as recorded in TIMS data, which is in-program data. About 89 percent of the I/M sequences were produced by vehicles that simply initially passed. Of course, the emissions reductions from these I/M events were zero. Additionally, about 10 percent of the I/M sequences were produced by vehicles that initially failed, were repaired, and finally passed. When all ASM sequences were considered together using the TIMS data, the apparent changes in emissions concentrations at the inspection event were: ASM HC decreased 13 to 18 percent, ASM CO decreased 24 to 27 percent, and ASM NO_x decreased 15 to 18 percent. TSI HC emissions decreased 17 to 19 percent and TSI CO emissions decreased 19-22 percent.

Estimate of Annual I/M Benefits from Paired I/M and RS Data (Section V.B) – The analysis of RS data, which is out-of-program data, provides a different view of the Annual I/M Benefit of the Texas 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 89 percent of the vehicles measured by RS had I/M sequences produced by passing their initial inspections, while 5 percent had a Fail-

Pass I/M test sequence. Initial pass vehicles had RS emissions increases of roughly 26.7 percent for HC, 5.1 percent for CO, and 9.5 percent for NO_x, while the Fail-Pass vehicles had RS emissions decreases of 3.7 percent for HC, 0.4 percent for CO, and 1.0 percent for NO_x.

Measures for Evaluating Station Performance (Section VI) – This section strives to consolidate the analyses performed that pertain to the evaluation of station performance. Distinctions between errors of commission versus 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 an error of commission would be a Vehicle Identification Number (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 a highly suspicious case, the exact same OBD-downloaded VIN may be 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 as this will not result in falsely passing or failing the I/M test. In all, there were six error of commission metrics and ten error of omission metrics developed and each station was ranked according to their respective overall score in these two categories.

E. RECOMMENDATIONS

As a result of performing this biennial evaluation of the Texas I/M program, ERG has developed a list of recommendations the TCEQ may consider implementing. As in the earlier reports, 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. For each recommendation, ERG has provided an importance rating of High **(***)**, Medium **(**)**, or Low **(*)**. These ratings are provided to assist the TCEQ in prioritizing efforts to improve the Texas I/M program.

OBD Recommendations

The future of vehicle testing at Texas I/M inspection stations will continue to be dominated by OBD testing as it replaces ASM and TSI tailpipe emissions testing due to fleet turnover. Since the 2006 report, the OBD test fleet has grown from 70 percent to over 98 percent of the vehicles inspected in the Texas I/M Program. Because this trend toward OBD testing will continue, any OBD problems identified in this evaluation are viewed as more critical to the overall success of the program, and any recommendations pertaining to tailpipe testing should be closely evaluated to ensure changes are cost effective for the TCEQ.

OBD Recommendation 1 (***): Investigate requiring a "set" status for certain monitors to prevent hiding malfunctions. Our analysis found that in 2 percent to 39 percent of instances when a vehicle received an initial fail for a certain monitored component, the re-test 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 the TCEQ investigate implementing a software change that would require certain monitors to have a "set" readiness status on an OBD re-test that follows certain types of initial failures.

OBD Recommendation 2 (***): Improve response to trigger flags. ERG believes the current trigger system is well designed and well run. However, in other state I/M programs it has been found that the trigger system can identify more issues than can be addressed with available resources. Therefore, ERG's primary recommendation is to assess the current level of response to the existing triggers, and then determine if additional triggers would be beneficial to the program. Specifically, a simple count of the number of triggers and the corresponding number of responses would be helpful to assess the current effectiveness of the triggers program.

OBD Recommendation 3 (*): Diesel OBD and Heavy-duty Gasoline OBD. Per the EPA guidance, Texas does not perform testing on OBD light or heavy-duty diesels or heavy-duty gasoline vehicles. However, this topic continues to be discussed in the I/M community. The EPA's position on this may change in the future or pilot testing could be performed in some jurisdictions. ERG suggests the TCEQ stay abreast of any developments in this area.

ASM and TSI Recommendations

In the current reporting period (2016-2017), ASM and TSI inspections represent less than 2 percent of total inspections. By the year 2020, when this I/M Evaluation is performed again, all vehicles 2-24 years will be model year 1996 and newer, so no vehicles will receive ASM inspections. As the focus shifts more toward OBD inspections, program evaluation should shift toward OBD and away from tailpipe inspections as well; however, there was one finding worth mentioning.

Recommendation 1 (**): Inaccurate Inspection Type. It was found that the TIMS variable indicating which inspection type was performed (ASM or TSI) was not always accurate.

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.

Recommendation 1 (***): Volume of RS data collected in DFW & HGB. The Comprehensive RS method has been used in Section V each time the I/M program evaluation is done. The number of RS records collected each year increased through calendar year 2013 and has declined each year since then. Since almost all vehicles will now receive OBD inspections instead of tailpipe inspections, the RS records will be the only data source that will be available to track actual fleet emissions levels over time. A robust RS dataset, with a high volume of records, will be of great value in future program evaluation.

Recommendation 2 (**): Collect RS data in San Antonio. In the 2009 Report, ERG was able to use RS data from San Antonio to analyze the DFW/HGB RS fleet data using the Reference Method. If possible, efforts should continue to obtain RS data from San Antonio for future evaluations. That analysis was not possible in this study as there was insufficient RS data from San Antonio to perform the analysis. However, as long as sufficient data is collected in the DFW and HGB I/M program areas, a paired I/M TIMS / RS air quality analysis can be performed.

Repair Tracking Recommendations

Whether malfunctioning vehicle emission control systems are detected by ASM, TSI, 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.

Repair Tracking Recommendation 1 (***). Use a more detailed, but short list of repairs for I/M inspectors to choose from. The TIMS provides inspectors with five general repair categories for reporting I/M-induced repairs and these categories appear to be too broad to be useful. It is recommended that the TCEQ develop an improved system for reporting I/M-induced vehicle repairs that contains more detail, providing inspectors a list of the five to ten most effective repairs for each vehicle technology. Key repair types have already been identified 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 provide a convenient, short list of repairs for inspectors that would make the inspector's task simpler, while recording valuable repair information that is most important for the I/M program. This information is critical for program evaluation projections, since it is not possible to link emission reductions to repair without reliable repair data.

It might be worthwhile to consider a software change that would require the inspector to input repair information within set limits of price and from a menu selection of repair choices. Providing more standardized menu options would also help improve the accuracy of this data by standardizing the entries as well as making it more onerous for the technician to enter incorrect data than to actually enter real data. If it becomes more difficult to input bogus data than the actual real data, then technicians would be motivated to be more accurate when completing these electronic entry forms.

Repair Tracking Recommendation 2 (***). Recording Repair Costs. There are a large number of repairs with a cost of $0 or greater than $2,000. ERG recommends that if values of $0 or above $2,000 are entered into the TIMS, an explanation be required before the records can be closed.

Repair Tracking Recommendation 3 (***). Recognized Emissions Repair Facility Data. In previous reports, repair information collected from the Texas Department of Public Safety (DPS) RERF program was also included. However, because of a transition to a new data collection system, insufficient RERF data were available to analyze for the current report. ERG recommends that the TCEQ ask the DPS if this change is permanent.

I/M Program Evaluation 2020 Recommendations

By the year 2020, when the next I/M program evaluation will be conducted, almost all vehicles will receive OBD inspections. More than 98 percent of the fleet was OBD tested during this (2018) I/M program evaluation; that percentage will be close to 100 percent in the next evaluation. Therefore, for the next I/M program evaluation in 2020, ERG recommends an increased emphasis on OBD evaluation, and a greatly reduced evaluation of tailpipe inspection results. ERG recommends major changes to most of the sections in the I/M program evaluation report:

Section II, Coverage. This section does not need to be changed, as it is independent of inspection type.

Section III, Inspection. This section should receive a major overhaul. Sections A through C should be revisited to provide a smoother summary of inspections statistics for the OBD program. Subsection D provides a very detailed look at tailpipe analyzer performance and should be removed from the report. Sections E and F should be expanded for a more detailed evaluation of OBD analyzer performance.

Section IV, Repair. This section should be modified to exclude emissions changes for tailpipe inspections.

Section V, Estimates of I/M Benefits. The first part of this section, estimate of benefits from TIMS data, currently looks at tailpipe emissions reductions. For an OBD-only program, the TIMS data could be used in combination with an OBD-to-IM240 model, to predict an IM240-based benefit resulting from the OBD inspections. ERG has developed an OBD-to-IM240 correlation and has used it in other state I/M program evaluations. The second part of this section, which uses paired RS and I/M records, should be retained. It might also be useful to expand this section to look at RS fleet emissions levels over time (not paired to I/M records, just the on-road RS levels).

Section VI, Measures for Evaluation Station Performance. This section contains a large amount of tailpipe inspection evaluation, which should be removed from future reports. Only the OBD factors should be used, with an emphasis on VIN/electronic VIN (eVIN) mismatch, and electronic profile mismatch. ERG has also been working to develop additional OBD inspection validation protocols, including electronic profile "fingerprints" for different vehicle types, eVIN mismatch patterns to identify clean-scanning using OBD simulators, and other OBD record evaluations focused on identifying potentially-fraudulent OBD inspections, and recommends that some of these new protocols be included in the next I/M program evaluation. Also, it would be useful for this section to include additional comparisons of potentially-fraudulent inspection rates over time, as these provide good indicators of changes that may be taking place in the quality of emissions inspection performance.

In summary, ERG highly recommends revisiting the outline of the report before the next I/M Program Evaluation is begun to ensure that a targeted, relevant analysis is performed.

I. INTRODUCTION

The EPA requires that states with I/M programs submit an evaluation of their programs every two years to their EPA regional office. The most recent biennial evaluation of the Texas program was performed by the TCEQ in 2016. This report follows a similar format by choosing a set of evaluation elements that will comprehensively, yet simply, document the performance of the Texas I/M program for the most recent two years and adhere to the program evaluation requirements outlined by the EPA.

A. EVALUATION ANALYSIS APPROACH

The Clean Air Act requires that states evaluate their I/M programs every two years. The Sierra Method was initially used to evaluate the Texas I/M program in 2000 [ERG 2003] and later ERG used the updated EPA guidance [EPA 2001, EPA 2004] as a framework for an evaluation performed in 2006 [ERG 2006]. Since then, ERG has performed evaluations in 2009 [ERG, 2009], 2012 [ERG 2012], 2014 [ERG 2014] and 2016 [ERG 2016] using the same approach as the 2006 Report.

This 2018 report follows the same general methodology, 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 a reasonable cost, as well as provide an objective assessment on the overall status of the Texas I/M program, with the intent of identifying both areas that may be improved and those that are performing well.

B. STRUCTURE OF THE REPORT

As previously stated, this report follows the same outline as past reports. Section II investigates coverage by comparing vehicle license plates read during RS measurements with the vehicles seen in the Texas I/M program TIMS database.

Section III 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 OBD communication rates and test outcomes were examined.

In Section IV, the TIMS data and RERF data were analyzed to determine the level, cost, and effects, such as emissions changes and OBD system status, resulting from repairs associated with the Texas I/M program.

Section V provides emission benefits estimates based on the 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.

Section VI is a detailed analysis of station performance based on TIMS data. It covers errors of commission, such as “clean-scanning” or VIN mismatches, as well as errors that are more difficult to categorize such as data entry issues or anomalous test results.

II. COVERAGE

An important component of an I/M program is the level of fleet coverage, or the vehicle compliance rate. In this section, coverage is evaluated by estimating the fraction of vehicles observed on the road using RS data that also have a current and valid Texas I/M program TIMS record.

A. PARTICIPATION RATES

Estimates of the participation rate of vehicles subject to I/M in the DFW program area and in the HGB program area were made through a comparison of RS data and TIMS data. The RS data provides a sample of vehicles that were driven on the road, and if these vehicles were eligible for I/M, they should have an I/M test record in the TIMS database.

To perform this analysis, ERG first created a dataset of I/M-eligible vehicles captured on the road by RS at least once. This dataset was created by merging RS data (by license plate) to Texas' registration records. This dataset does not include vehicles from out-of-state or registered in non-I/M counties. It only consists of I/M-eligible model years. Therefore, vehicles newer than 2 years and older than 24 years at the time of the RS measurement are excluded from the analysis. Table II-1 shows the counts of unique I/M-eligible vehicles from the DFW or HGB program areas that were measured by RS between January 1, 2016 and December 31, 2017.

Table II-1. Count of Unique I/M-Eligible Remote Sensing Vehicles Registered in Texas I/M Program Areas by Calendar Year

Registered at Time of Remote Sensing	Unique RS-Captured Vehicles by Calendar Year		
	2016	**2017**	**Total**
DFW	71,508	75,332	146,840
HGB	61,747	83,589	145,336
Total	**133,255**	**158,921**	**292,176**

Next, the number of unique I/M-compliant vehicles (i.e. vehicles that were tested and ultimately passed or received a waiver) in each of the Texas I/M program areas during that same time frame was determined. Table II-2 shows the overall counts for the I/M tests in the DFW and HGB program areas.

Table II-2. Count of Unique I/M-Compliant Vehicles in Texas I/M Program Areas

I/M Area where Test Performed	Unique I/M-Tested Vehicles
DFW	5,206,383
HGB	4,711,741
Total	**9,918,124**

The I/M tests were then matched to RS/registration dataset by VIN. If an I/M test occurred any time between January 1, 2016, and December 31, 2017, and was found to have a corresponding VIN with a RS measurement taken any time during the same time period, this was a matched pair. Table II-3 summarizes these results for the DFW and HGB program areas. These values were then divided by their respective values for each program area in Table II-1 to obtain an estimate for the Texas I/M program participation rate (e.g. in 2016 the DFW program area participation rate was calculated as [66,360/71,508] x 100). Table II-3 shows that the participation rate did increase slightly overall from 2016 to 2017.

Table II-3. Count of Unique I/M Eligible Remote Sensing Vehicles Paired with Unique I/M-Compliant Vehicles in Texas I/M Program Areas by Calendar Year

I/M Program Area where Test Performed	Paired RS and TIMS VIN Matches		Participation Rate	
	2016	**2017**	**2016**	**2017**
DFW	66,360	71,392	92.8%	94.8%
HGB	57,585	79,864	93.3%	95.5%
Total	**123,945**	**151,256**	**93.0%**	**95.2%**

III. INSPECTION

A. CHECK MAJOR DATA FIELDS FOR APPROPRIATENESS

The goal of this section was to analyze the ranges and values of the primary variables that make up the TIMS database. This analysis is an indication of the ability of the Texas I/M program's analyzers and database system to accurately record the activities of the Texas I/M program. If any variables have values that are out of range or missing for unexplained reasons, it suggests that the Texas I/M program activities are not being conducted properly or adequately monitored. An iterative series of steps were used to evaluate the accuracy and completeness of the data in the database. First, a set of basic filters were applied to remove unusual or incomplete inspections from the dataset (e.g., aborted inspections, inspections with no emissions component, covert audits, etc.). Then, a frequency distribution was performed on nearly all database variables to evaluate the accuracy and completeness of data fields. Additional records with obvious problems were tallied and removed from the dataset (such as invalid/undefined characters stored for a coded categorical variable, or dramatically out-of-range numerical results). Finally, combinations of variables were evaluated for consistency (such as TSI results recorded for an inspection that is marked as an ASM inspection). These steps are described in detail below.

Initial filters and frequency distributions

The first set of filters removed incomplete or unusual inspections from the dataset, as well as non-emissions inspections. Beginning with the full database of 25.5 million inspection records for 2016 – 2017, any records that were not for successful inspections that included an emissions inspection were deleted. This deletion covered:

- Out-of-area inspections (not from HGB or DFW areas);
- aborted inspections (TX96_ABORT="J","A");
- safety-only or visual-only inspections (TX96_TEST_TYPE="H", "P");
- inspections that timed-out due to a dilution condition (TX96_EMISS_PF_FL="T","D");
- inspections that were covert audits (TX96_covert_FL not "N");
- out-of-program model years, older than 1992 or newer than 2017;
- inspections with invalid VINs, either fewer than 17 characters, including invalid characters (such as "!", "@", etc), or flagged (TX96_VIN_FL="B"); and
- any remaining inspections with TX96_TEST_SEQUENCE less than 1.

In total, these deletions removed 7.6 million records from the dataset (mostly for safety-only inspections), leaving 17.9 million emissions inspections in the dataset.

Almost every database variable that stores a categorical result was checked for completeness and appropriateness of information. The vast majority of the variables in the dataset contained the expected information. After the record deletions described above, a few variables that still contained anomalous information included:

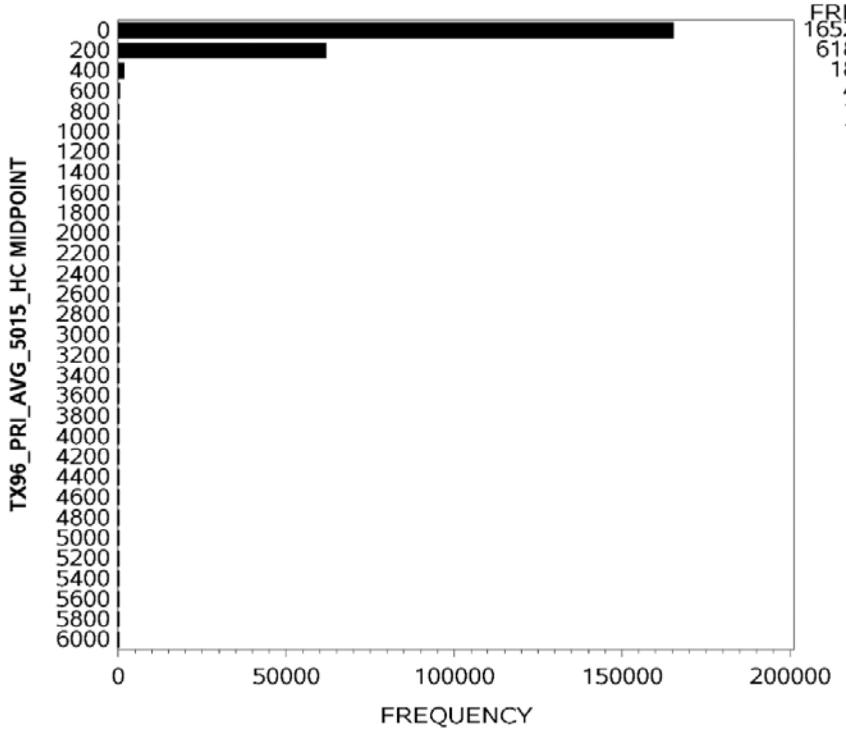
- 15,000 records with an overall inspection cost greater than $100 (TX96_OVERALL_COST>100);
- 199 records with a repair cost greater than $2000 (TX96_REP_OVERALL_COST>2000);
- 65 TSI inspections recorded a curb idle RPM greater than 3000 RPM (TX96_PRI_CURB_IDLE_RPM>3000);
- 18 percent of TSI and 23 percent of ASM inspections included an RPM Bypass (TX96_RPM_BYPASS=”B”); and
- Various other variables had a small number of missing value results or otherwise odd results that did not appear to be significant.

The anomalous records in the list above were counted and listed but were not deleted from the dataset. Most of the anomalies are investigated in further detail in other areas of the report.

A distribution of the emissions measurements is a special case of the above. Ideally, no observations with missing values or extremely high values (outliers) should be present.

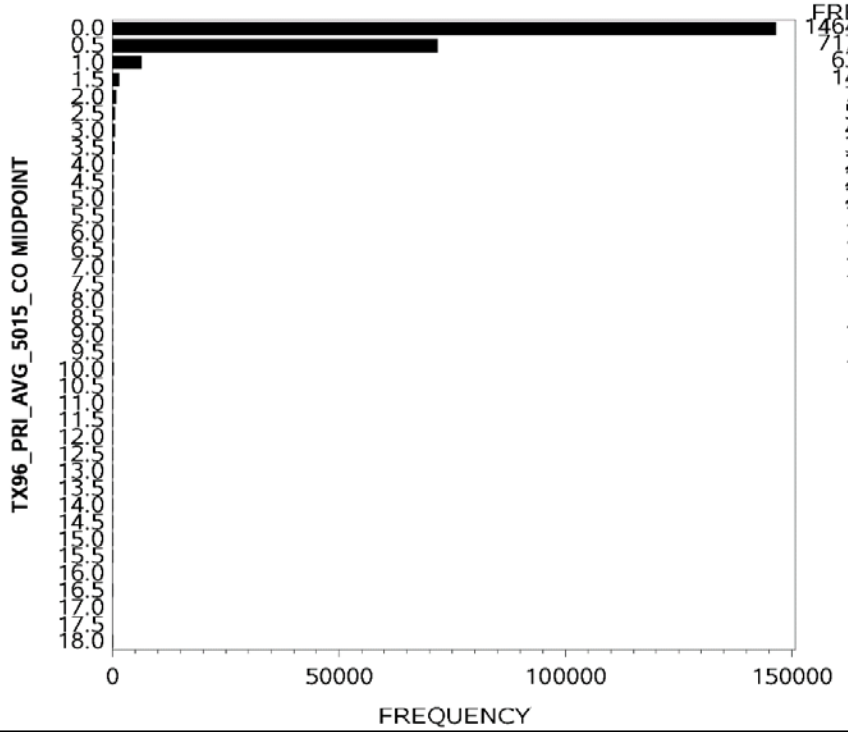
Figure III-1 through Figure III-4 show the distributions of the emissions measurements for HC, CO, NO_x, and CO_2 for the ASM5015 inspection. Similar results were seen for the ASM2525 data. Figure III-5 through Figure III-7 show the HC, CO, and CO_2 concentrations for the TSI curb idle inspection. The distributions are all positively skewed (i.e., most observations are at low emissions concentrations), and there is no evidence of large numbers of 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 percent and 16 percent, indicating a combustion process is occurring in the vehicle’s engine and exhaust dilution is in an acceptable range. The figures for CO_2 show that this is almost always the case. The exceptions will be investigated further in later sections of this report.

Figure III-1. Distribution of HC (ppm) Emissions for ASM5015 Inspection



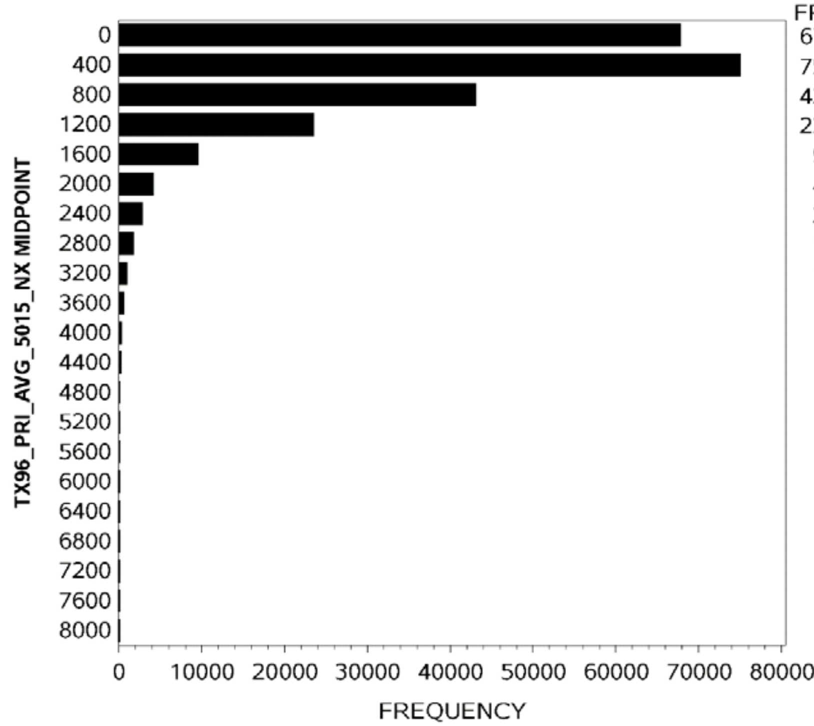
TX96_PRI_AVG_5015_HC MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
0	165233	165233	71.76	71.76
200	61855	227088	26.86	98.62
400	1814	228902	0.79	99.41
600	446	229348	0.19	99.60
800	198	229546	0.09	99.69
1000	120	229666	0.05	99.74
1200	87	229753	0.04	99.78
1400	69	229822	0.03	99.81
1600	53	229875	0.02	99.83
1800	43	229918	0.02	99.85
2000	39	229957	0.02	99.87
2200	37	229994	0.02	99.88
2400	32	230026	0.01	99.90
2600	29	230055	0.01	99.91
2800	36	230091	0.02	99.93
3000	18	230109	0.01	99.93
3200	14	230123	0.00	99.94
3400	15	230138	0.00	99.95
3600	10	230148	0.00	99.95
3800	15	230163	0.00	99.96
4000	13	230176	0.00	99.96
4200	9	230185	0.00	99.97
4400	7	230192	0.00	99.97
4600	8	230200	0.00	99.97
4800	5	230205	0.00	99.98
5000	9	230214	0.00	99.98
5200	5	230219	0.00	99.98
5400	5	230224	0.00	99.98
5600	7	230231	0.00	99.99
5800	4	230235	0.00	99.99
6000	27	230262	0.01	100.00

Figure III-2. Distribution of CO (%) Emissions for ASM5015 Inspection



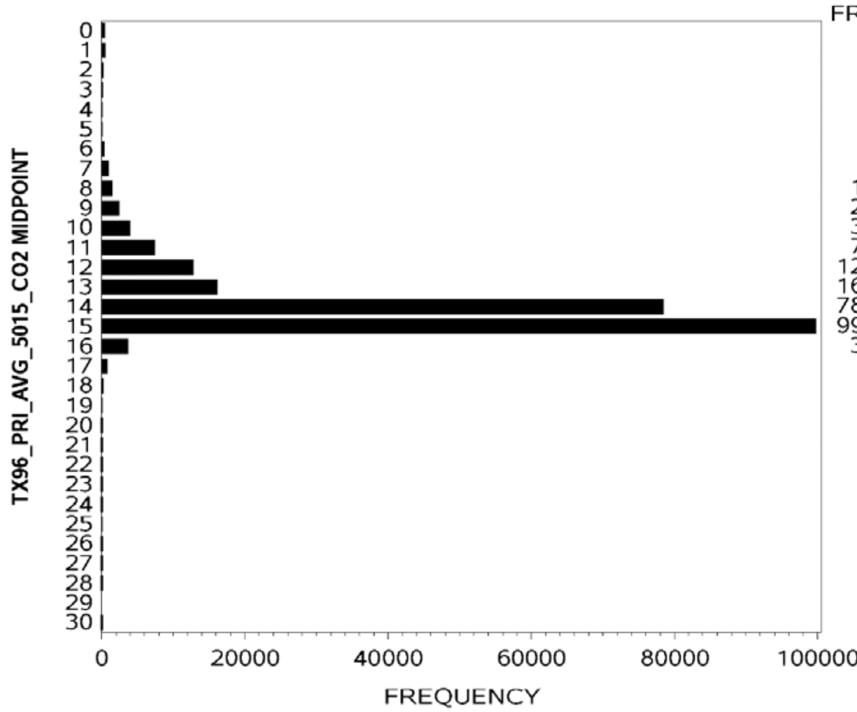
TX96_PRI_AVG_5015_CO MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
0.0	146412	146412	63.58	63.58
0.5	71771	218183	31.17	94.75
1.0	6316	224499	2.74	97.50
1.5	1450	225949	0.63	98.13
2.0	747	226696	0.32	98.45
2.5	517	227213	0.22	98.68
3.0	400	227613	0.17	98.85
3.5	335	227948	0.15	99.00
4.0	254	228202	0.11	99.11
4.5	226	228428	0.10	99.20
5.0	217	228645	0.09	99.30
5.5	192	228837	0.08	99.38
6.0	185	229022	0.08	99.46
6.5	147	229169	0.06	99.53
7.0	136	229305	0.06	99.58
7.5	112	229417	0.05	99.63
8.0	94	229511	0.04	99.67
8.5	91	229602	0.04	99.71
9.0	102	229704	0.04	99.76
9.5	85	229789	0.04	99.79
10.0	133	229922	0.06	99.85
10.5	94	230016	0.04	99.89
11.0	82	230098	0.04	99.93
11.5	65	230163	0.03	99.96
12.0	44	230207	0.02	99.98
12.5	23	230230	0.01	99.99
13.0	14	230244	0.00	99.99
13.5	7	230251	0.00	100.00
14.0	3	230254	0.00	100.00
14.5	1	230255	0.00	100.00
15.0	2	230257	0.00	100.00
15.5	1	230258	0.00	100.00
16.0	0	230258	0.00	100.00
16.5	1	230259	0.00	100.00
17.0	0	230259	0.00	100.00
17.5	0	230259	0.00	100.00
18.0	3	230262	0.00	100.00

Figure III-3. Distribution of NO_X (ppm) Emissions for ASM5015 Inspection



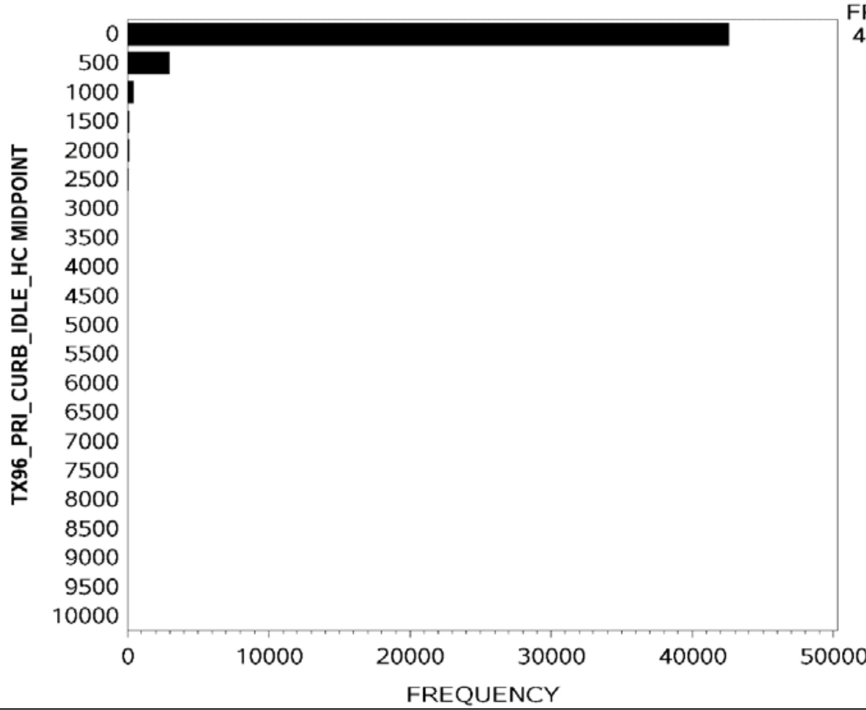
TX96_PRI_AVG_5015_NX MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
0	67816	67816	29.45	29.45
400	75011	142827	32.58	62.03
800	43123	185950	18.73	80.76
1200	23533	209483	10.22	90.98
1600	9545	219028	4.15	95.12
2000	4128	223156	1.79	96.91
2400	2832	225988	1.23	98.14
2800	1773	227761	0.77	98.91
3200	1008	228769	0.44	99.35
3600	596	229365	0.26	99.61
4000	348	229713	0.15	99.76
4400	211	229924	0.09	99.85
4800	114	230038	0.05	99.90
5200	86	230124	0.04	99.94
5600	64	230188	0.03	99.97
6000	21	230209	0.01	99.98
6400	17	230226	0.01	99.98
6800	9	230235	0.00	99.99
7200	8	230243	0.00	99.99
7600	8	230251	0.00	100.00
8000	11	230262	0.00	100.00

Figure III-4. Distribution of CO_2 (%) Emissions for ASM5015 Inspection



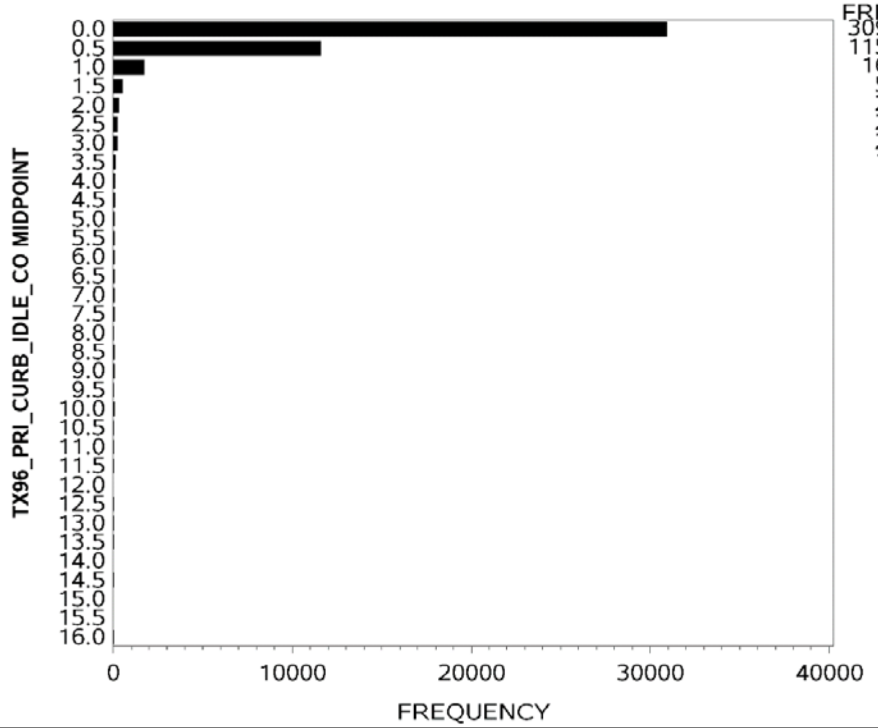
TX96_PRI_AVG_5015_CO2 MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
0	397	397	0.17	0.17
1	541	938	0.23	0.41
2	207	1145	0.09	0.50
3	140	1285	0.06	0.56
4	88	1373	0.04	0.60
5	81	1454	0.04	0.63
6	339	1793	0.15	0.78
7	965	2758	0.42	1.20
8	1444	4202	0.63	1.82
9	2433	6635	1.06	2.88
10	3948	10583	1.71	4.60
11	7377	17960	3.20	7.80
12	12803	30763	5.56	13.36
13	16121	46884	7.00	20.36
14	78502	125386	34.09	54.45
15	99754	225140	43.32	97.78
16	3696	228836	1.61	99.38
17	765	229601	0.33	99.71
18	253	229854	0.11	99.82
19	108	229962	0.05	99.87
20	54	230016	0.02	99.89
21	27	230043	0.01	99.90
22	39	230082	0.02	99.92
23	36	230118	0.02	99.94
24	10	230128	0.00	99.94
25	117	230245	0.05	99.99
26	1	230246	0.00	99.99
27	1	230247	0.00	99.99
28	1	230248	0.00	99.99
29	0	230248	0.00	99.99
30	14	230262	0.01	100.00

Figure III-5. Distribution of Curb Idle HC (ppm) Emissions for TSI Inspection



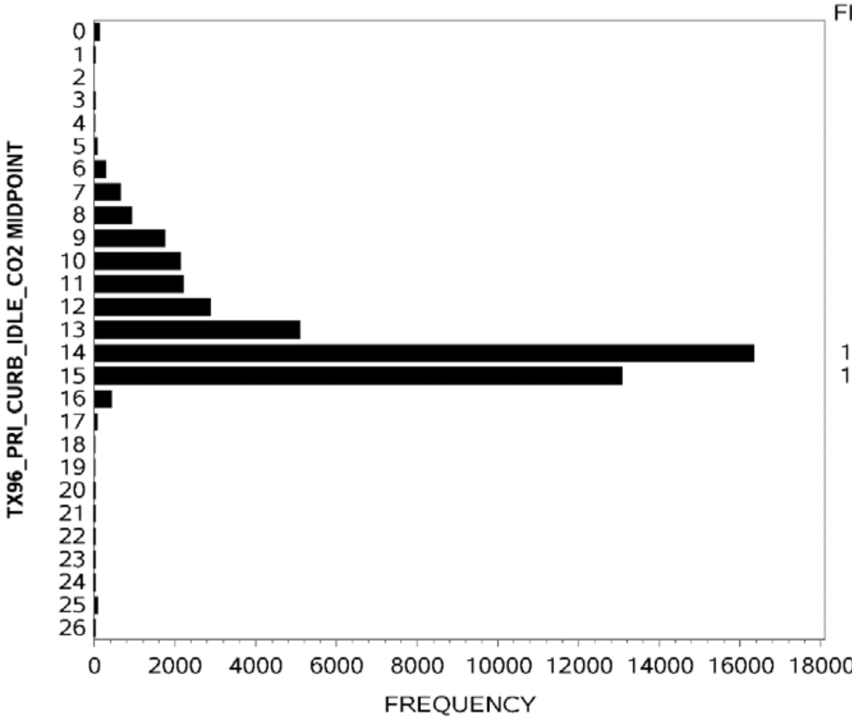
TX96_PRI_CURB_IDLE_HC MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
0	42569	42569	92.00	92.00
500	2969	45538	6.42	98.42
1000	408	45946	0.88	99.30
1500	117	46063	0.25	99.55
2000	71	46134	0.15	99.70
2500	50	46184	0.11	99.81
3000	26	46210	0.06	99.87
3500	19	46229	0.04	99.91
4000	32	46261	0.07	99.98
4500	1	46262	0.00	99.98
5000	3	46265	0.00	99.99
5500	2	46267	0.00	99.99
6000	1	46268	0.00	99.99
6500	1	46269	0.00	100.00
7000	1	46270	0.00	100.00
7500	0	46270	0.00	100.00
8000	0	46270	0.00	100.00
8500	0	46270	0.00	100.00
9000	0	46270	0.00	100.00
9500	1	46271	0.00	100.00
10000	0	46271	0.00	100.00

Figure III-6. Distribution of Curb Idle CO (%) Emissions for TSI Inspection



TX96_PRI_CURB_IDLE_CO MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
0.0	30954	30954	66.90	66.90
0.5	11587	42541	25.04	91.94
1.0	1692	44233	3.66	95.60
1.5	504	44737	1.09	96.68
2.0	298	45035	0.64	97.33
2.5	227	45262	0.49	97.82
3.0	221	45483	0.48	98.30
3.5	121	45604	0.26	98.56
4.0	86	45690	0.19	98.74
4.5	77	45767	0.17	98.91
5.0	58	45825	0.13	99.04
5.5	63	45888	0.14	99.17
6.0	42	45930	0.09	99.26
6.5	59	45989	0.13	99.39
7.0	43	46032	0.09	99.48
7.5	38	46070	0.08	99.57
8.0	27	46097	0.06	99.62
8.5	35	46132	0.08	99.70
9.0	31	46163	0.07	99.77
9.5	15	46178	0.03	99.80
10.0	72	46250	0.16	99.95
10.5	3	46253	0.00	99.96
11.0	2	46255	0.00	99.97
11.5	9	46264	0.02	99.98
12.0	0	46264	0.00	99.98
12.5	3	46267	0.00	99.99
13.0	1	46268	0.00	99.99
13.5	1	46269	0.00	100.00
14.0	0	46269	0.00	100.00
14.5	1	46270	0.00	100.00
15.0	0	46270	0.00	100.00
15.5	0	46270	0.00	100.00
16.0	1	46271	0.00	100.00

Figure III-7. Distribution of Curb Idle CO_2 (%) Emissions for TSI Inspection



MIDPOINT	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
0	140	140	0.30	0.30
1	1	141	0.00	0.30
2	0	141	0.00	0.30
3	7	148	0.02	0.32
4	22	170	0.05	0.37
5	72	242	0.16	0.52
6	295	537	0.64	1.16
7	651	1188	1.41	2.57
8	938	2126	2.03	4.59
9	1752	3878	3.79	8.38
10	2131	6009	4.61	12.99
11	2201	8210	4.76	17.74
12	2880	11090	6.22	23.97
13	5093	16183	11.01	34.97
14	16353	32536	35.34	70.32
15	13083	45619	28.27	98.59
16	427	46046	0.92	99.51
17	82	46128	0.18	99.69
18	16	46144	0.03	99.73
19	13	46157	0.03	99.75
20	5	46162	0.01	99.76
21	6	46168	0.01	99.78
22	6	46174	0.01	99.79
23	5	46179	0.01	99.80
24	3	46182	0.01	99.81
25	88	46270	0.19	100.00
26	1	46271	0.00	100.00

This procedure of checking the contents of the variables in the database is simply an initial Quality Assurance/Quality Control (QA/QC) procedure. Most of the variables will be investigated much more thoroughly in the other sections of the report.

B. INSPECTION STATISTICS: NUMBER OF VEHICLES INSPECTED BY INSPECTION TYPE

As a basic summary of the emissions inspections being performed under the Texas I/M program, a number of inspection statistics were calculated. Table III-1 shows the total number of each type of emissions inspection that were performed in the 2016 – 2017 calendar years, the number of these that were initial inspections (the first inspection in a test cycle), and the number of these that were unique vehicles, for the HGB and DFW program areas separately. A unique vehicle is synonymous with a unique VIN, i.e. the VIN is only associated with that specific vehicle and not duplicated elsewhere in the database. A unique initial inspection is the first inspection in a test cycle on a unique vehicle. There are considerably fewer unique initial inspections than total inspections. It should be noted that the unique initial inspection count appears small relative to the number of total inspections and initial inspections. This is because the Texas program is annual and many vehicles received an initial inspection in 2016 and another one in 2017; however, this would only be counted as one unique initial inspection.

Table III-2 shows the number of initial inspections that were passed and failed, by program area and inspection type, and Table III-3 shows the number of re-test inspections that were passed and failed, by program area and inspection type.

Table III-1. Number of Inspections

	DFW			HGB		
Test Type	Total Inspections	Initial Inspections	Unique Initial Inspections	Total Inspections	Initial Inspections	Unique Initial Inspections
OBD	9,257,284	8,782,861	5,119,395	8,393,739	7,944,110	4,635,254
TSI	26,293	23,469	16,177	19,978	17,933	11,739
ASM	122,298	103,026	70,811	107,964	94,321	64,748
Total	**9,405,875**	**8,909,356**	**5,206,383**	**8,521,681**	**8,056,364**	**4,711,741**

Table III-2. Number of Passed and Failed Initial Inspections

	DFW			HGB		
Test Type	Pass	Fail	Failure Percent	Pass	Fail	Failure Percent
OBD	8,448,289	334,567	3.81%	7,634,387	309,715	3.90%
TSI	21,934	1,535	6.54%	16,767	1,166	6.50%
ASM	88,930	14,096	13.68%	85,154	9,167	9.72%
Total	**8,559,153**	**350,198**	**4.09%**	**7,736,308**	**320,048**	**4.14%**

Table III-3. Number of Passed and Failed Retest Inspections

	DFW			HGB		
Test Type	Pass	Fail	Failure Percent	Pass	Fail	Failure Percent
OBD	422,629	51,789	10.92%	406,869	42,759	9.51%
TSI	2,112	712	25.21%	1,630	414	20.25%
ASM	12,586	6,686	34.69%	10,445	3,198	23.44%
Total	**437,327**	**59,187**	**13.53%**	**418,944**	**46,371**	**11.07%**

Inspection counts by model year are presented in the figures below. In Figure III-8 and Figure III-9, the number of inspections of each type are shown by model year, for the DFW and HGB program areas, respectively. The number of inspections by month of inspection is shown in Figure III-10, where the impact of Hurricane Harvey in August 2017 can be seen by the dip in HGB inspections. Finally, the failure rate by model year and type of inspection is shown in Figure III-11 and Figure III-12 for the DFW and HGB program areas, respectively. Only initial inspections are included (no re-tests). In general, the trends shown are as expected: more vehicles of newer model years are inspected than vehicles of older model years, and failure rates are considerably higher for older vehicles.

Figure III-8. Number of Inspections by Model Year per Inspection Type, DFW Program Area

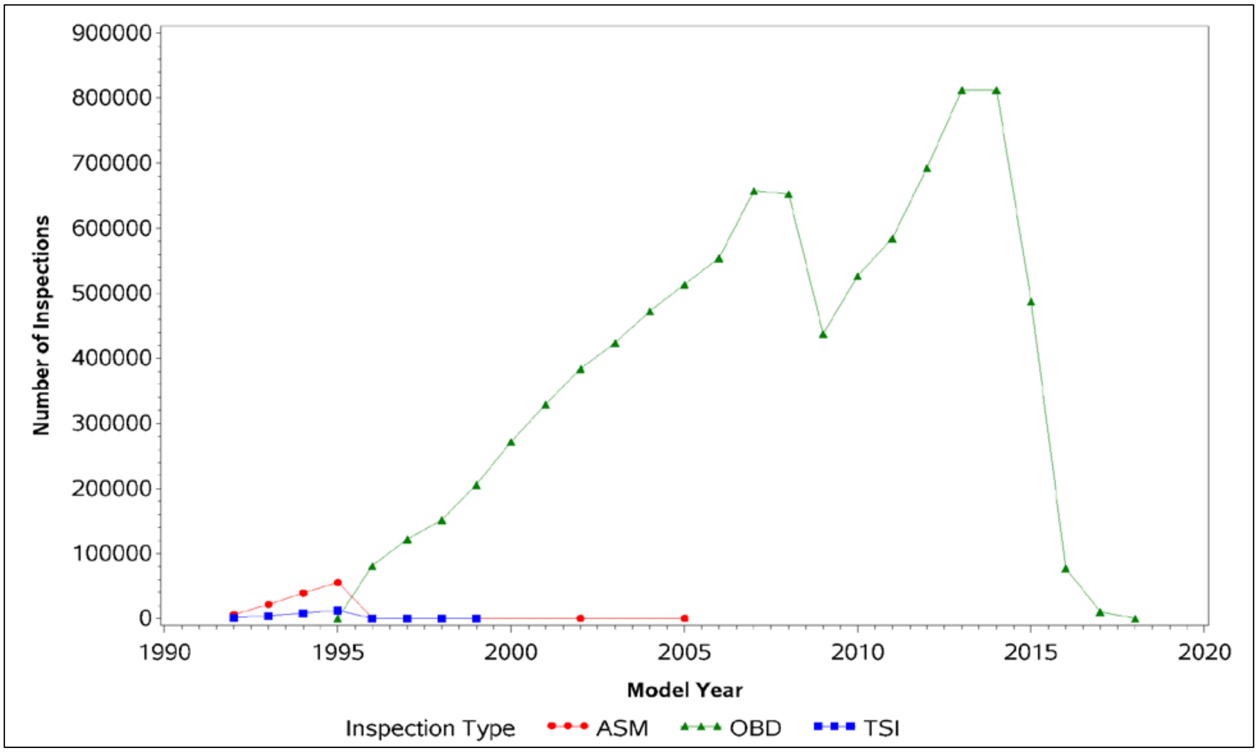


Figure III-9. Number of Inspections by Model Year per Inspection Type, HGB Program Area

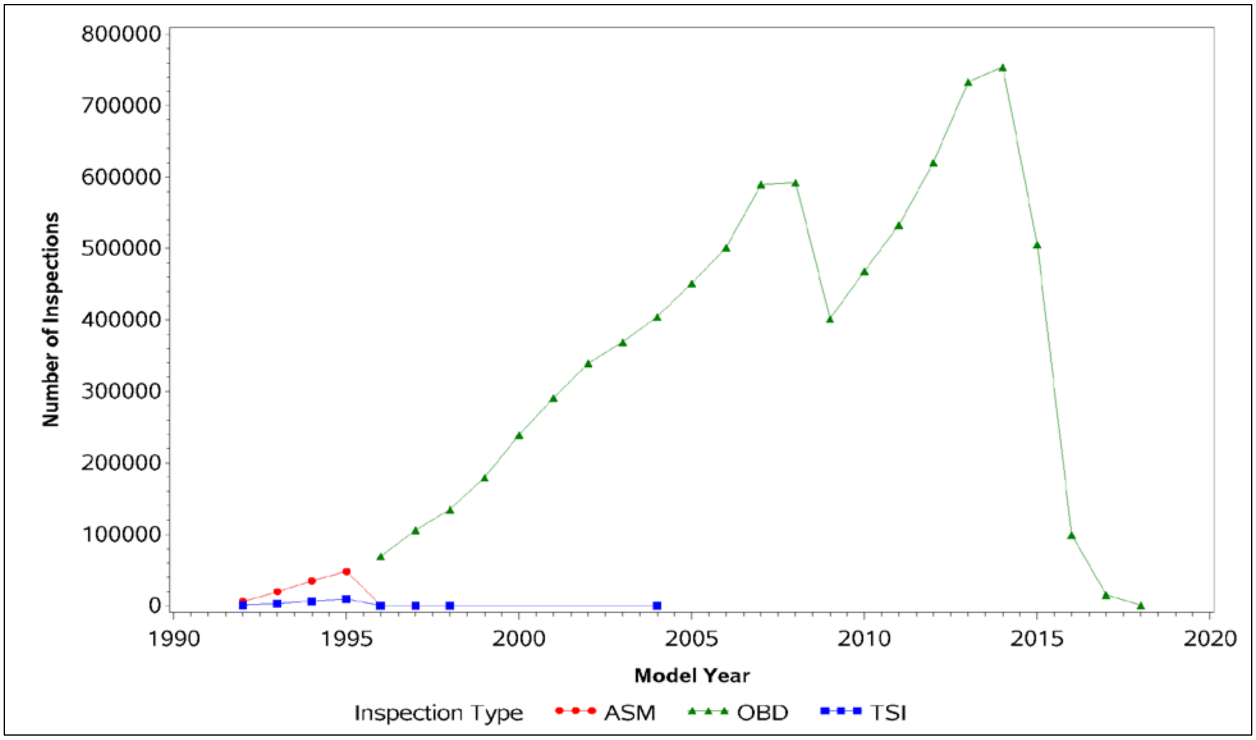


Figure III-10. Number of Inspections by Year and Month of Inspection

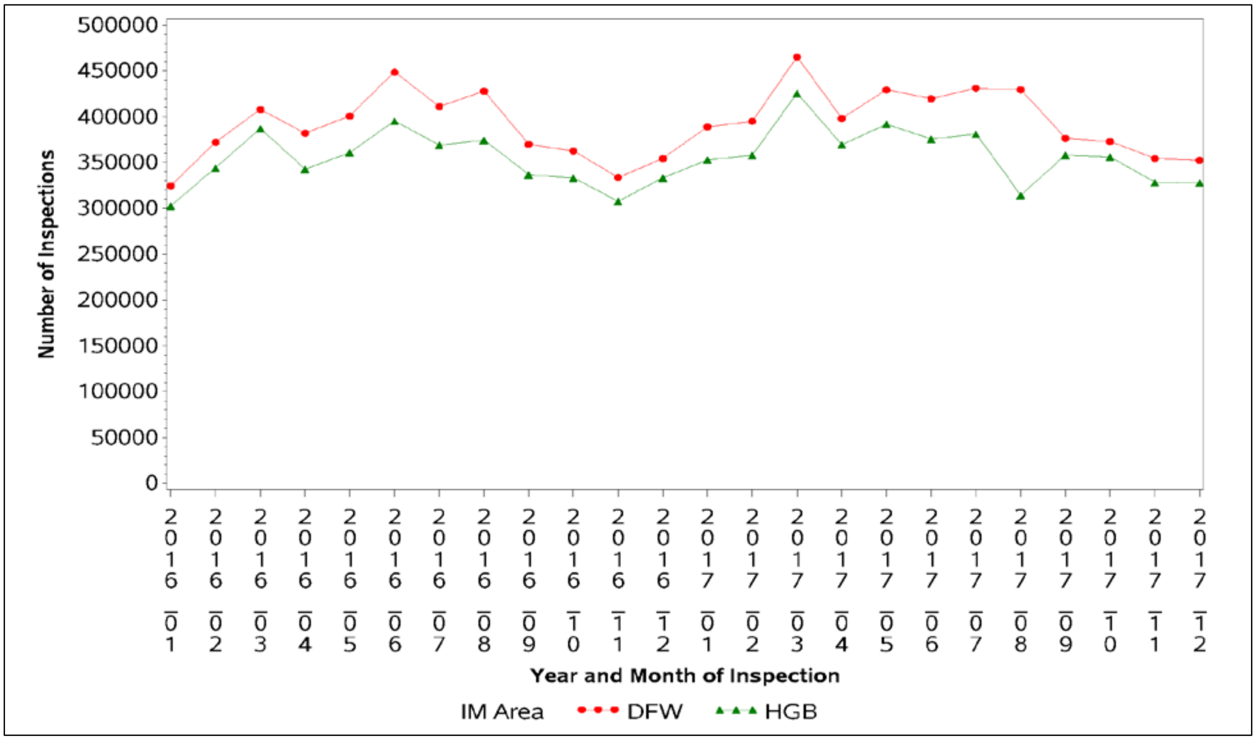


Figure III-11. Initial Inspection Failure Rate by Model Year per Inspection Type, DFW Program Area

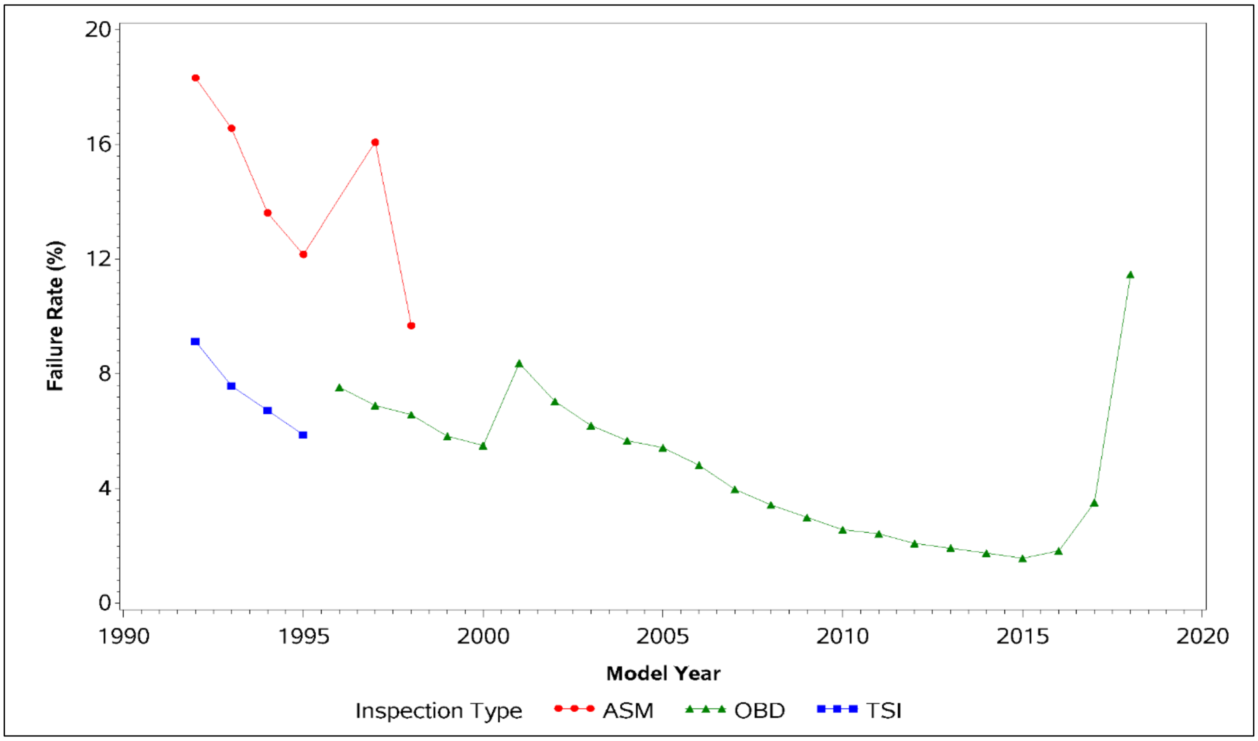
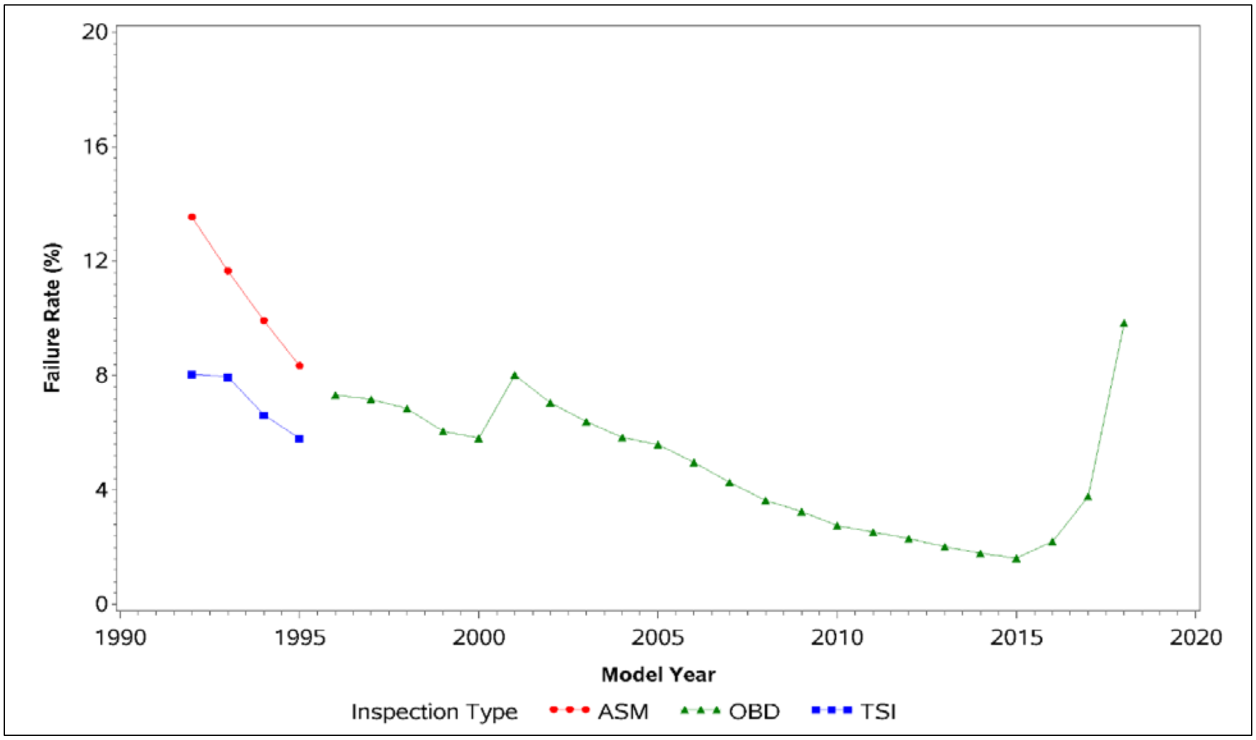


Figure III-12. Initial Inspection Failure Rate by Model Year per Inspection Type, HGB Program Area



C. REPEAT I/M FAILURE PATTERNS

ERG examined the TIMS data to determine the patterns of repeat I/M failures. This illustrates the extent and characteristics of repairs related to the Texas I/M program. This analysis was based on the two-year inspection period including all of 2016 and 2017. Initial and re-test inspections were not determined using the TX96_TEST_SEQUENCE or TX96_TEST_TYPE variables. These database variables are intended to store the number of inspections in an inspection sequence, and whether an inspection is an initial or a re-test inspection. However, many factors can affect the information stored in these variables (such as the time span between an initial and a re-test inspection, whether the motorist chose a different inspection station for the re-test, or whether a safety-only inspection was performed at some point). For the purposes of this section and this report, ERG made new initial/re-test assignments. The first inspection for a VIN was labeled an initial inspection. Additional inspections to that VIN were labeled as re-tests, until an inspection was passed, or a waiver was granted. The next inspection following a passed inspection, or a waiver was labeled an initial inspection. For identifying initial inspections, inspection cycles that appeared to begin in the first three months of 2016 were excluded from the counts, as they could have been preceded by additional inspections in 2015. Also, for the purpose of identifying final inspections, any inspection cycles that appeared to end in the last three months of 2017 were excluded, as there could be additional inspections in early 2018.

An “inspection sequence” is the series of inspections a vehicle receives as it moves through the Texas I/M program requirements. By far, the most common sequence is a single passed inspection. The second most common sequence is a failed inspection, followed by repair and a passed re-test. Additional sequences might include additional failed inspections before the ultimately passed inspection. Sequences should not be found where additional re-test inspections follow a passed inspection as these indicate that the measurements and efficacy of the repairs made to the vehicles in the program are less than ideal. For example, a sequence that is fail, fail, fail, fail, pass might indicate either that the motorist is “shopping around” for a passing result, that no repairs were made to the vehicle, 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 dataset contains a variable that gives the type of test (Initial or Retest) and a variable that gives the result of the emissions test (Pass or Fail). Failed inspections were designated with an “F” and passes with a “P.” Inspections that resulted in a waiver were designated with a “W.” For each unique VIN in the dataset, the designators were concatenated in chronological order to create a sequence that describes the test 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 is shown in Table III-4, with results for the DFW and HGB program areas shown separately. The waiver inspections are included in the “Other” category.

Table III-4. Frequency Distribution of Test Sequences

DFW			HGB		
Inspection Sequence	Number of Vehicles	Percent of Vehicles	Inspection Sequence	Number of Vehicles	Percent of Vehicles
P	7,444,481	94.73%	P	6,684,136	94.48%
FP	350,751	4.46%	FP	338,229	4.78%
F	29,020	0.37%	F	25,504	0.36%
FFP	22,036	0.28%	FFP	18,069	0.26%
FFFP	5,462	0.07%	FFFP	4,280	0.06%
FF	3,187	0.04%	FF	2,276	0.03%
FFFFP	1,383	0.02%	FFFFP	979	0.01%
FFF	759	0.01%	FFF	467	0.01%
Other	1,454	0.01%	Other	906	0.00%

In Table III-4, the top two rows, which represent the two “ideal” inspection sequences, comprise about 99 percent of the total distribution, both in the DFW and HGB program areas. However, some of the other sequences raise questions, such as, what becomes of the vehicles that fail an inspection and do not receive a passing re-test? One check that was performed for this set of vehicles was to make sure that they are not being affected by sequences that start near the end of the dataset and might have later re-tests. It was found that the sequences that end with a failed inspection are distributed fairly uniformly over all months of 2016 and 2017, although some increase is seen in the later months of the dataset. The vehicles that did not complete their inspection sequences and ended with no final passed inspection (NFP), may have moved (or have been re-registered) out of the I/M program area, and therefore may no longer be required to participate in the I/M program. However, some of the NFP vehicles were observed in the I/M program area by remote sensing after their incomplete inspection cycle. These non-compliant vehicles were observed at approximately half the frequency as compliant vehicles.

Several hundred less common sequences accounted for the remaining 0.01-0.02 percent of the tested fleets. Many of these remaining sequences seem to be unlikely, involving numerous failed inspections and/or multiple passed inspections. Some of these could be the result of resale vehicles, unidentified covert audit vehicles, or possibly test classification errors instead of real situations. While it might be possible to reduce the occurrence of these unlikely test sequences, the problem is relatively uncommon.

D. 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 TIMS data: Drift, Dilution Correction Factors, Gas Audits, and Lockouts.

Analyzer Drift

Texas I/M program emissions analyzers require 72-hour calibrations. 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_x, 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 retain calibrations 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_x 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 percent of the bottle gas values. Next, the analyzer is tested on the low-span gases and must fall within 2 percent 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 any I/M test until it is successfully adjusted.

Table III-5 shows the specified bottle gas values for the low-span and mid-span portions of the calibration. The bottled gases are permitted a 5 percent 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 percent mid-span and 2 percent 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, the low-span HC bottle gas concentration is specified to be 200 parts per million (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 III-5. 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
O_2 (%)	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 percent of calibration records include bottle gas label concentrations within the tolerances listed in Table III-5. However, the remaining small fraction of records include some surprisingly high and low bottle gas values, such as 13 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 the TCEQ restrict the inspector-entered bottle gas values to a range that corresponds to the specifications. Thus, the analyzer software would not allow a calibration to proceed unless reasonable bottle gas values were entered.

Results

Span test calibration records (381,565 records) from the TIMS between January 1, 2016, and December 31, 2017 were available for this analysis. Records with a propane equivalency factor (PEF) result of "0" were deleted, since these records appeared to contain no calibration information, leaving 358,191 records in the dataset. Records for the Austin and El Paso program areas were deleted from the dataset by deleting all analyzers where the NO_x calibration readings were always zero, leaving 269,093 HGB/DFW program area records in the dataset. Finally, an additional 8 records in which the pre-calibration reading for each gas concentration was zero were deleted, leaving 269,085 records in the dataset. Although these records contained no span gas calibration readings, each did include a pass or fail result for the span gas calibration. Some of these records did contain dynamometer calibration information, and some contained a pass or fail result for the leak check. Therefore, these might be records for calibration events that did not include a span gas calibration. However, if that is the case, the analyzer software should not have allowed a pass/fail result to be recorded for the span gas audit.

Figure III-13 through Figure III-26 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 Figure III-17 and Figure III-18. The pre-calibration value of O_2 should be 20.7 percent, corresponding to the O_2 content of ambient air. It was found that analyzers with manufacturer codes of SE, John Bean (JB, manufactured by Snap-On), and Worldwide measured near 20.7 percent O_2 in more than almost all calibrations, while analyzers with the manufacturer code ESP (Environmental System Products) measured less than 3 percent O_2 in almost all calibrations. It may be that ESP 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 percent O_2 than at 20.7 percent 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 fell within the tolerance for that gas type/concentration level.

Figure III-13. Distribution of Difference Between Zero and HC Pre-Calibration Reading

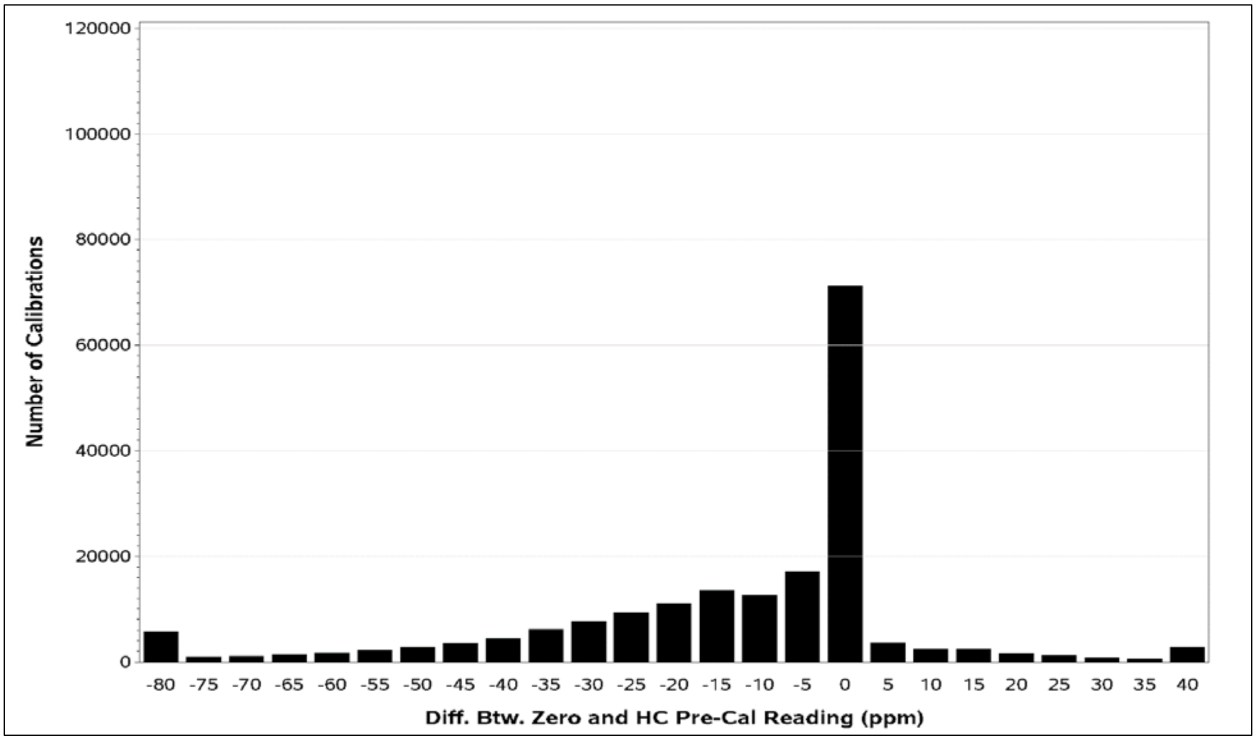


Figure III-14. Distribution of Difference Between Zero and CO Pre-Calibration Reading

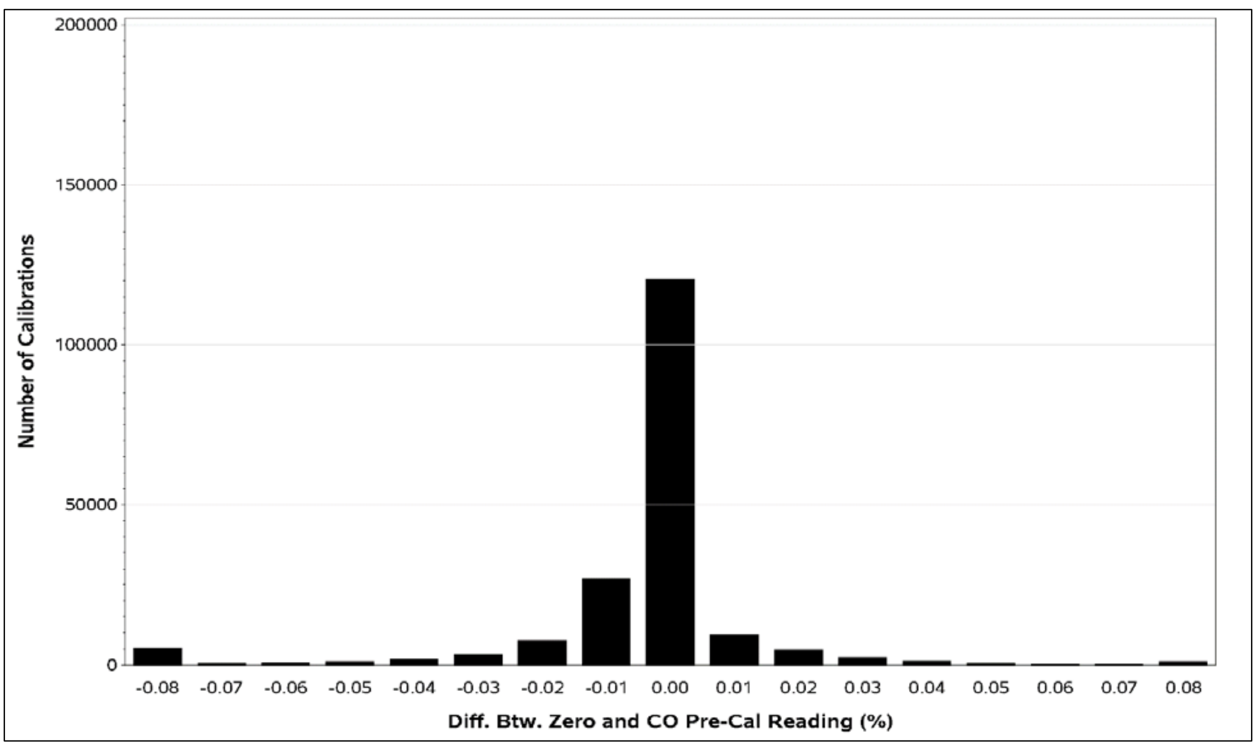


Figure III-15. Distribution of Difference Between Zero and NO_x Pre-Calibration Reading

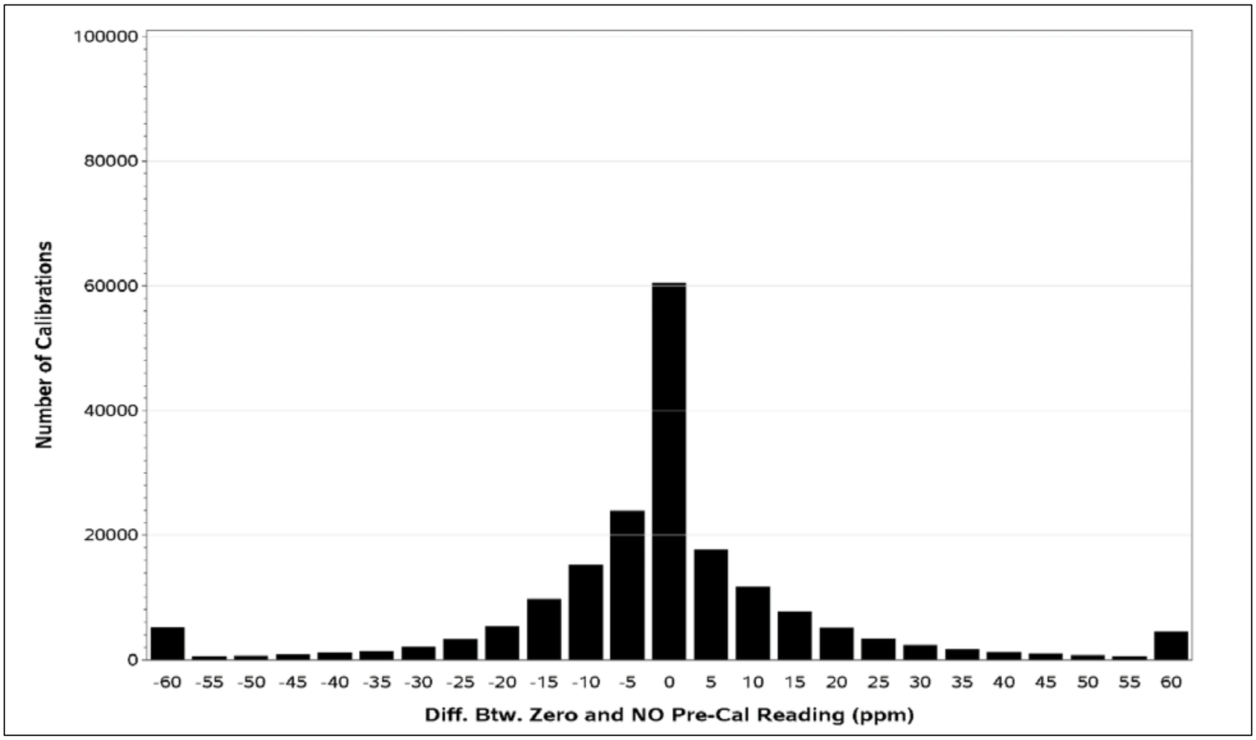


Figure III-16. Distribution of Difference Between Zero and CO_2 Pre-Calibration Reading

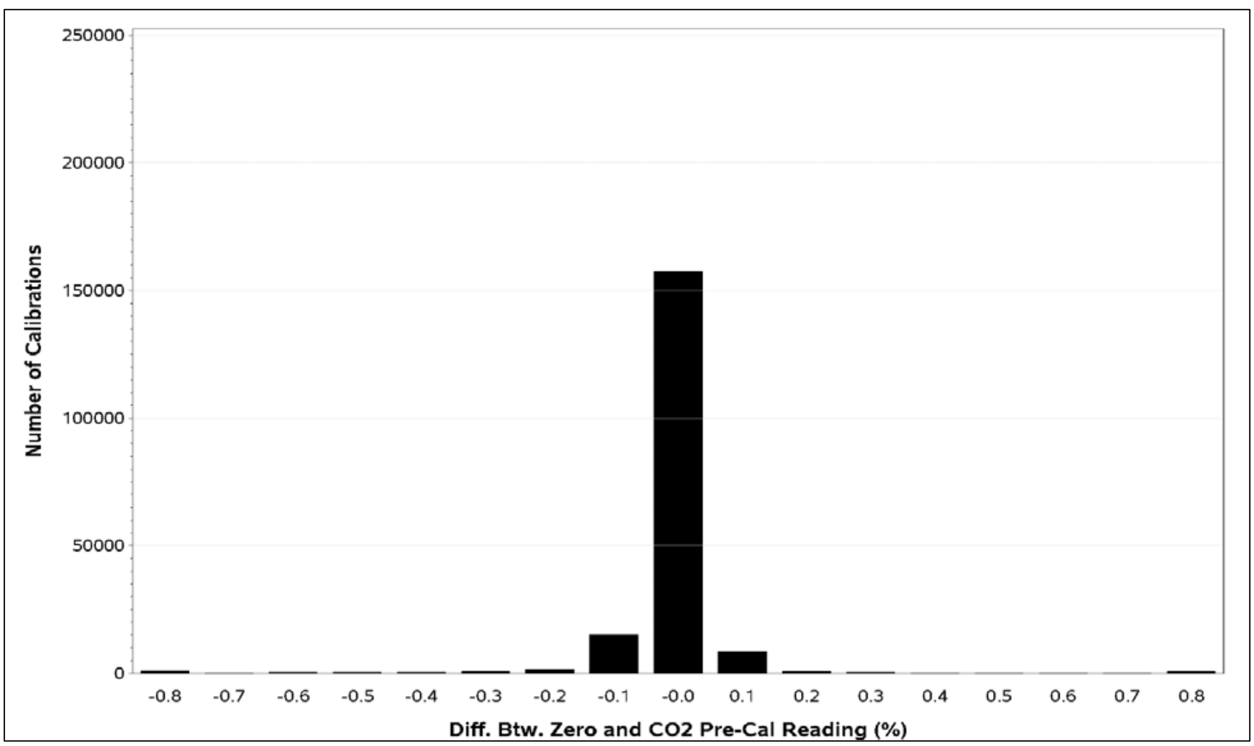


Figure III-17. Distribution of Difference Between Zero and O_2 Pre-Calibration Reading

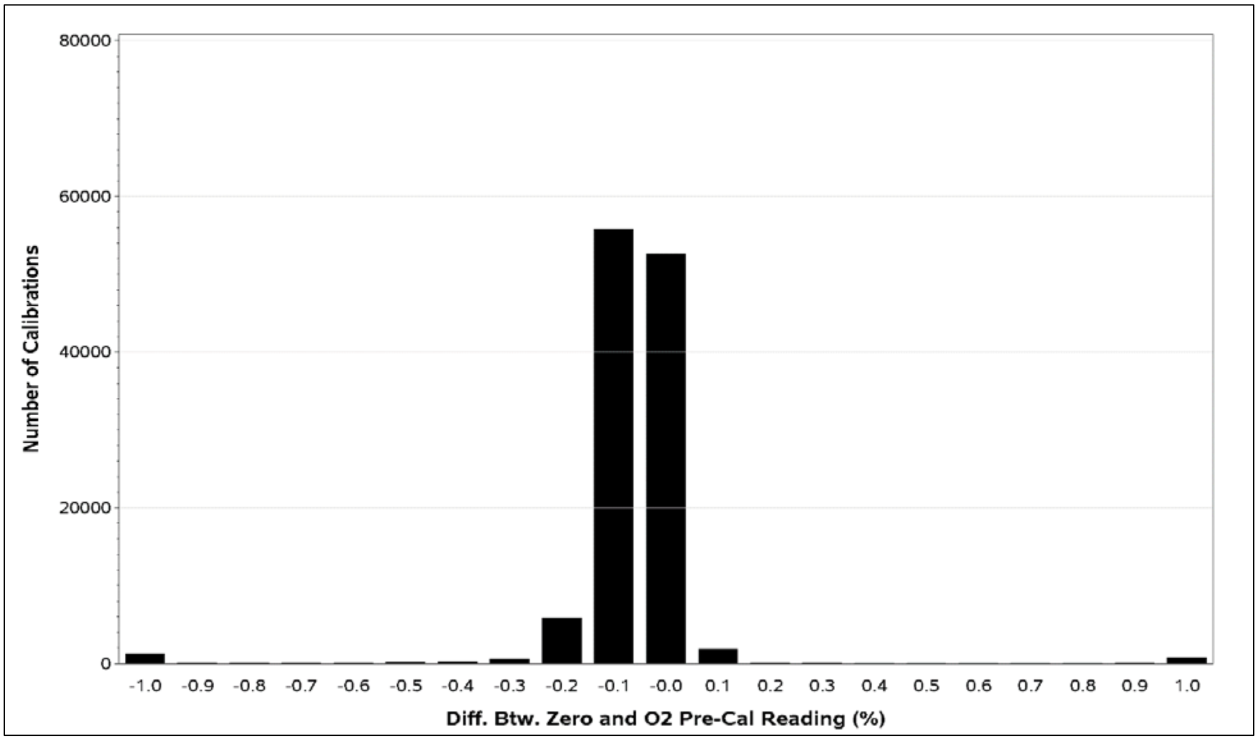


Figure III-18. Distribution of Difference Between 20.7% and O_2 Pre-Calibration Reading

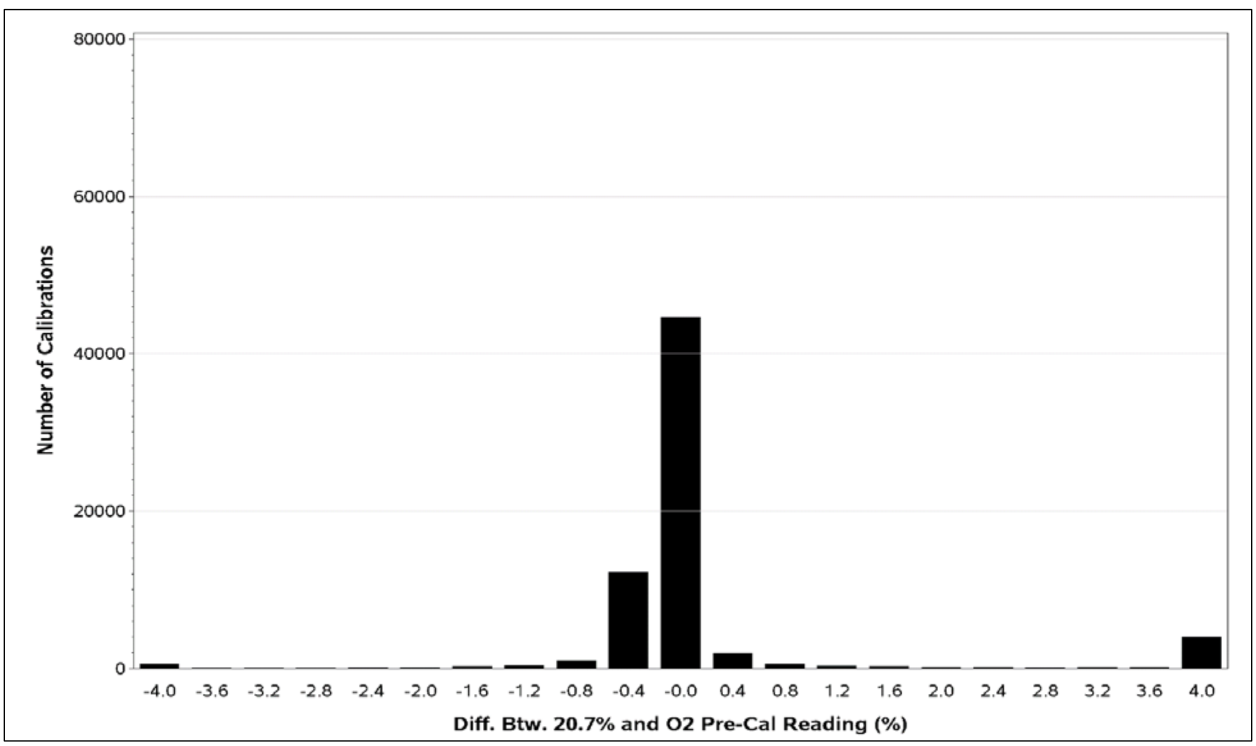


Figure III-19. Distribution of Difference Between Low-Span Bottle and HC Pre-Calibration Reading

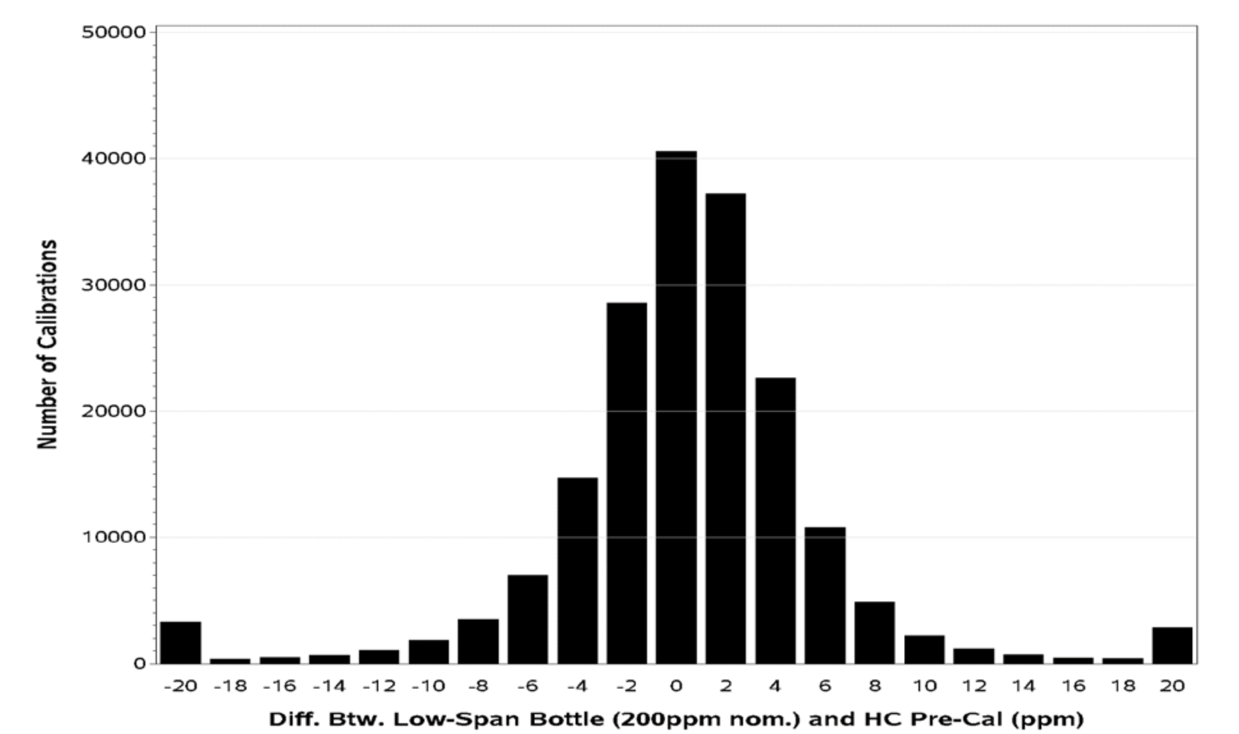


Figure III-20. Distribution of Difference Between Low-Span Bottle and CO Pre-Calibration Reading

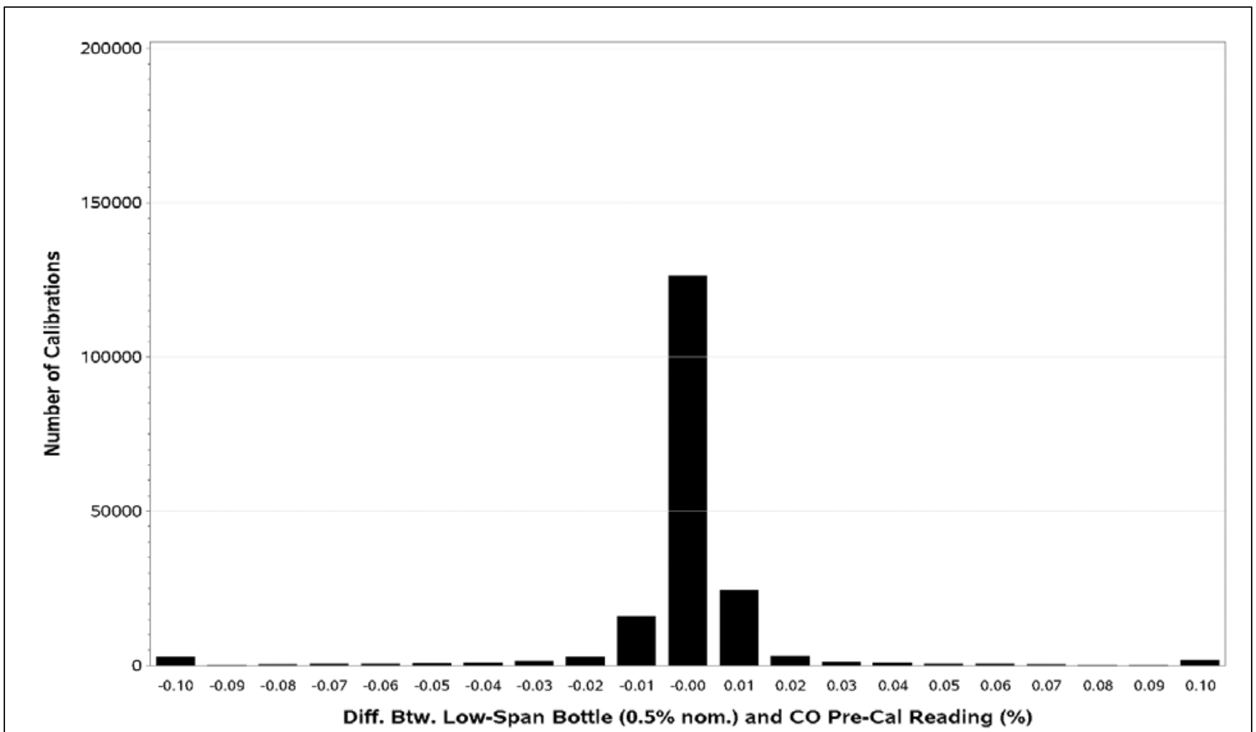


Figure III-21. Distribution of Difference Between Low-Span Bottle and NO_x Pre-Calibration Reading

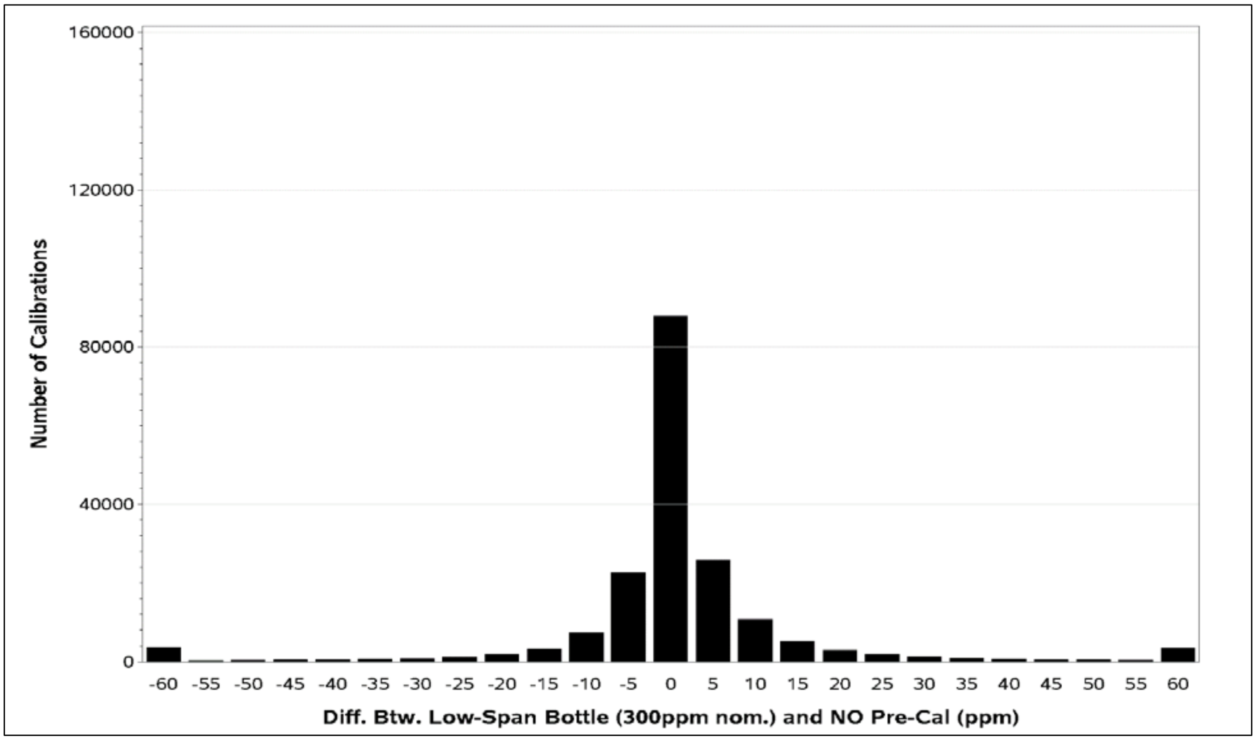


Figure III-22. Distribution of Difference Between Low-Span Bottle and CO_2 Pre-Calibration Reading

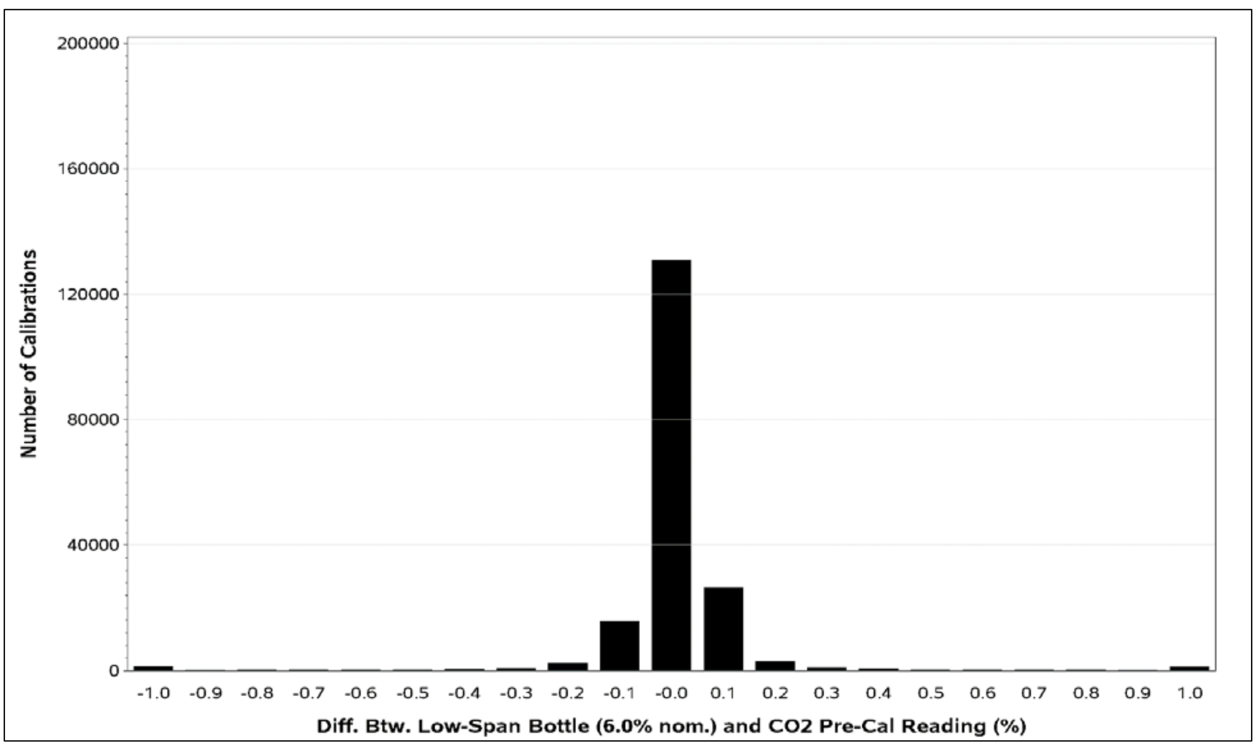


Figure III-23. Distribution of Difference Between Mid-Span Bottle and HC Pre-Calibration Reading

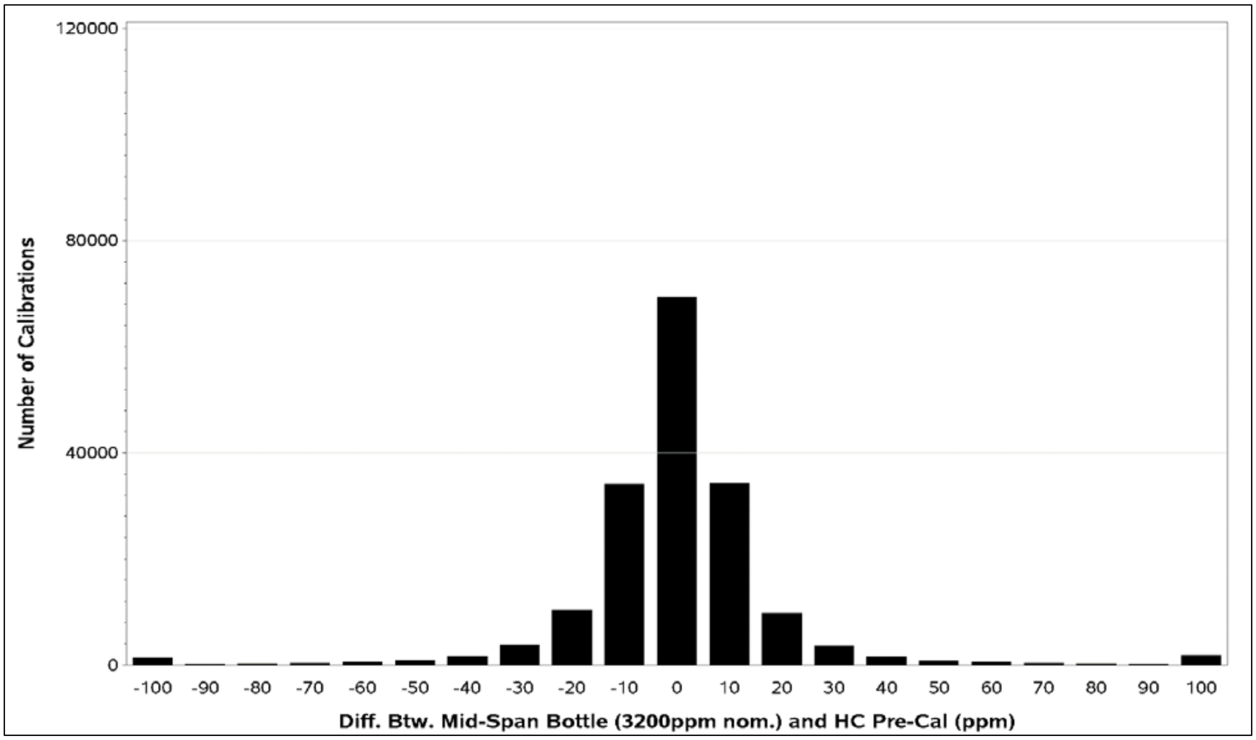


Figure III-24. Distribution of Difference Between Mid-Span Bottle and CO Pre-Calibration Reading

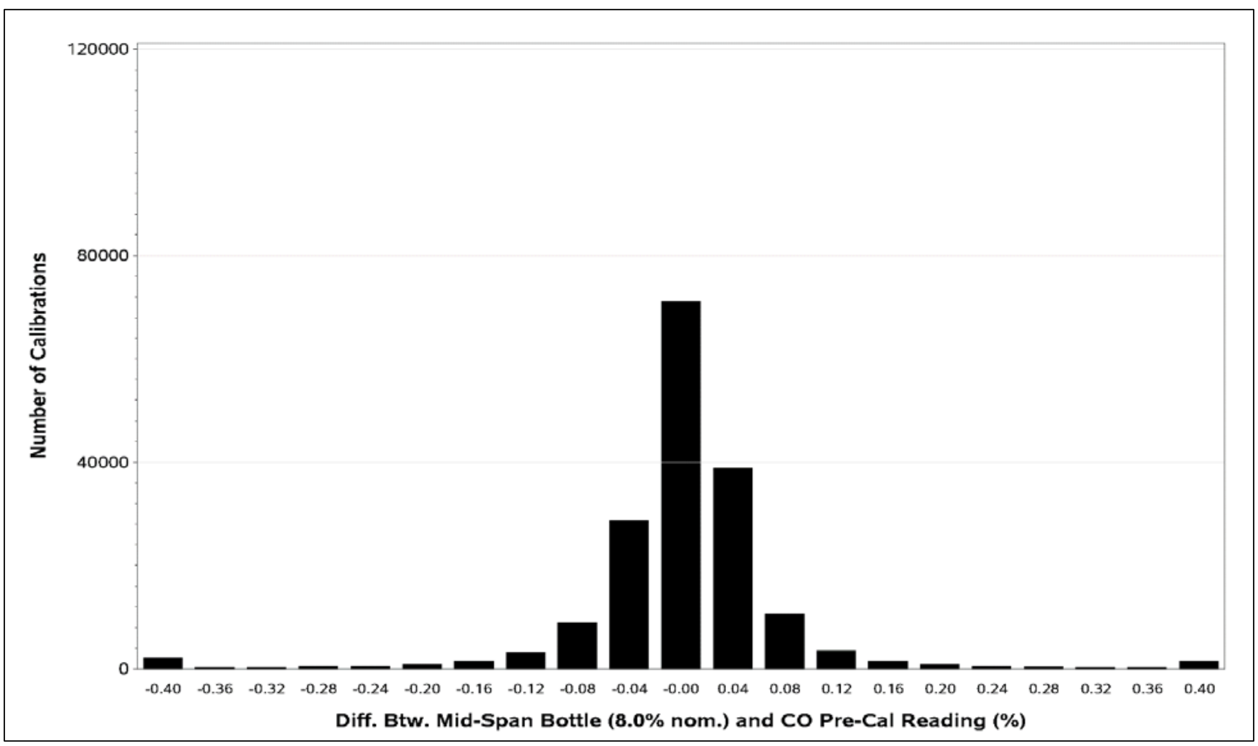


Figure III-25. Distribution of Difference Between Mid-Span Bottle and NO_x Pre-Calibration Reading

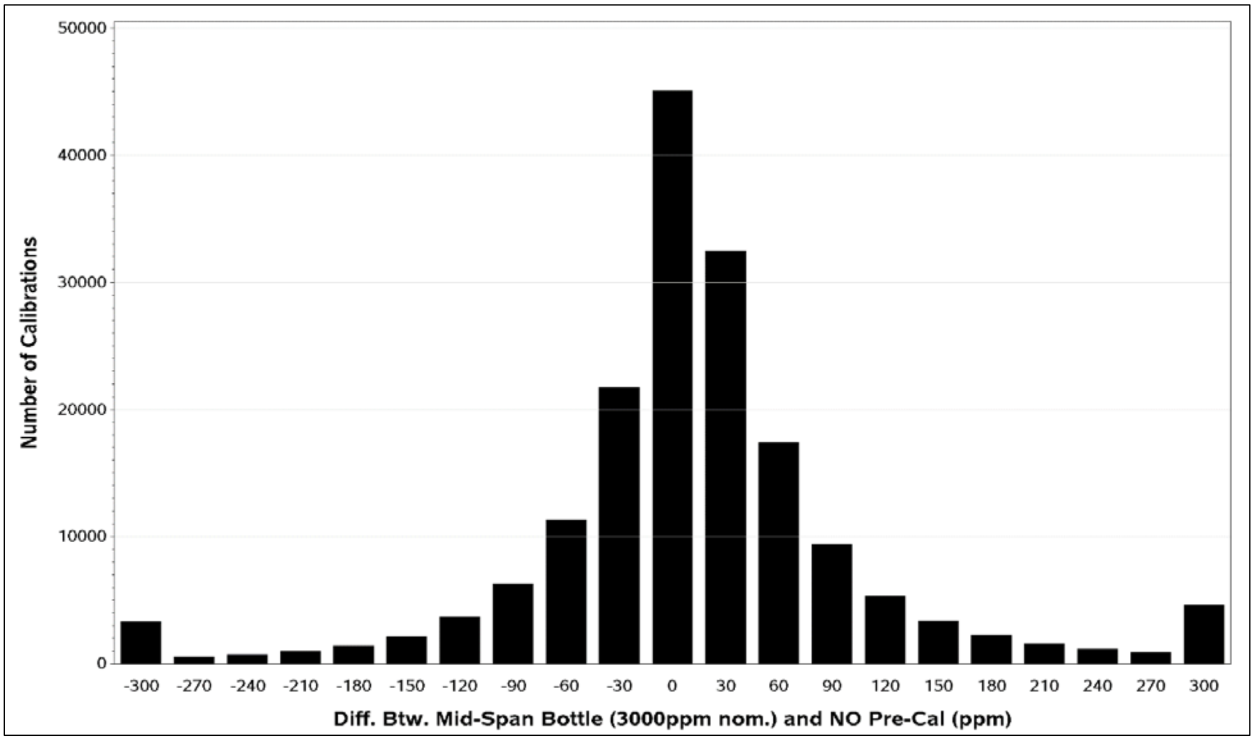


Figure III-26. Distribution of Difference Between Mid-Span Bottle and CO_2 Pre-Calibration Reading

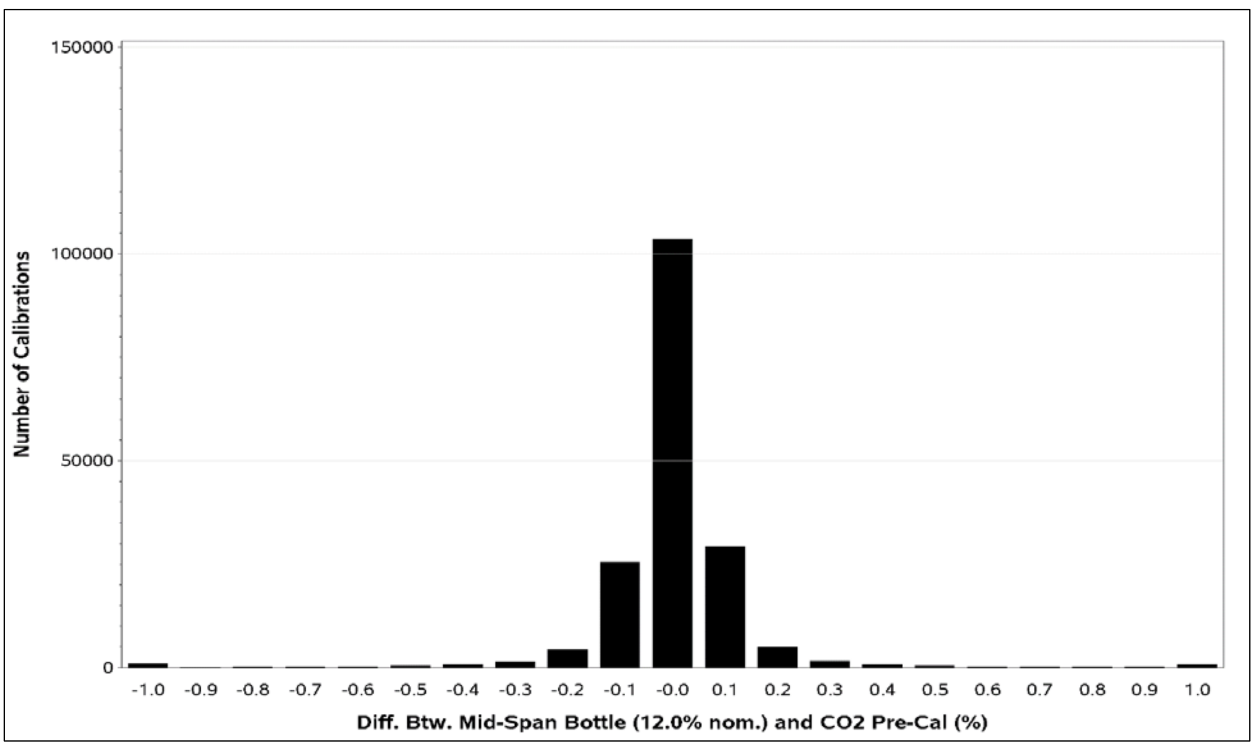


Table III-6 shows the specified value and tolerance for each gas type/concentration level, the total number of pre-calibration records available at that level, the percent of records whose values fell within the tolerance bounds, and finally, the amount of difference from the specified value that would include 90 percent of calibration records (i.e., the 90th percentile).

Note that the number of total record counts vary somewhat by concentration level in Table III-6. About 186,900 records were available at the zero level, 184,000 to 185,000 records at the low-span level, and more than 175,000 at the mid-span level. This variation is likely a result of calibration records with zero pre-calibration values but no low-span or mid-span values.

For almost all gas type/concentration level combinations, more than 85 percent of pre-calibration records fell within the tolerance of the analyzer. The exception is the zero level HC, where only 44 percent of records were within tolerance (the wide distribution can be seen in Figure III-13 as well). This indicates that results for more than 85 percent 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 III-6. Number and Percent of Pre-Calibration Records Occurring Within Analyzer Tolerance

Gas	Specification	Total Number of Pre-Cal Records	Within Tolerance		90th Percentile
			N	%	
Zero Gas					
HC (ppm)	0 ± 4	186,979	82,821	44.3	46
CO (%)	0.00 ± 0.02	186,979	168,795	90.3	0.02
NOx (ppm)	0 ± 25	186,979	161,049	86.1	33
CO_2 (%)	0.0 ± 0.3	186,979	184,330	98.6	0.1
O_2 (%)	0.0 ± 0.1	119,829	110,257	92.0	0.1
O_2 (%)	20.7 ± 1.04	67,150	60,514	90.1	1
Low-Span Gas					
HC (ppm)	200 ± 6	185,116	158,572	85.7	8
CO (%)	0.50 ± 0.02	185,115	166,812	90.1	0.01
NOx (ppm)	300 ± 25	184,060	169,225	91.9	20
CO_2 (%)	6.0 ± 0.3	185,111	179,909	97.2	0.1
Mid-Span Gas					
HC (ppm)	3200 ± 160	175,965	174,202	99.0	26
CO (%)	8.00 ± 0.24	175,984	170,009	96.6	0.1
NOx (ppm)	3000 ± 150	175,409	148,830	84.8	164
CO_2 (%)	12.00 ± 0.36	175,986	170,692	97.0	0.1

Analyzer Dilution Correction Factors

For every ASM or TSI emissions test, a dilution correction factor (DCF) based on the measured CO and CO_2 concentration is calculated. DCFs can also be calculated based on the measured O_2 concentration. The DCFs from these two separate sources of tailpipe emissions should be within agreement with a relatively small tolerance. For 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 emissions measurement is in error but does indicate that something is wrong with one of the CO, CO_2, or O_2 measurements used to calculate the DCF. Unless all three of these pollutants are in agreement with respect to their corresponding DCFs, the HC, CO, and NO_x measurements reported by the instrument are in question.

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.

Although the CO/CO_2 DCFs are the official DCFs used for the emissions test, 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 DCFs, the resulting HC, CO, and NO_x measurements reported by the instrument are in question.

Background

Assuming stoichiometric combustion of gasoline, an exhaust DCF 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 percent, the exhaust oxygen measurement can also be used to estimate dilution in the exhaust. A DCF 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 percent O_2. Typically, new vehicles with no exhaust system leaks and operating at stoichiometric air/fuel ratio have 0.0 percent 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 3].

Results

For this analysis, vehicle inspection records from the TIMS for vehicles tested in the DFW and HGB program areas were used. Results for 276,566 inspections of gasoline-fueled vehicles that received either the ASM or TSI test were available. Any records with flags that indicated the inspection had been aborted, timed out, or ended due to a dilution condition were deleted.

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 230,196 records for the ASM2525 test condition, 230,229 records for the ASM5015 test condition, 46,150 records for the low-idle TSI inspection, and 46,227 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 III-27 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 Figure III-28, Figure III-29, and Figure III-30. 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 two ASM plots also show a smaller horizontal ray (DCF CO/CO_2 ≈1 while DCFO_2 increases) and a vertical ray (DCF O_2≈1 while DCF CO/CO_2 increases). 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 which follow.

Figure III-27. Comparison of ASM2525 DCF CO/CO_2 and DCF O_2

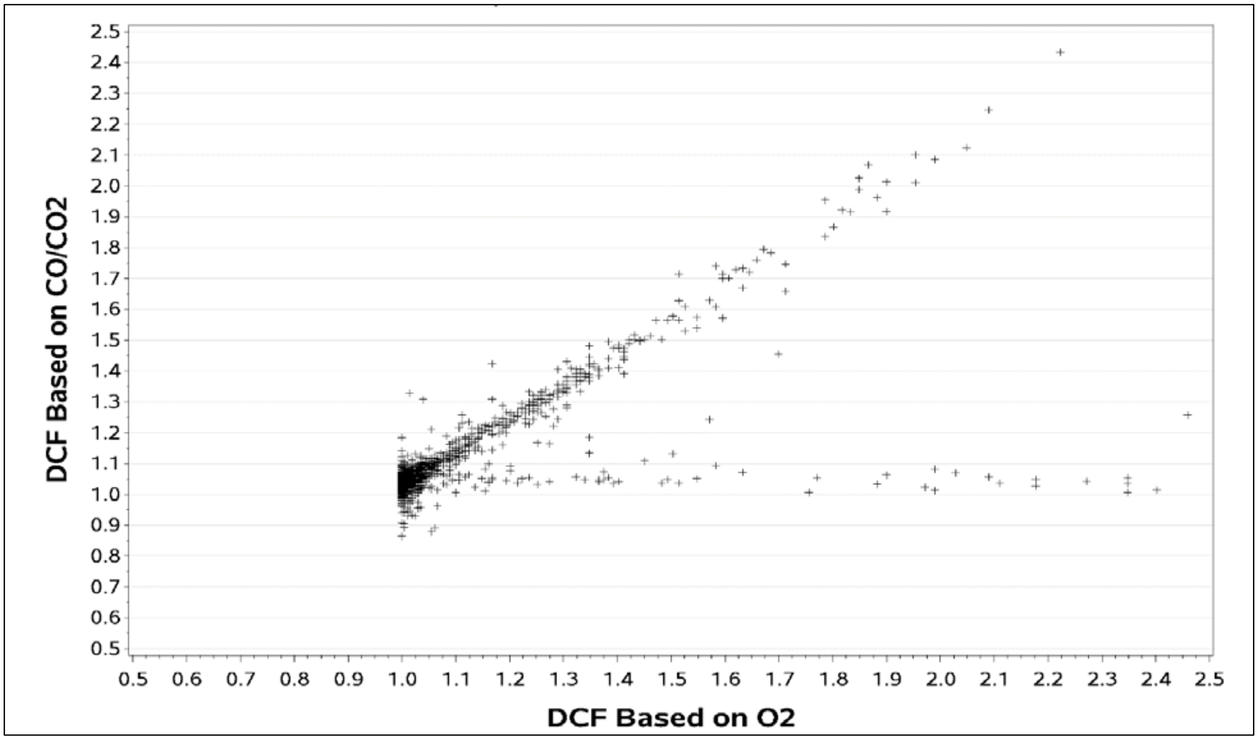


Figure III-28. Comparison of ASM5015 DCF CO/CO_2 and DCF O_2

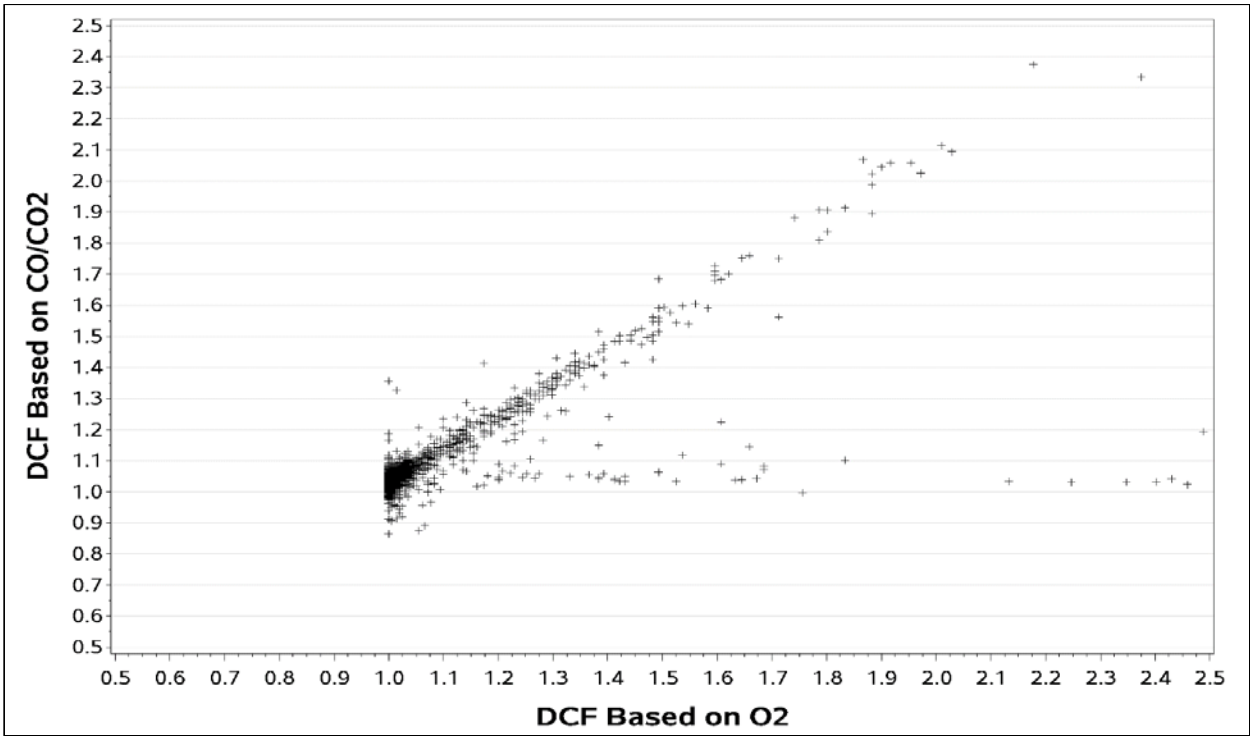


Figure III-29. Comparison of Low-Speed Idle TSI DCF CO/CO_2 and DCF O_2

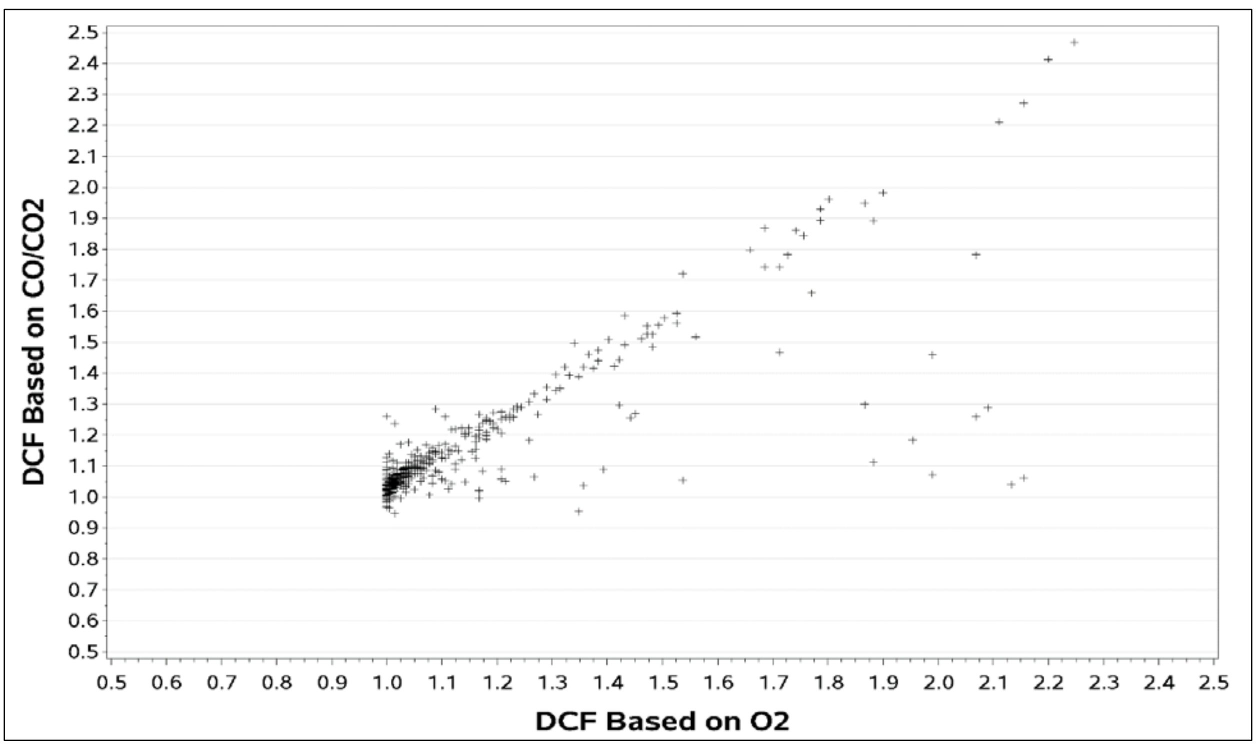
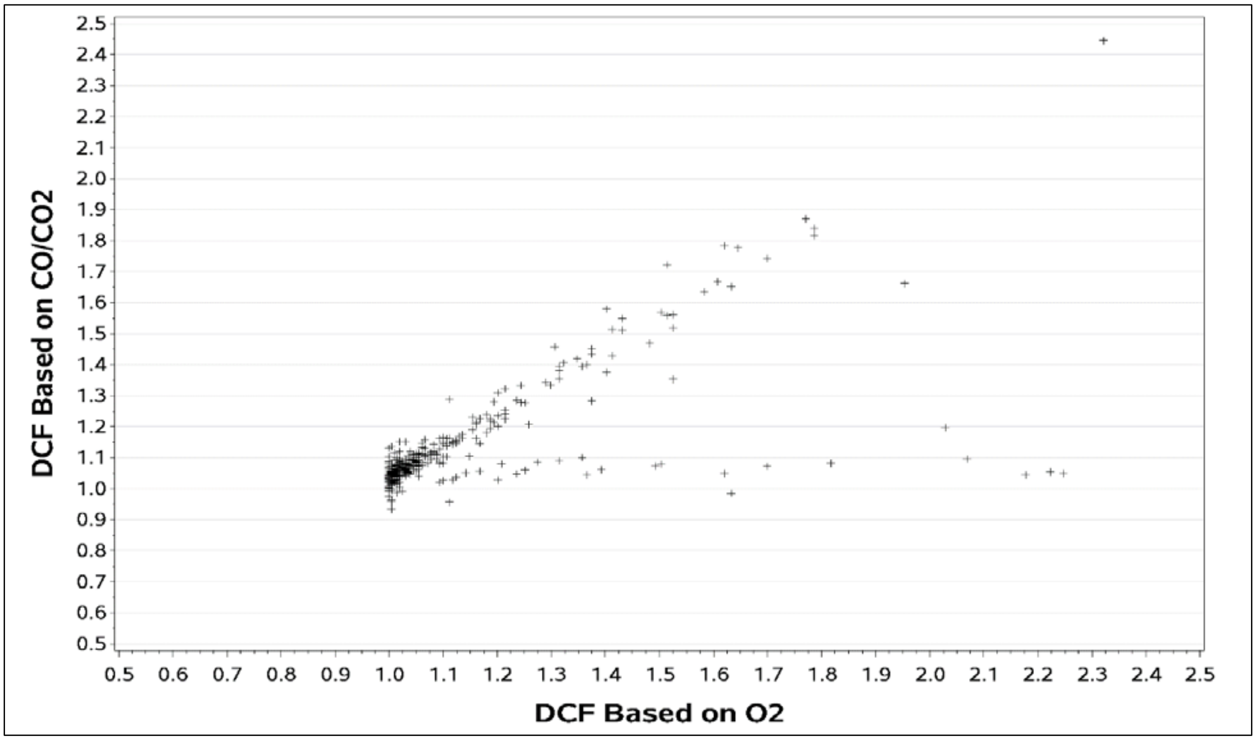


Figure III-30. Comparison of High-Speed Idle TSI DCF CO/CO_2 and DCF O_2



The information presented graphically in Figure III-27 through Figure III-30 is quantified in Table III-7. 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 III-7 that for the ASM inspection, 86 percent of records have a difference of less than 0.14. For the TSI inspection records, 83 percent have a difference of less than 0.14.

Table III-7. Distribution of Differences Between DCFCO/CO_2 and DCFO2

DCF Difference	ASM2525		ASM5015		TSI Low		TSI High	
<0.01	17,244	7.49%	19,322	8.39%	3,000	6.50%	2,604	5.63%
0.01-0.14	181,891	79.02%	179,476	77.96%	35,650	77.25%	36,388	78.72%
0.14-0.3	3,781	1.64%	3,709	1.61%	1,313	2.85%	1,021	2.21%
0.3-1.0	3,062	1.33%	3,099	1.35%	1,061	2.30%	1,047	2.26%
1-10	6,304	2.74%	6,456	2.80%	1,420	3.08%	1,394	3.02%
>10	17,914	7.78%	18,167	7.89%	3,706	8.03%	3,773	8.16%
Total	**230,196**	**100.00%**	**230,229**	**100.00%**	**46,150**	**100.00%**	**46,227**	**100.00%**

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 III-8. 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 III-8 that agreement was very good; more than 98 percent of records had a difference of less than 0.14.

Table III-8. Distribution of Differences Between ERG DCF CO/CO_2 and TIMS DCF CO/CO_2

DCF Difference	ASM2525		ASM5015	
<0.01	211,928	92.06%	208,415	90.53%
0.01-0.14	15,863	6.89%	19,258	8.36%
0.14-0.3	680	0.30%	716	0.31%
0.3-1.0	354	0.15%	447	0.19%
1-10	535	0.23%	578	0.25%
>10	836	0.36%	815	0.35%
Total	**230,196**	**100.00%**	**230,229**	**100.00%**

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, as shown in Table III-9. The ESP and Worldwide rates of differences of less than 0.14 are 91-96 percent, while the JB and SE rates of differences of less than 0.14 are much lower (19 percent and 4 percent, respectively). This is probably due to erroneous O_2 concentrations for these manufacturer's analyzers, as discussed in the following section.

Table III-9. Distribution of Differences Between DCF CO/CO_2 and DCF O_2 by Analyzer Manufacturer, for ASM5015 Inspections

DCF Difference	ESP		JB		SE		WW	
<0.01	14,449	9.67%	0	0.00%	56	0.33%	4,817	7.59%
0.01-0.14	122,218	81.76%	89	19.35%	668	3.97%	56,501	89.03%
0.14-0.3	2,507	1.68%	0	0.00%	188	1.12%	1,014	1.60%
0.3-1.0	2,149	1.44%	0	0.00%	543	3.23%	407	0.64%
1-10	3,182	2.13%	6	1.30%	3,057	18.17%	211	0.33%
>10	4,980	3.33%	365	79.35%	12,309	73.18%	513	0.81%
Total	**149,485**	**100.00%**	**460**	**100.00%**	**16,821**	**100.00%**	**63,463**	**100.00%**

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 percent O_2, while the ambient air concentration of O_2 is approximately 20.9 percent. The percent of otherwise valid inspection records that included O_2 concentrations greater than 20.5 percent is shown in Table III-10, for each test condition. From the table, roughly 6 percent of ASM and 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 values to have a very high (or undefined, when O_2 is equal to exactly 20.9 percent) value.

Table III-10. Number and Percent of Suspicious O_2 Concentrations by Test Mode

	ASM2525		ASM5015		TSI Low		TSI High	
O_2 >20.5%	13,968	6.07%	14,164	6.15%	2,954	6.40%	3,024	6.54%
O_2 <20.5%	216,228	93.93%	216,065	93.85%	43,199	93.60%	43,206	93.46%
Total	230,196	100.00%	230,229	100.00%	46,153	100.00%	46,230	100.00%

It was also found that the rate of suspicious O_2 concentrations was much higher for the JB and SE analyzer manufacturers than for the other two, as shown in Table III-11. The ESP and Worldwide analyzers were responsible for 90 percent of inspection records, but only approximately 3 percent of suspicious O_2 concentrations (4,286 of 14,164 tests with O_2>20.5 percent).

Table III-11. Number and Percent of Suspicious O_2 Concentrations (O_2 >20.5%), by Analyzer Manufacturer, for ASM5015

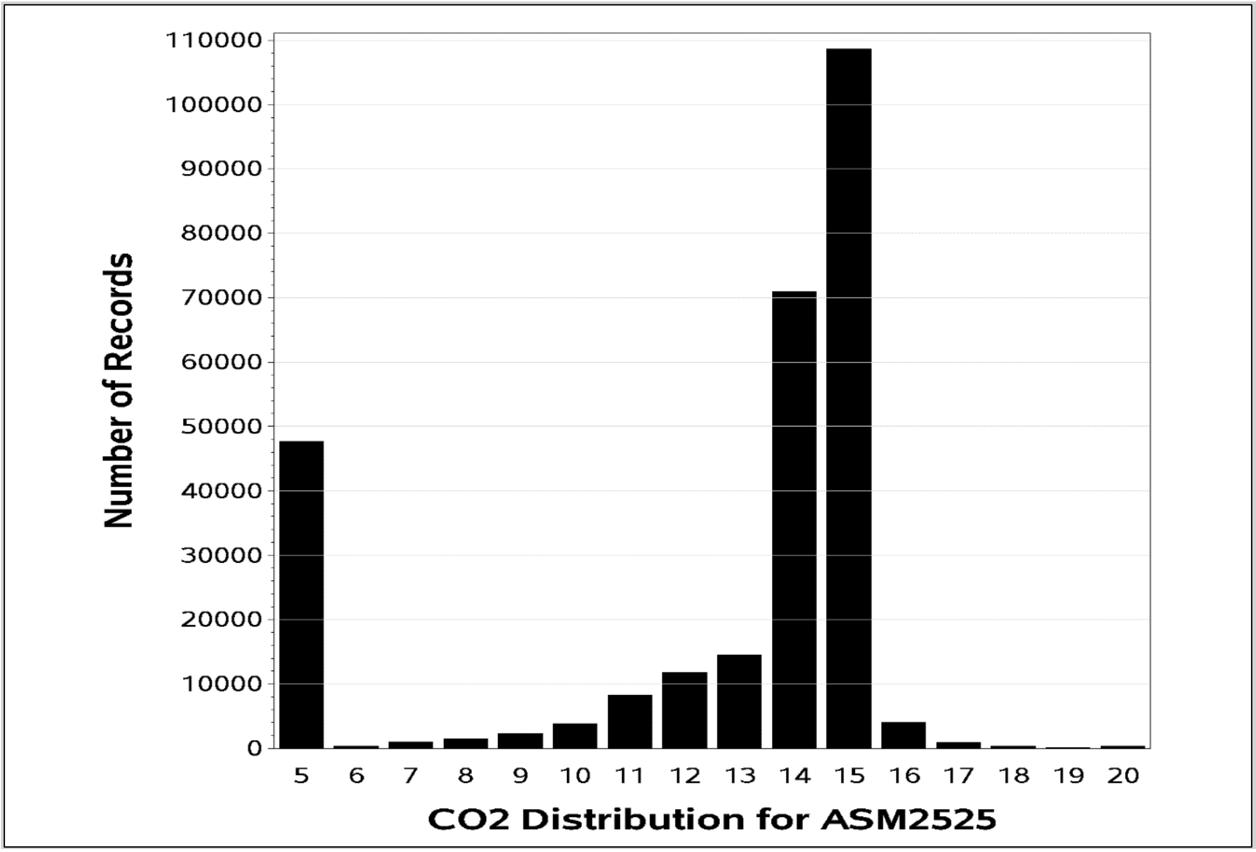
Analyzer Mfg. ID	O_2 >20.5%	O_2 <20.5%	Total
ESP	3,876	145,609	149,485
	2.6%	97.4%	100.0%
JB	291	169	460
	63.3%	36.7%	100.0%
SE	9,587	7,234	16,821
	57.0%	43.0%	100.0%
WW	410	63,053	63,463
	0.6%	99.4%	100.0%
Totals	**14,164**	**216,065**	**230,229**
	6.2%	**93.8%**	**100.0%**

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 CO_2 concentration for stoichiometric combustion and no air-in-leakage should be 15.6 percent CO_2. CO_2 values lower than 15.6 percent can occur because of air-in-leakage or because some of the carbon is in the form of CO or HC, but any CO_2 values higher than 15.6 percent would be cause for suspicion as that is not theoretically possible.

The distribution of CO_2 values for the ASM2525 inspection is shown in Figure III-31. It can be seen from the figure that the CO_2 values are concentrated around 15 percent, as expected. However, a small fraction of CO_2 values exceeds 16.5 percent, for 0.5 percent of ASM2525 inspection records. These records were investigated further.

Figure III-31. Distribution of CO_2 Values for ASM2525 Inspection



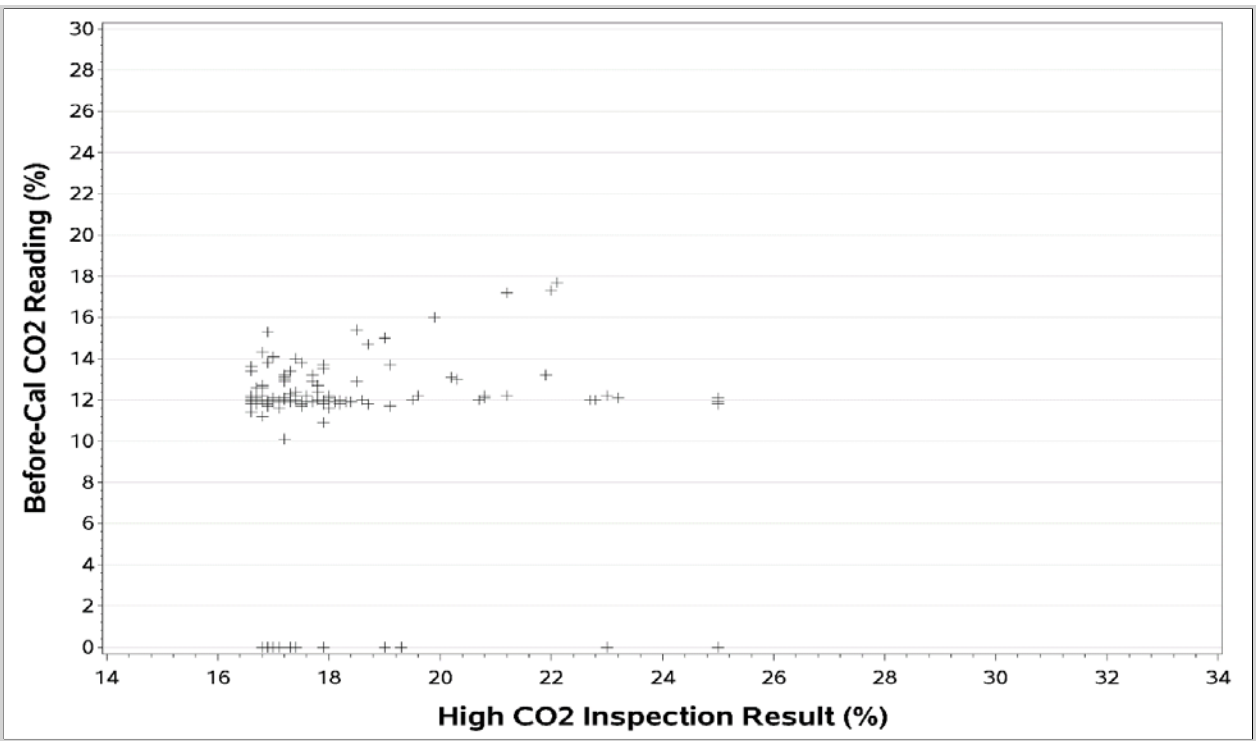
The rate of high CO_2 concentrations was found to vary slightly among the different analyzer manufacturers, as shown in Table III-12, although the differences were not as pronounced as those found for the suspicious O_2 concentrations.

Table III-12. Number and Percent of Suspicious CO_2 Concentrations (CO_2 >16.5%), by Analyzer Manufacturer, for ASM2525

Analyzer Mfg. ID	CO_2 >16.5%	CO_2 <16.5%	Total
ESP	904	177,719	178,623
	0.5%	99.5%	100.0%
JB	0	553	553
	0.0%	100.0%	100.0%
SE	47	19,991	20,038
	0.2%	99.8%	100.0%
WW	503	76,649	77,152
	0.7%	99.3%	100.0%

The high-CO_2 inspection records were matched to calibration records (described in Section III.D) 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 III-32, 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 percent for the mid-span bottle gas), so analyzer drift does not seem to be responsible for the high CO_2 results.

Figure III-32. High CO_2 Inspection Results Compared to CO_2 Pre-Calibration Readings



One consequence of recording a CO_2 concentration greater than 15.6 percent is that the CO/CO_2-based DCF 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 Figure III-27 through Figure III-30. For the ASM2525 inspection, 51 records (0.01 percent of total inspection records) have DCF CO/CO_2 between 0 and 0.55, and

5,224 records have DCF CO/CO_2 between 0.55 and 0.95 (1.2 percent of total inspection records).

Extra Vertical and Horizontal Rays

It was noted above that Figure III-27 and Figure III-28 with the CO/CO_2-based DCF plotted against the O_2-based DCF for ASM inspections, 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 did not 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 Figure III-33 through Figure III-35.

Figure III-33 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 percent 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. Figure III-34 and Figure III-35 show that the distributions of CO_2 and CO concentration for the horizontal ray are very similar to the distributions for the diagonal ray.

In contrast, the vertical ray (comprised of records with high DCF CO/CO_2 and DCF O_2 near 1) is characterized by lower CO_2 concentrations (Figure III-34) and similar O_2 concentrations (Figure III-33) compared to the diagonal ray. The CO_2 concentration for records in the vertical ray was almost always less than 10 percent, instead of the 15 percent seen for the diagonal ray. The CO concentration for records in the vertical ray was similar to that of records in the diagonal ray (Figure III-35). Overall, Figure III-33, Figure III-34, and Figure III-35 indicate the records in each ray were systematically different from the records in each other ray.

Figure III-33. Distribution of O_2 Concentrations, by Ray

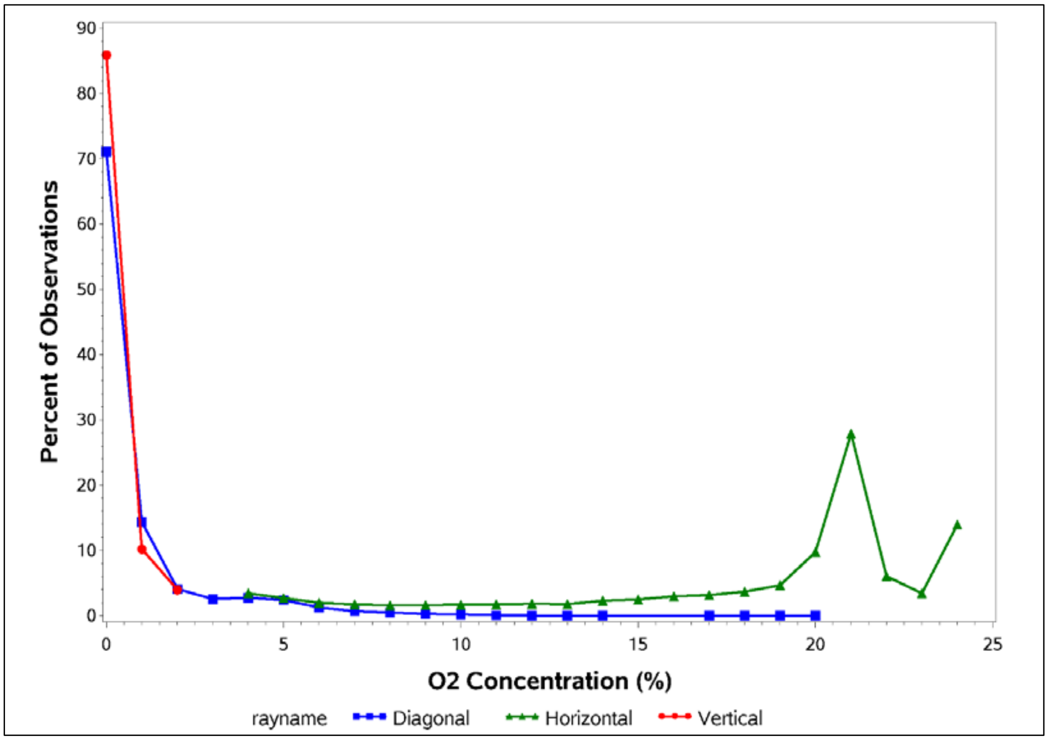


Figure III-34. Distribution of CO_2 Concentrations, by Ray

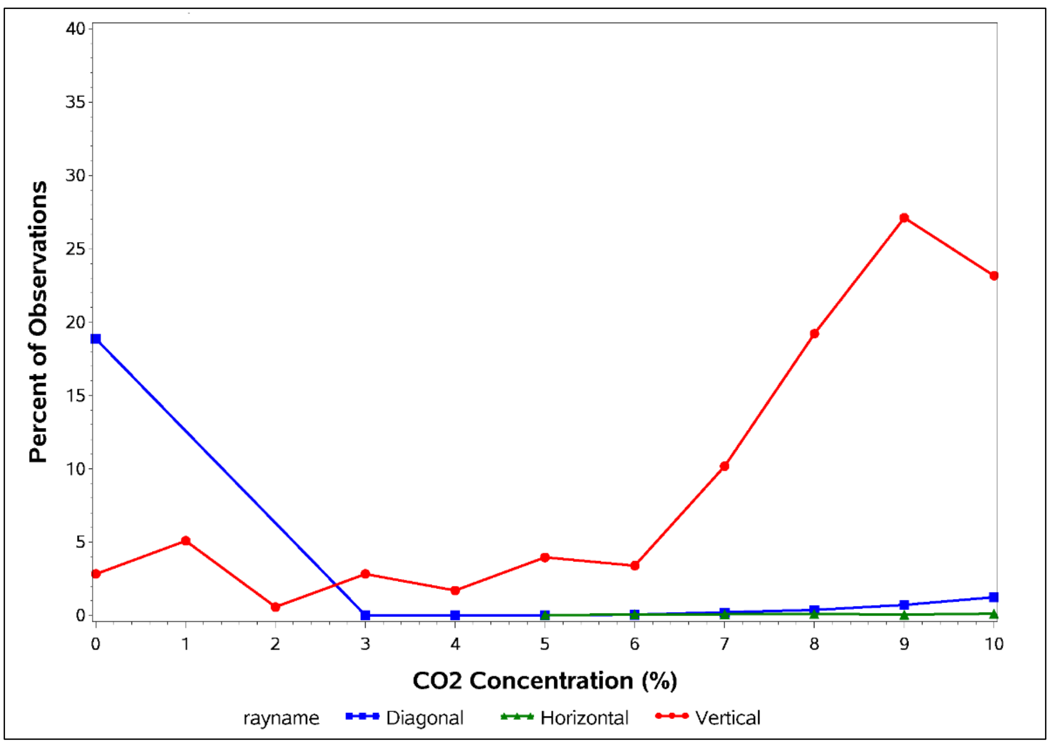
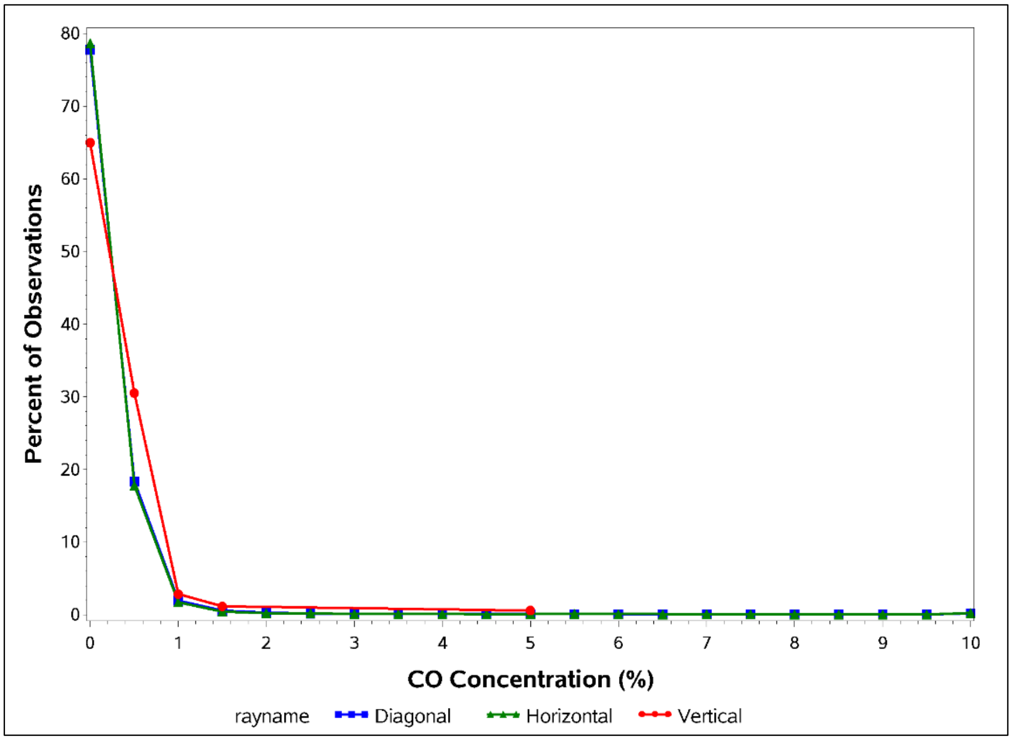


Figure III-35. Distribution of CO Concentrations, by Ray



The distribution of records into each ray-group was tabulated by analyzer manufacturer, as shown in Table III-13 below. As expected, the manufacturers represented by codes JB and SE contributed a large portion of the records for the horizontal ray. In Figure III-33, it was seen that this ray includes most of the records with O_2 concentrations near 20.9 percent (ambient concentration), and in Table III-11 it was seen that the JB and SE manufacturers contributed the majority of the records with the high O_2 concentrations. Table III-13 also shows that the JB and SE analyzers were responsible for a greater proportion of the records in the "Other" column than were the ESP and Worldwide analyzers. The "Other" group includes all records that did not 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.

Table III-13. Number and Percent of Records in Each Ray by Analyzer Manufacturer, for ASM2525

Analyzer Mfg. ID	Vertical	Horizontal	Diagonal	Other	Total
ESP	159	6,825	166,064	5,640	178,688
	0.09%	3.82%	92.94%	3.16%	100%
JB	0	235	182	136	553
	0.00%	42.50%	32.91%	24.59%	100%
SE	11	11,643	3,995	4,393	20,042
	0.05%	58.09%	19.93%	21.92%	100%
WW	64	739	75,123	1,333	77,259
	0.01%	0.96%	97.31%	1.73%	100%

Analyzer Gas Audits

One component of a station equipment audit is the emissions analyzer gas audit. This audit is performed by independent auditors using bottled audit gases (independent of the station's calibration gases), and the gas is introduced by the auditor at the tailpipe sampling probe rather than directly through 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 sample transport line 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.

Bottled gases containing zero gas and blends of HC, CO, NO_X, and CO_2 at low and mid-span concentration levels are used in a gas audit. The analyzer specification requires that the measured pollutant concentrations fall within 5.5 percent of the labeled (actual) 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 III-14 (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 percent from the nominal values, so the labeled bottle gas values are recorded in the analyzer and transmitted to the TIMS for each audit.

Table III-14. Bottle Gas Concentrations for Low and Mid Span Audits

Gas	Low Span Nominal Concentration	Mid Span Nominal Concentration
HC (ppm)	200	3,200
CO (%)	0.5	8.0
NO_X (ppm)	300	3,000
CO_2 (%)	6.0	12.0

The Texas SIP requires that each analyzer be audited at least twice per year. For the two-year dataset used for this analysis, this should result in an average of 4 audits per analyzer. A frequency distribution of the number of audits per analyzer is shown in

Table III-15. As can be seen from the table, 1,331 of the 1,598 analyzers, or approximately 83 percent, received 4 or more audits and 94 percent received 2 or more audits. Ninety percent of the analyzers with fewer than 4 audits were enrolled in the TIMS by January 1, 2016. Some stations may not have been operating the entire period, so it may have been appropriate for them to only receive a few audits. Many of the analyzers received more than four audits; in fact, about 30 percent of the analyzers received eight 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 III-15. Number of Gas Audits per Analyzer Over a Two-Year Period

Number of Audits	Number of Analyzers	Percent of Analyzers
1	91	5.7%
2	80	5.0%
3	96	6.0%
4	118	7.4%
5	143	8.9%
6	185	11.6%
7	186	11.6%
8	212	13.3%
More than 8	487	30.5%
Total	**1,598**	**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 percent of the labeled bottle gas value:

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

The distribution of percentage differences between readings and bottle gas values is shown in Figure III-36 through Figure III-43 for CO, HC, CO_2, and NO_X, at the low- and mid-span levels. In almost all of the figures, the vast majority of readings fall between ± 4 percent of the labeled gas values. The main exceptions were the low-span HC, with a somewhat wider spread, and the low- and mid-span NO_X, which were both biased toward low readings.

Figure III-36. Percent Difference Between Reading and Bottle Gas, Low-Span CO

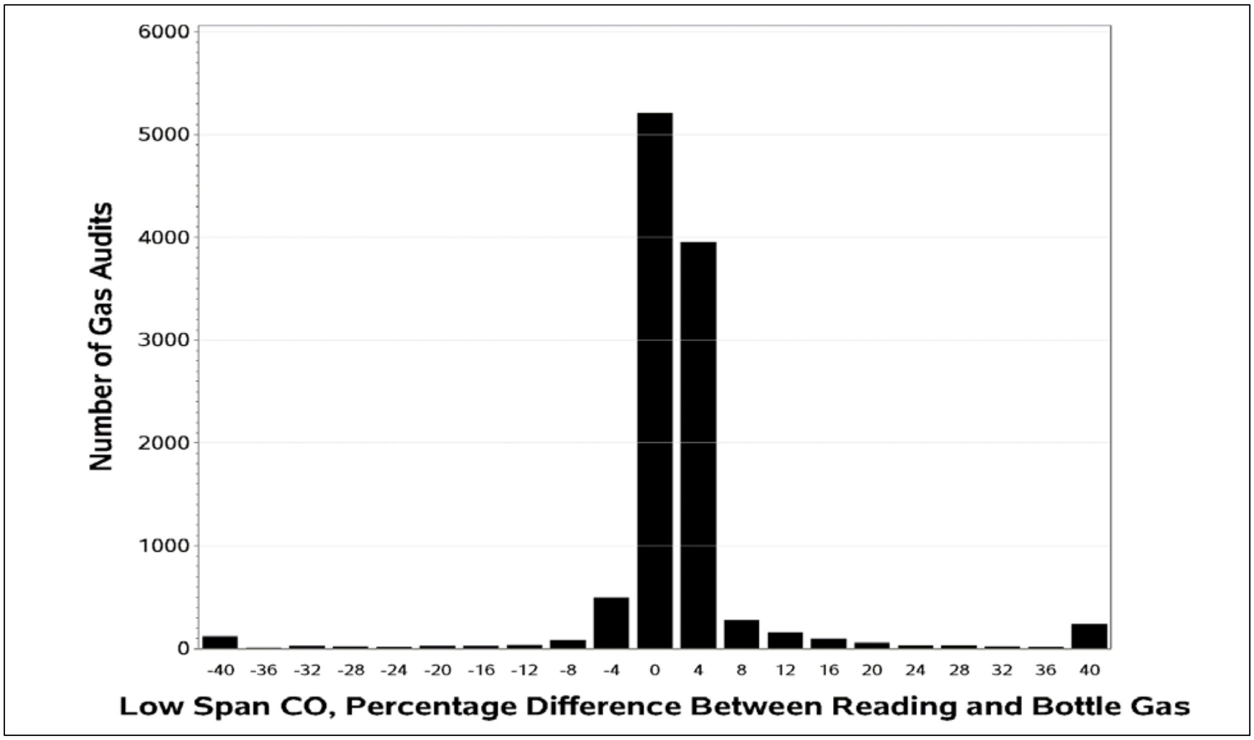


Figure III-37. Percent Difference Between Reading and Bottle Gas, Low-Span HC

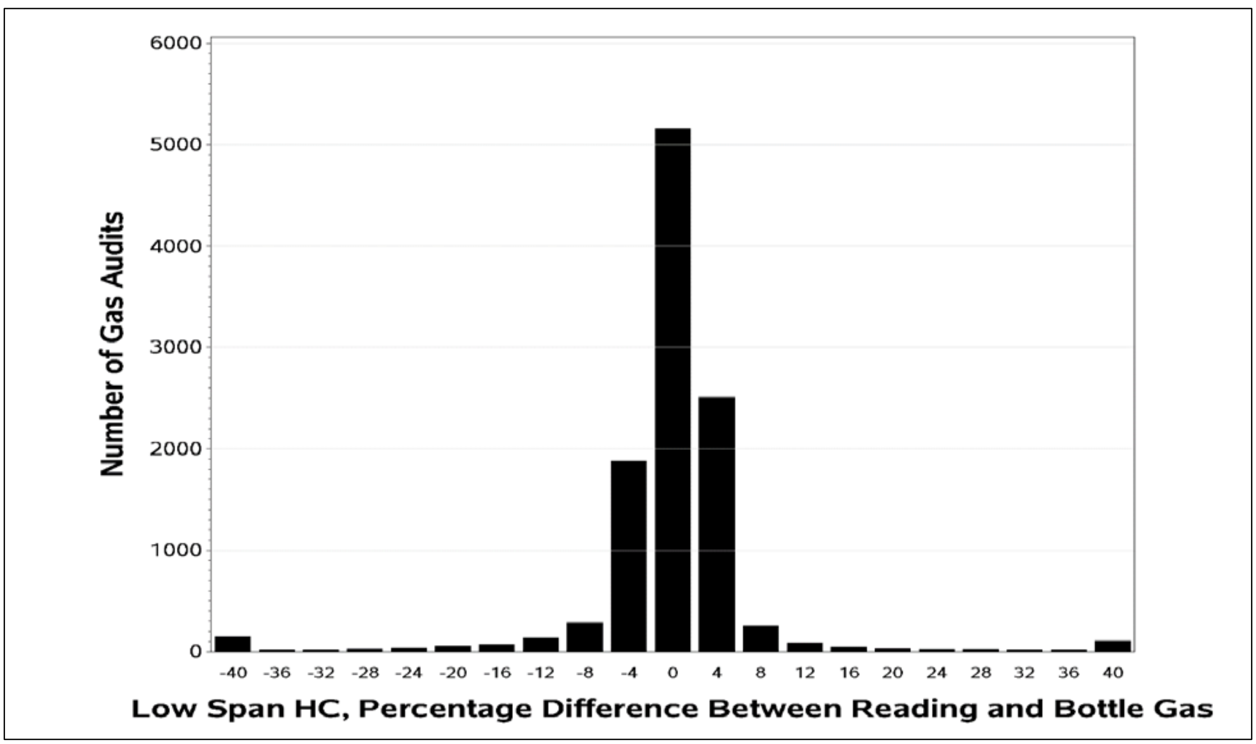


Figure III-38. Percent Difference Between Reading and Bottle Gas, Low-Span CO_2

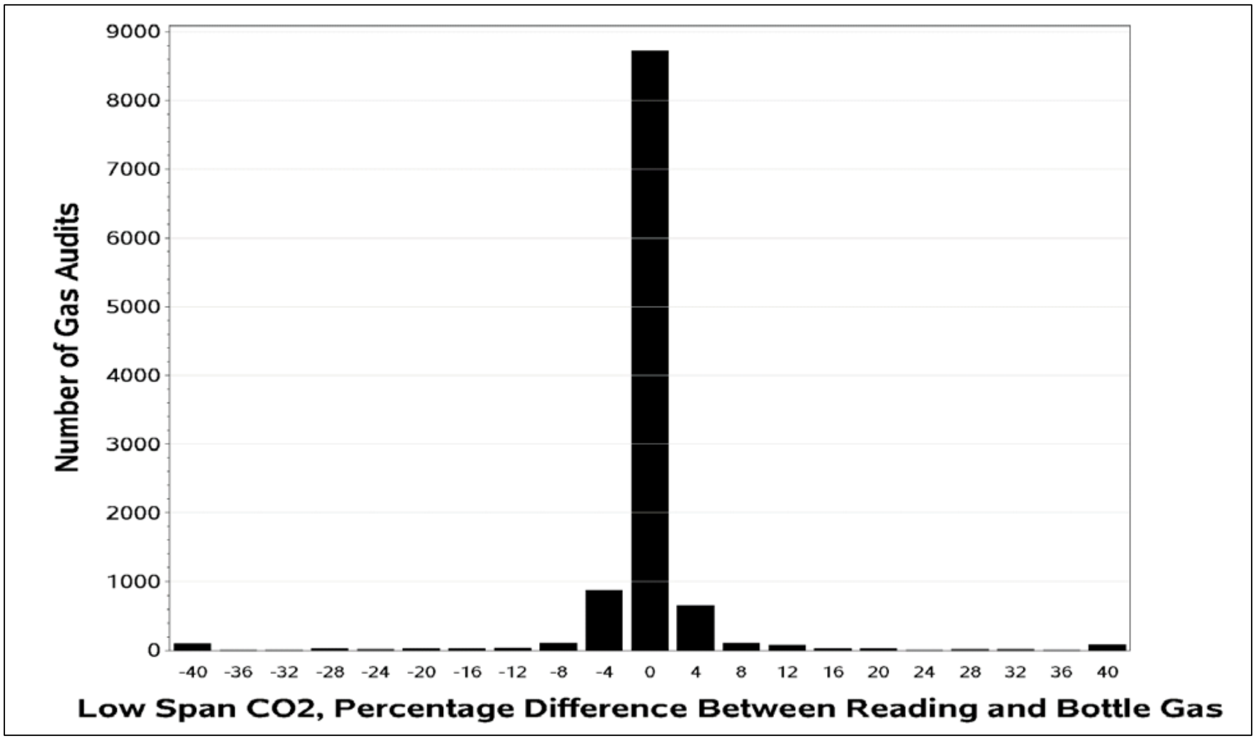


Figure III-39. Percent Difference Between Reading and Bottle Gas, Low-Span NO_X

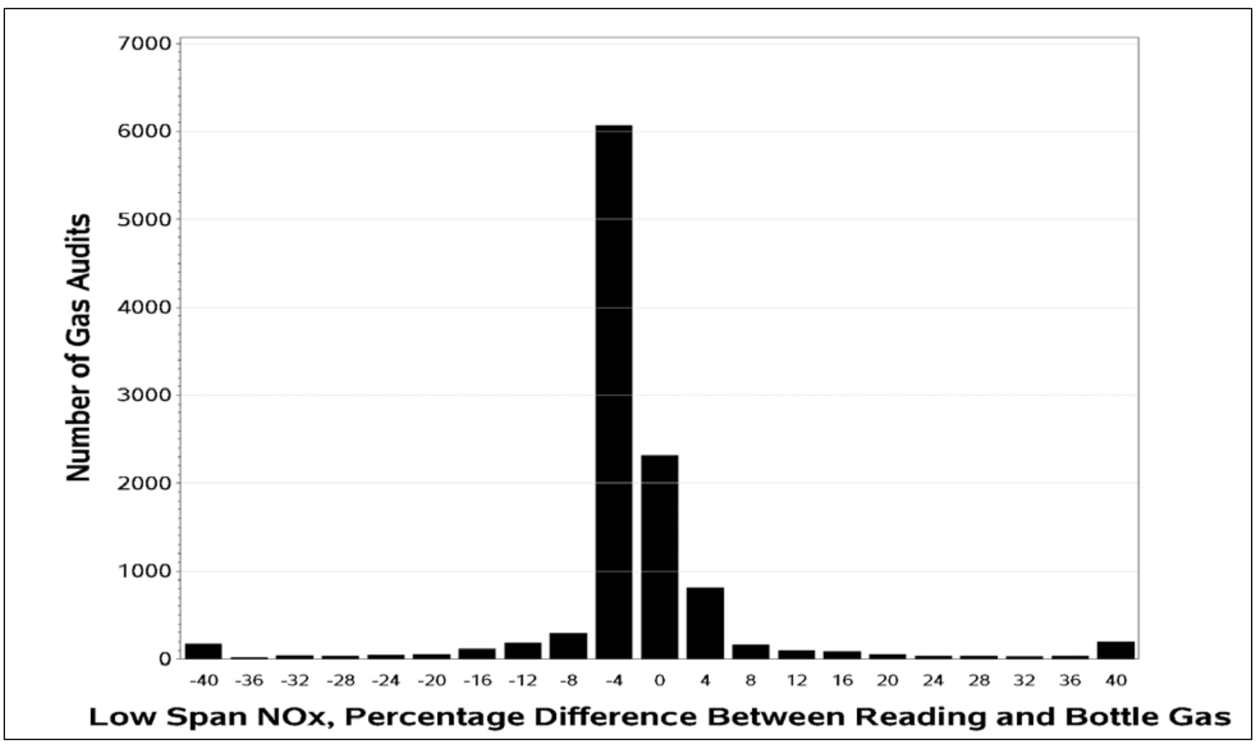


Figure III-40. Percent Difference Between Reading and Bottle Gas, Mid-Span CO

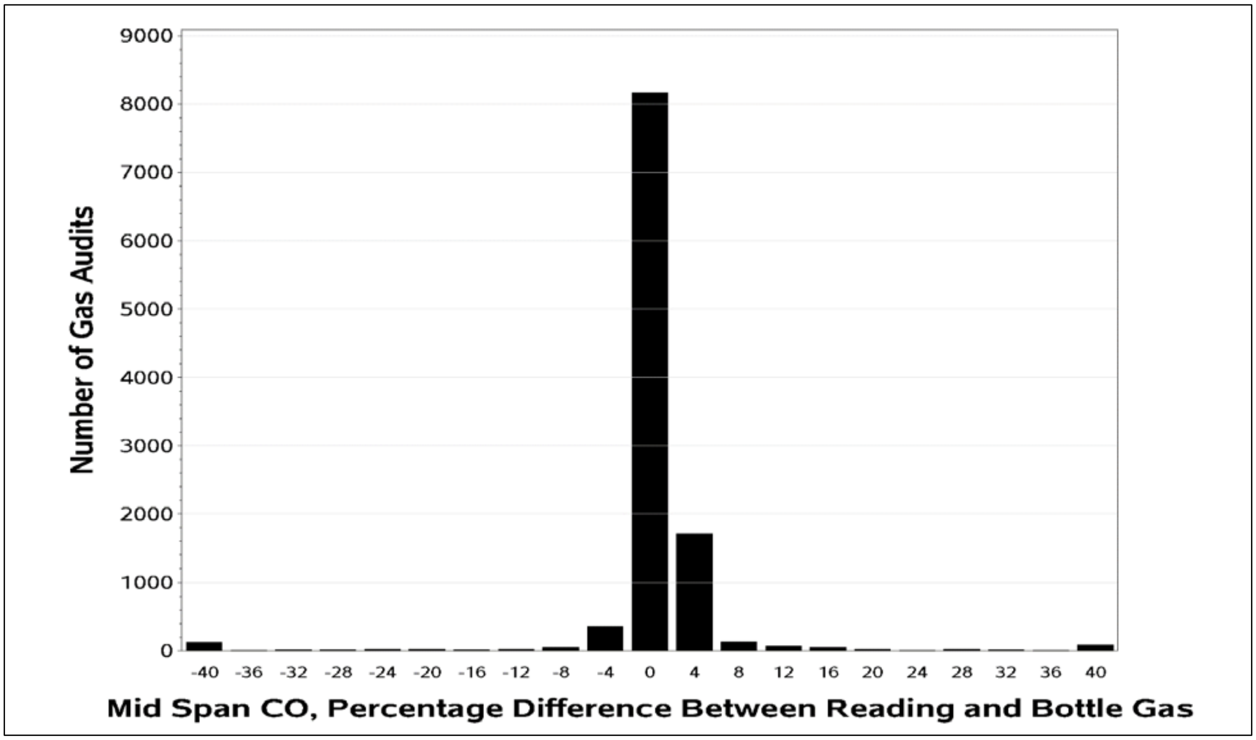


Figure III-41. Percent Difference Between Reading and Bottle Gas, Mid-Span HC

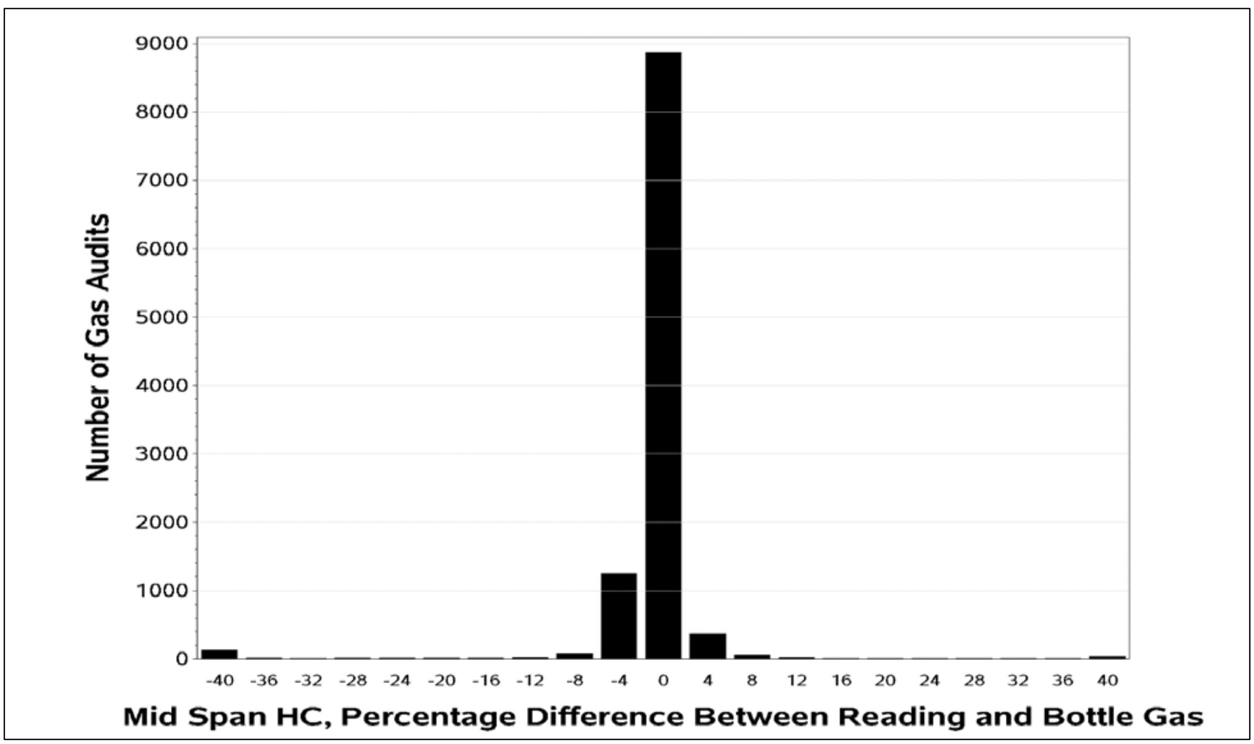


Figure III-42. Percent Difference Between Reading and Bottle Gas, Mid-Span CO_2

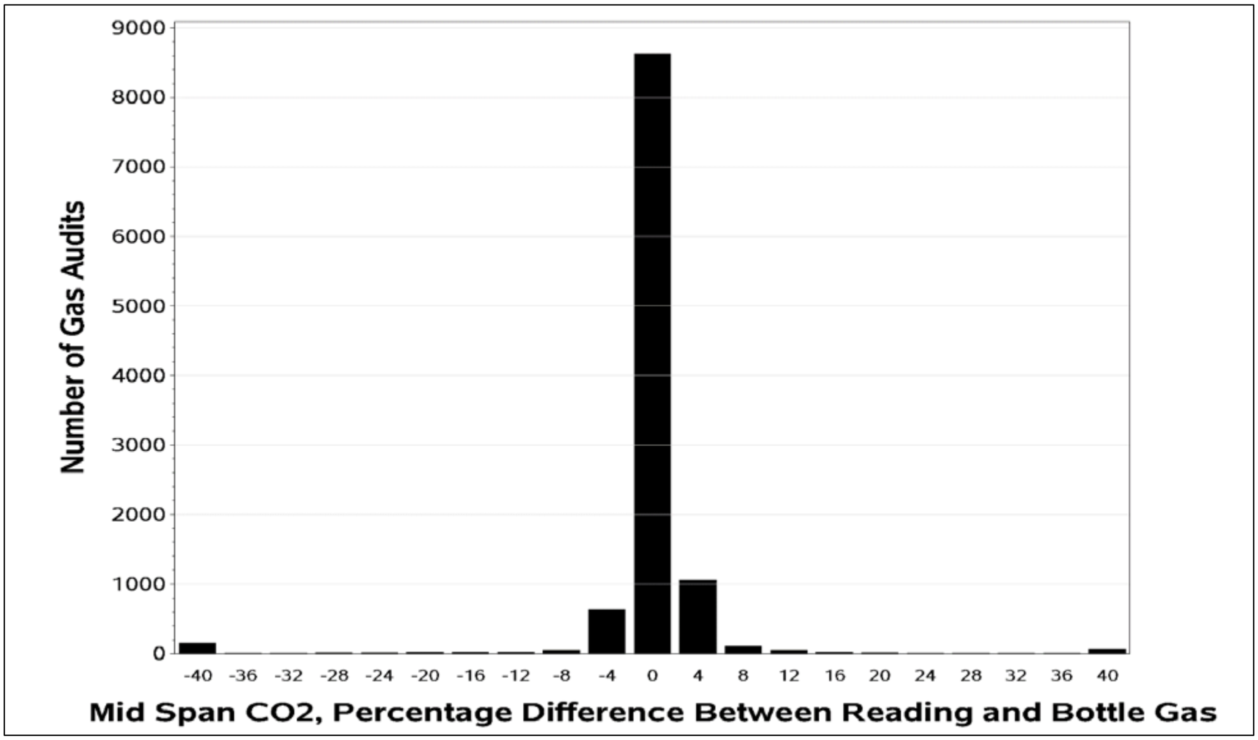


Figure III-43. Percent Difference Between Reading and Bottle Gas, Mid-Span NO_X

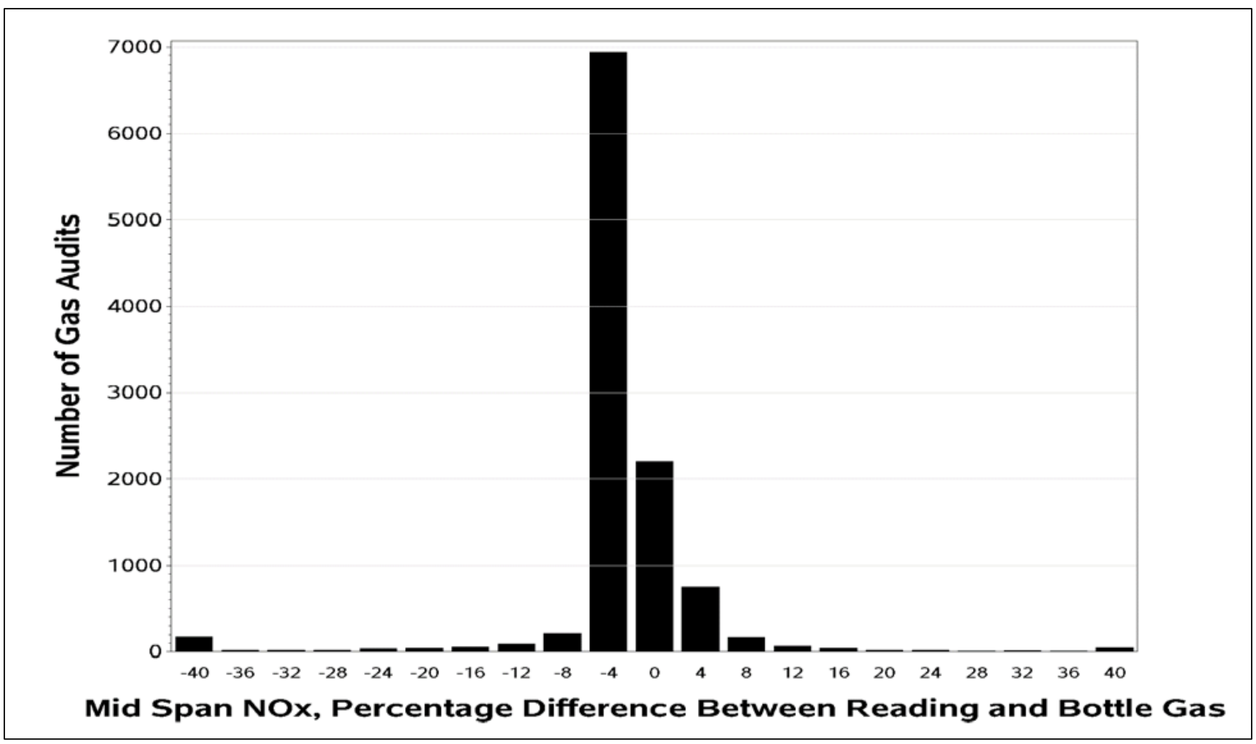


Table III-16 shows pass/fail results for gas audits at the low- and mid- span levels. The table includes the pass/fail results that were recorded in the TIMS, as well pass/fail results calculated by ERG for this analysis (based on the labeled bottle gas value entered in the TIMS, the measured emissions concentration, and a 5.5 percent tolerance). It can be seen from Table III-16 that the pass/fail results stored in the TIMS reconcile well with the pass/fail results ERG calculated from the measured span gas values. The largest discrepancies are 10 audits for which a failing result was calculated by ERG but a passing result was recorded in the TIMS. Almost all of those audits had one or more span gas measurements that were just slightly more than 5.5 percent different from the labeled bottle gas value, indicating that the discrepancy is probably caused by a slight difference in the rounding of results.

Table III-16. Span Gas Pass/Fail Results from TIMS Compared to Calculated Results

Calculated Results	TIMS Result			
	Pass	Fail	No Result	Total
Pass	7,833	14	18	7,865
Fail	8	3,023	59	3,090
Combined Pass & Missing	2	37	1	40
Entirely Missing	1	14	0	15
Total	**7,844**	**3,088**	**77**	**11,010**

The gas audit procedures specify that if an analyzer fails a gas audit, it must be locked out, repaired as necessary, and calibrated in order to pass a re-audit. 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 37 percent of cases, an analyzer that failed an audit was calibrated or re-audited and passed within the next 60 minutes. In an additional 6 percent of cases, the failing analyzer was calibrated or re-audited and passed within 24 hours, and another 9 percent of failing analyzers were calibrated or re-audited and passed within one week. The remaining 48 percent 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.

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:

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

- Dynamometer calibrations must be successfully verified using a coast-down check at least every 72 hours, or they cannot be used for ASM inspections.
- 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 Texas I/M inspection records. Only I/M inspection records for the HGB or DFW program areas in calendar years 2016 or 2017 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 III-17. 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, 4 percent of ASM inspections were performed at times that the dynamometer was overdue for calibration and should have been locked out, and 0.4 percent of ASM and TSI inspections were performed at times that the analyzer was overdue for calibration and should have been locked out.

Table III-17. 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	1,183	0.43	276,533
Leak Check	274	0.10	276,533
Dynamometer Check	9,341	4.06	230,262

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.

The rate of inspections being performed while the analyzer should have been locked out was not the same for the different analyzer manufacturers, as shown in Table III-18. The table shows that Worldwide analyzers had a much higher overall rate of performing inspections while they should have been locked out, and that most of those were done while the dynamometer should have been locked out (not the analyzer).

Table III-18. I/M Inspections More Than 72 Hours After Successful Calibration or Check, by Analyzer Manufacturer

Analyzer ID	Inspections while not locked out		ASM Inspections while dyno should be locked out / analyzer in compliance		ASM & TSI Inspections while analyzer should be locked out / dyno in compliance		ASM & TSI Inspections with combo of lockout for analyzer / dyno / leak check		Total Inspections	
ESP	178,319	99.8%	0	0.0%	414	0.2%	0	0.0%	178,733	100.0%
JB	553	100.0%	0	0.0%	0	0.0%	0	0.0%	553	100.0%
SE	17,615	87.9%	2,224	11.1%	200	1.0%	3	0.0%	20,042	100.0%
WW	69,540	90.1%	7,049	9.1%	551	0.7%	65	0.1%	77,205	100.0%
Total for all analyzers	**266,027**	**96.2%**	**9,273**	**3.4%**	**1,165**	**0.4%**	**68**	**0.0%**	**276,533**	**100.0%**

E. OBD INSPECTION ANALYZER COMMUNICATION PERFORMANCE

ERG analyzed TIMS OBD data to look for proper analyzer communication, as it is possible that certain models of analyzers cannot communicate with certain model year, make, and model vehicles. The objective of this task was to analyze TIMS data to determine if certain manufacturers of OBD inspection analyzers appear to have communication problems with certain makes, models, or model year vehicles, which would result in elevated failure to communicate rates for those vehicle groups.

For this task, ERG reviewed OBD inspection records to identify all tests with a result other than “P” 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 the following four subsections.

Twenty-one of the 21,066,018 OBD test records had no information stored in the OBD communication result field. These records all had null values for ready result, fault code result, downloaded MIL status, and OBD pass/fail result. Of these 21 records, 13 had an overall passing result (a "P" in the "OVERALL_RESULTS" field); one had an overall failing result ("F" in the "OVERALL_RESULTS" field); and seven had a null value in the "OVERALL_RESULTS" field. There were also 611,577 records for vehicles of unknown gross vehicle weight rating (GVWR) or heavy-duty (HD) vehicles (i.e. >8,500 lbs. GVWR). All these records were excluded from the following results, leaving 20,454,418 OBD records in the dataset.

Communication Rates by Vehicle Model Year - Table III-19 provides a summary of communication rates by model year of vehicles tested in the program.

The “MODEL_YEAR” field from the vehicle test result tables was used to determine model year. Values and percentages shown in the table are listed by model year. For example, 170,690 OBD tests were conducted on model year 1996 vehicles, and only 410 of these 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 very low. In addition, most tests with a “failure to communicate” result were followed by a subsequent test of the same vehicle in which OBD communication was successfully established. The overall program-wide communication rate between vehicles and analyzers, excluding the inspections that were removed from the data set as described in Section III.A, is 99.87 percent.

Table III-19. 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	104	0.06%	410	0.24%	170,176	99.70%	170,690
1997	127	0.05%	528	0.20%	259,106	99.75%	259,761
1998	150	0.05%	545	0.17%	327,402	99.79%	328,097
1999	168	0.04%	893	0.21%	433,925	99.76%	434,986
2000	219	0.04%	1,114	0.19%	576,159	99.77%	577,492
2001	228	0.03%	1,240	0.18%	699,291	99.79%	700,759
2002	258	0.03%	1,401	0.17%	823,776	99.80%	825,435
2003	283	0.03%	1,741	0.19%	905,470	99.78%	907,494
2004	363	0.04%	2,134	0.21%	1,007,340	99.75%	1,009,837
2005	339	0.03%	2,008	0.18%	1,113,142	99.79%	1,115,489
2006	329	0.03%	2,065	0.17%	1,220,300	99.80%	1,222,694
2007	313	0.02%	1,701	0.12%	1,459,601	99.86%	1,461,615
2008	247	0.02%	1,341	0.09%	1,461,144	99.89%	1,462,732
2009	139	0.01%	765	0.08%	982,783	99.91%	983,687
2010	116	0.01%	795	0.07%	1,172,100	99.92%	1,173,011
2011	146	0.01%	1,011	0.08%	1,290,810	99.91%	1,291,967
2012	148	0.01%	1,246	0.08%	1,522,161	99.91%	1,523,555
2013	135	0.01%	1,008	0.06%	1,795,556	99.94%	1,796,699
2014	120	0.01%	855	0.05%	1,820,963	99.95%	1,821,938
2015	80	0.01%	521	0.05%	1,152,696	99.95%	1,153,297
2016	14	0.01%	107	0.05%	203,238	99.94%	203,359
2017	3	0.01%	11	0.04%	28,996	99.95%	29,010
2018	1	0.12%	0	0.00%	813	99.88%	814
Total	**4,030**	**0.02%**	**23,440**	**0.11%**	**20,426,948**	**99.87%**	**20,454,418**

Communication Rates by Equipment Manufacturer –Table III-20 provides results of communication rates among the various analyzer manufacturers.

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 two rightmost columns provide counts of tests and percentages of tests by each analyzer manufacturer relative to the total number of tests. For the most part, the rate of communication problems was consistently low for each manufacturer.

Communication Rates by Vehicle Make - To assess communication rates by vehicle make, vehicle registration records were merged with vehicle test records by VIN. Makes that were represented by 100 or fewer vehicles were removed from the table, since sample sizes would be too small to provide meaningful results.

Table III-21 provides a summary of communication rates among the various vehicle makes. Except for a small number of very uncommon vehicle makes (e.g., Rolls Royce, Ferrari), the incident rates for "damaged, inaccessible, or cannot be found" or "no communication" were very low.

Communication Rates by Vehicle Model - To assess communication rates by vehicle models, the model codes and model names (series) as reported in the vehicle test results tables were used. Table III-22 lists communication rates for each vehicle model code. Records for the more uncommon series, i.e., less than 100 inspection records, were excluded. Because Table III-22 is very long, in the text below only vehicle makes through Audi are listed. The full table can be found in Appendix A.

It can be seen from the table that no model codes/vehicle series had "damaged, inaccessible, or cannot be found" or "no communication" rates that were greater than 1 percent, and all were below 0.8 percent except for Winnebago and Aston Martin. All other vehicles were below 0.5 percent.

Table III-20. 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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
ESP	2,986	0.02%	16,618	0.12%	14,162,994	99.86%	14,182,598	69.34%
JB	0	0.00%	20	0.30%	6,579	99.70%	6,599	0.03%
SE	383	0.05%	1,789	0.25%	711,254	99.70%	713,426	3.49%
WW	661	0.01%	5,013	0.09%	5,546,121	99.90%	5,551,795	27.14%
Total	**4,030**	**0.02%**	**23,440**	**0.11%**	**20,426,948**	**99.87%**	**20,454,418**	**100.00%**

Table III-21. 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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
ACURA	42	0.02%	169	0.07%	249,917	99.92%	250,128	1.22%
ASTON MARTIN	1	0.05%	16	0.83%	1,916	99.12%	1,933	0.01%
AUDI	16	0.01%	132	0.12%	112,199	99.87%	112,347	0.55%
BENTLEY	1	0.03%	3	0.09%	3,463	99.88%	3,467	0.02%
BMW	87	0.02%	641	0.16%	390,551	99.81%	391,279	1.91%
BUICK	43	0.02%	297	0.14%	209,844	99.84%	210,184	1.03%
CADILLAC	90	0.03%	554	0.19%	285,957	99.78%	286,601	1.40%
CHEVROLET	782	0.03%	4,068	0.15%	2,657,611	99.82%	2,662,461	13.02%
CHRYSLER	59	0.02%	386	0.11%	347,940	99.87%	348,385	1.70%
DODGE	223	0.02%	1,115	0.11%	1,053,636	99.87%	1,054,974	5.16%
FERRARI	2	0.07%	11	0.39%	2,779	99.53%	2,792	0.01%
FORD	748	0.03%	4,009	0.14%	2,805,198	99.83%	2,809,955	13.74%
GEO	2	0.08%	3	0.12%	2,519	99.80%	2,524	0.01%
GMC	153	0.03%	872	0.16%	552,528	99.81%	553,553	2.71%
HONDA	224	0.01%	1,050	0.06%	1,682,039	99.92%	1,683,313	8.23%
HUMMER	10	0.05%	55	0.30%	18,461	99.65%	18,526	0.09%
HYUNDAI	75	0.01%	571	0.11%	528,654	99.88%	529,300	2.59%
INFINITI	23	0.01%	162	0.07%	244,090	99.92%	244,275	1.19%
ISUZU	12	0.04%	63	0.22%	28,861	99.74%	28,936	0.14%
JAGUAR	10	0.02%	63	0.15%	40,657	99.82%	40,730	0.20%
JEEP	58	0.01%	493	0.10%	516,369	99.89%	516,920	2.53%
KIA	27	0.01%	224	0.06%	400,050	99.94%	400,301	1.96%
LAND ROVER	11	0.02%	79	0.15%	54,028	99.83%	54,118	0.26%

Table III-21. 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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
LEXUS	46	0.01%	478	0.08%	565,574	99.91%	566,098	2.77%
LINCOLN	81	0.05%	434	0.26%	165,891	99.69%	166,406	0.81%
MASERATI	1	0.02%	6	0.14%	4,173	99.83%	4,180	0.02%
MAZDA	107	0.03%	797	0.22%	366,630	99.75%	367,534	1.80%
MERCEDES	37	0.03%	165	0.14%	114,962	99.82%	115,164	0.56%
MERCURY	57	0.02%	337	0.09%	378,506	99.90%	378,900	1.85%
MINI	1	0.04%	6	0.22%	2,758	99.75%	2,765	0.01%
MITSUBISHI	69	0.05%	360	0.24%	149,696	99.71%	150,125	0.73%
NISSAN	189	0.01%	1,087	0.08%	1,437,008	99.91%	1,438,284	7.03%
OLDSMOBILE	13	0.06%	34	0.15%	22,613	99.79%	22,660	0.11%
PLYMOUTH	2	0.02%	11	0.13%	8,718	99.85%	8,731	0.04%
PONTIAC	45	0.03%	292	0.18%	159,810	99.79%	160,147	0.78%
PORSCHE	22	0.04%	243	0.48%	50,640	99.48%	50,905	0.25%
ROLLS ROYCE	1	0.14%	1	0.14%	689	99.71%	691	0.00%
SAAB	4	0.03%	24	0.19%	12,442	99.78%	12,470	0.06%
SATURN	69	0.07%	481	0.45%	105,521	99.48%	106,071	0.52%
SCION	5	0.01%	76	0.09%	86,360	99.91%	86,441	0.42%
SUBARU	10	0.01%	136	0.12%	115,132	99.87%	115,278	0.56%
SUZUKI	13	0.04%	70	0.20%	34,919	99.76%	35,002	0.17%
TOYOTA	271	0.01%	1,745	0.07%	2,436,350	99.92%	2,438,366	11.92%
VOLKSWAGEN	46	0.02%	401	0.14%	278,130	99.84%	278,577	1.36%
VOLVO	26	0.03%	82	0.09%	95,300	99.89%	95,408	0.47%
WINNEBAGO	1	0.86%	1	0.86%	114	98.28%	116	0.00%

Table III-21. 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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
OTHER	210	0.01%	1,127	0.07%	1,643,064	99.92%	1,644,401	8.04%
Total	3,965	0.02%	23,110	0.12%	20,056,772	99.87%	20,083,847	98.20%

Table III-22. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
ACURA								
3.2CL Premium	1	0.12%	1	0.12%	836	99.76%	838	0.00%
3.2TL	2	0.04%	3	0.06%	5,003	99.90%	5,008	0.03%
Integra	2	0.09%	10	0.44%	2,247	99.47%	2,259	0.01%
MDX	2	0.01%	12	0.04%	27,958	99.95%	27,972	0.16%
RSX Type-S	1	0.06%	3	0.19%	1,597	99.75%	1,601	0.01%
TL	6	0.02%	16	0.05%	30,095	99.93%	30,117	0.17%
BLANK	26	0.02%	88	0.07%	129,788	99.91%	129,902	0.75%
ASTON MARTIN								
BLANK	1	0.07%	13	0.85%	1,513	99.08%	1,527	0.01%
AUDI								
A4/S4	1	0.02%	15	0.24%	6,270	99.75%	6,286	0.04%
A4/S4 Cabriolet	3	0.25%	11	0.92%	1,182	98.83%	1,196	0.01%
A6	1	0.07%	4	0.30%	1,339	99.63%	1,344	0.01%
BLANK	10	0.02%	64	0.12%	55,398	99.87%	55,472	0.32%

F. TIMS HANDLING OF OBD CODES

ERG analyzed TIMS OBD data to evaluate the accuracy of OBD data collected in the Texas I/M program. This is a process-based measure for inspection effectiveness. The handling of OBD readiness, diagnostic trouble codes, and communication failures varies among I/M programs. The objective of this task was to analyze OBD inspection records to ensure OBD test results are appropriate for various OBD test dispositions, such as a vehicle with too many OBD monitors "not ready," a vehicle with "pending" DTCs, or a vehicle that fails to communicate with the analyzer.

Program Description and Results of Analysis

Proper handling of various OBD test scenarios is defined in Parts 85.2207 and 85.2222 of Title 40 of the Code of Federal Regulations (CFR) and also in various OBD implementation guidance documents issued by the EPA. Appropriate responses to the various test scenarios are summarized here, and serve as the basis for analysis for this task. The dataset for this analysis included records for OBD inspections between January 1, 2016 and December 31, 2017. 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" (pass) or "F" (fail). Because this analysis was performed with the goal of determining whether OBD inspection guidelines are enforced, only records for light-duty vehicles were used. OBD test pass/fail results are not enforced for HD vehicles (i.e., vehicle whose GVWR is greater than 8,500 pounds); therefore, these vehicles were removed from the dataset. HD vehicles were identified as those with the tx96_type field equal to 1 and the tx96_gvw_actual field between zero and 8,501. Vehicles with no GVWR given were also removed, since these might be HD vehicles. Following these removals, 20,452,762 records remained 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 III-23.

Table III-23. Comparison of DLC Communication Status with Overall OBD Test Results

DLC Communication Status	Overall OBD Test Results	
	Fail	Pass
"D" (damaged)	1,795	1
"I" (DLC is inaccessible)	964	2
"L" (inspector cannot find DLC)	1,194	54
"N" (connected but will not communicate)	23,371	1
Total count of "D", "I", "L", and "N" Tests	27,324	58
"P" (communication successful)	856,163	19,569,217
Total	**883,487**	**19,569,275**

As can be seen in the table, 58 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). 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 records. In conclusion, the DLC failure to communicate was enforced on most, but not all, OBD tests conducted on light-duty vehicles during the period of evaluation.

Because successful communication with the inspection analyzer 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 20,425,380 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 recorded 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_FLAG" field) but passed the overall OBD test ("P" in the "OVERALL_RESULTS" field). Table III-24 shows that only 2 tests were recorded with a "fail" in the OBD portion of the test but a "pass" for the overall test (this is down from 2,000 in the 2016 report).

Table III-24. Comparison of OBD Test Result with Overall Test Result

Result of OBD Test	Overall Test Result				Total	
	Fail		Pass			
Fail	856,161	100.0%	2	0.0%	856,163	4.19%
Pass	332,099	1.7%	19,237,118	98.3%	19,569,217	95.81%
Total	**1,188,260**	**5.8%**	**19,237,120**	**94.2%**	**20,425,380**	**100%**

Inspector-Entered Malfunction Indicator Light (MIL) bulb check - This is also referred to as the Key On / Engine Off (KOEO) check. The inspector is instructed to turn the vehicle's ignition key to the "on" position, but 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 the 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 or keyless ignition), and "N", which is a fail (no, the MIL did not illuminate). There were 83 records where a KOEO MIL result of "N" (fail) did not receive a failing OBD result. The results are presented in Table III-25 below.

Table III-25. 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	
N (fail)	20,546	83	20,629
K (pass)	20,270	1,022,132	1,042,402
Y (pass)	815,347	18,547,002	19,362,349
Total	**856,163**	**19,569,217**	**20,425,380**

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 III-26 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. As shown in Table III-27, in 239,955 inspections a "pass" result was manually entered when the downloaded MIL status indicated a "fail" result, and a "fail" result was entered 8,418 times when the MIL status indicated a "pass" result.

Table III-26. Comparison of Inspector-Entered MIL Illumination Status (Engine Running, KOER) with Overall OBD Test Result

Result of MIL Illumination Status	Overall OBD Test Result		Total
	Fail	Pass	
N (Fail)	54,190	0	54,190
Y (Pass)	801,973	19,569,217	20,371,190
Total	**856,163**	**19,569,217**	**20,425,380**

Table III-27. Comparison of Downloaded MIL Command Status with Inspector-Entered MIL Illumination Status (Engine Running, KOER)

Result of Downloaded MIL Status	Result of MIL Illumination Status		Total
	Fail	Pass	
Fail	45,772	239,955	285,727
Pass	8,418	20,131,235	20,139,653
Total	**54,190**	**20,371,190**	**20,425,380**

MIL commanded on – A vehicle with the MIL commanded on and with stored emissions-related DTCs should fail the OBD inspection, regardless of readiness status. Manufacturer-specific (non-generic) 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 III-28 provides the results of this review.

Table III-28. Comparison of Downloaded MIL Command Status with Overall OBD Test Result

Result of Downloaded MIL Status	Overall OBD Test Result				Total	
	Fail		Pass			
Fail	205,516	24.0%	80,211	0.4%	285,727	1.4%
Pass	650,647	76.0%	19,489,006	99.6%	20,139,653	98.6%
Total	**856,163**	**100.0%**	**19,569,217**	**100.0%**	**20,425,380**	**100.0%**

From Table III-28, it can be seen that 80,211 test records (0.4 percent of all OBD "pass" test records) have a MIL commanded on status yet receive an overall OBD pass result. However, 80,074 of the 80,211 tests had no stored DTCs, in which case it is appropriate to pass the test. The 137 remaining inspections had one or more DTCs stored, and should have resulted in a failed OBD result, since the MIL was commanded on. 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. However, 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, records with transitional vehicles were excluded from this analysis of readiness, leaving 20,420,082 records 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 the readiness guidelines. Vehicles of model years 1996-2000 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). The 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 III-29 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 III-29. Unset Monitors Vs. Test Readiness Status for Inspections

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	7	1,137,479	401	16,127,493
1	3	389,043	29	1,936,946
2	4	157,049	266,140	1,041
3	38,004	0	168,683	1
4	24,262	0	113,938	1
5	14,822	1	41,898	1
6	632	0	2,188	0
8	0	0	3	0
Total	**77,734**	**1,683,572**	**593,280**	**18,065,483**

Results in Table III-29 show that a small number of tests (a total of 408) appear to have received an OBD "not ready" status despite having no unset monitors. Also, 1,041 vehicles of model year 2001 or newer with two unset readiness monitors still received a readiness result of "pass." The majority of these were tested using the ESP equipment.

Table III-30 shows these data in greater detail, separated by model year.

Table III-30. Unset Monitors Vs. Test Readiness Status for Inspections, by Model Year

Model Year	Count of Unset Non-Continuous Monitors															
	0		1		2		3		4		5		6		8	
	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready
1996	1	100,656	0	42,430	0	16,796	4,894	0	2,870	0	887	1	69	0	0	0
1997	1	156,822	0	62,096	1	25,808	5,801	0	4,141	0	2,010	0	61	0	0	0
1998	1	210,074	0	70,992	1	29,940	7,023	0	4,596	0	3,239	0	81	0	1	0
1999	2	283,266	2	94,521	0	37,258	8,997	0	5,400	0	4,297	0	149	0	1	0
2000	2	386,661	1	119,004	2	47,247	11,289	0	7,255	0	4,389	0	272	0	0	0
2001	.	484,439	0	162,084	26,771	201	12,260	0	8,328	0	4,805	0	342	0	1	0
2002	8	604,541	1	168,630	24,469	171	13,391	0	8,564	0	3,673	0	267	0	0	0
2003	9	668,753	1	188,219	23,690	140	13,346	0	7,380	0	3,542	0	320	0	1	0
2004	7	778,824	2	179,372	23,500	130	14,206	0	8,186	0	2,818	0	251	0	0	0
2005	14	887,245	3	174,074	23,750	137	15,397	0	9,288	0	2,902	0	263	0	2	0
2006	27	988,814	5	182,102	22,321	112	15,355	0	8,666	0	2,687	0	155	0	1	0
2007	33	1,220,997	3	189,174	20,447	69	16,408	0	10,080	0	2,276	0	51	0	0	0
2008	49	1,265,550	4	152,424	19,346	48	13,245	0	8,516	0	1,880	0	30	0	4	0
2009	28	870,041	3	86,113	11,840	15	8,158	1	4,999	1	1,514	1	46	0	1	0
2010	40	1,060,501	1	84,271	11,578	4	7,631	0	5,722	0	2,268	0	60	0	0	0
2011	35	1,176,360	2	86,222	11,976	10	7,414	0	5,894	0	2,798	0	74	0	2	0
2012	40	1,409,395	2	82,773	12,327	3	7,921	0	6,751	0	2,827	0	105	0	1	0
2013	39	1,681,278	0	81,139	12,949	0	8,870	0	8,105	0	3,075	0	82	0	0	0
2014	51	1,717,051	1	72,815	11,813	1	8,613	0	7,676	0	2,852	0	74	0	0	0
2015	16	1,095,908	1	38,582	7,138	0	4,865	0	4,521	0	1,605	0	54	0	0	0
2016	4	191,603	0	7,349	1,678	0	1,264	0	1,012	0	315	0	12	0	0	0
2017	1	26,193	0	1,603	547	0	339	0	250	0	61	0	2	0	0	0
Total	**408**	**17,264,972**	**32**	**2,325,989**	**266,144**	**158,090**	**206,687**	**1**	**138,200**	**1**	**56,720**	**2**	**2,820**	**0**	**15**	**0**

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. These records with transitional vehicles were excluded from this analysis of readiness to prevent any confusion in the results, leaving 20,428,082 records in the dataset for this analysis. The results are shown in Table III-31.

Table III-31. Comparison of Readiness Status Field with Overall OBD Test Result

Readiness Status Check	Overall OBD Test Result				Total	
	Fail		Pass			
Fail (Not Ready)	669,928	78.2%	1,098	0.0%	671,026	3.3%
Pass (Ready)	185,725	21.7%	19,563,330	100.0%	19,749,055	96.7%
Total	**855,654**	**99.9%**	**19,564,427**	**100.0%**	**20,420,081**	**100.0%**

As can be seen in Table III-31, 1,098 of the vehicles with a "not ready" status received an overall "pass" result for the OBD portion of the test. This represents less than 0.006 percent; therefore, the value in Table III-31 is 0.0 percent. 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.

IV. REPAIR

ERG used two years of TIMS data to analyze repair activities in order to demonstrate the extent and effectiveness of repairs directed by the Texas I/M program. This task will cover process-based measures for repair effectiveness.

A. NUMBER AND TYPES OF REPAIRS

ERG performed analysis on the number and types of repairs for the two years of TIMS data. The inspectors at Texas I/M stations have an opportunity to enter vehicle repair information into the inspection analyzer prior to conducting an emissions re-test. A simple count of the number of repairs entered and stored in the TIMS and a distribution of the repair types suggests the Texas I/M program is causing repairs to be performed. Since the repairs performed through the AirCheckTexas LIRAP are documented on paper and not electronically, LIRAP repairs are not included in this analysis but will be described generally.

In previous reports, repair information collected from the DPS RERF program was also included. However, only 1,102 RERF records were available for the current report, which were too few to provide a meaningful analysis.

General I/M Repairs

The TIMS database, provided by the TCEQ for this analysis, contained a large number of repair entries, 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 IV-1 by model year group. Comparing Table III-2 test totals from the DFW and HGB program areas shows total OBD, ASM, and TSI fails increased from 586,091 fails in the 2016 report to 670,246 fails in this report (84,155 additional fails).

Table IV-1. Repairs Listed in the TIMS

Repair Type	Model Year	Number of Repairs	% of Repair Type	% of Total
Fuel System	1990-1995	1,893	4.8%	1.1%
	1996-1999	4,260	10.9%	2.5%
	2000-2006	19,304	49.3%	11.1%
	post-2007	13,722	35.0%	7.9%
	Total	*39,179*	*100.0%*	*22.6%*
Ignition / Electrical system	1990-1995	1,555	9.5%	0.9%
	1996-1999	1,838	11.2%	1.1%
	2000-2006	7,974	48.5%	4.6%
	post-2007	5,075	30.9%	2.9%
	Total	*16,442*	*100.0%*	*9.5%*
Emissions system	1990-1995	5,513	12.6%	3.2%
	1996-1999	5,169	11.8%	3.0%
	2000-2006	20,965	48.0%	12.1%
	post-2007	11,985	27.5%	6.9%
	Total	*43,632*	*100.0%*	*25.2%*
Engine Mechanical	1990-1995	194	6.5%	0.1%
	1996-1999	391	13.1%	0.2%
	2000-2006	1,483	49.8%	0.9%
	post-2007	908	30.5%	0.5%
	Total	*2,976*	*100.0%*	*1.7%*
Miscellaneous	1990-1995	4,824	6.8%	2.8%
	1996-1999	7,619	10.7%	4.4%
	2000-2006	34,944	49.2%	20.2%
	post-2007	23,611	33.3%	13.6%
	Total	70,998	100.0%	41.0%
	Grand Total	**173,227**		**100.0%**

Drive a Clean Machine (DACM) program

Texas created the DACM program to enhance the objectives of the Texas I/M program. Using the statutory authority granted in the LIRAP legislation, the DACM program provides financial assistance to low-income vehicle owners to repair or retire vehicles that have failed an emissions test or retire vehicles ten years old or older. To qualify for the DACM program, a vehicle owner's net family income cannot exceed 300 percent of the federal poverty level, which varies by family unit size.

To qualify for repair assistance, the vehicle must pass the safety portion of the DPS motor-vehicle safety and emissions inspection and be driven under its own power to the inspection station; must have failed an emissions test within 30 days of application submission; and must be currently registered in and have been registered in the program area for at least 12 of the 15 months preceding the application for assistance. The repair assistance portion of the DACM program provides a voucher worth up to $600 for emissions-related repairs performed at a participating DPS RERF.

To qualify for vehicle retirement and replacement assistance, the vehicle must have failed an emissions test, passed the DPS motor-vehicle safety and emissions inspection within 15 months of application submission and driven under its own power to the automobile dealership, and be currently registered in and have been registered in the program area for at least 12 of the 15 months preceding the application for assistance; or be at least 10 years old and gasoline powered, passed the DPS motor-vehicle safety inspection (if more than 24 years old) or safety and emissions inspection (if 24 years old or less) within 15 months of application and driven under its own power to the automobile dealership, and be currently registered in and have been registered in the program area for at least 12 of the 15 months preceding the application for assistance.

The retirement and replacement assistance portion of the DACM program offers a voucher up to $3,000 towards the purchase of a replacement car, current model year or up to three model years old; a voucher up to $3,000 towards the purchase of a replacement truck, current model year or up to two model years old; or a voucher up to $3,500 towards the purchase of a replacement car of the current model year or the previous three model years if the vehicle is a hybrid vehicle, an electric vehicle, or a natural gas vehicle, or is in a class or category of vehicles that has been certified to meet federal Tier 2, Bin 3 or cleaner Bin certification under 40 CFR §86.1811-04 or federal Tier 3, Bin 85 or cleaner Bin certification under 40 CFR §86.1811-17.

The replacement vehicle must have an odometer reading of not more than 70,000 miles, a gross vehicle weight rating less than 10,000 pounds, and a sales price of $35,000 or less, for a car, current model year or up to three model years old; a sales price of $35,000 or less, for a truck, current model year or up to two model years old; or a sales price of $45,000 or less for a hybrid vehicle, electric vehicle, natural gas vehicle or a vehicle certified to meet or exceed federal Tier 2, Bin 3 or cleaner Bin certification of the current model year or up to three model years old.

For the period covering December 1, 2015 through November 30, 2017, 5,262 vehicle repairs were done at RERF stations under the DACM program, with 5,025 being made in the DFW and HGB programs.

B. EMISSIONS CHANGES ASSOCIATED WITH REPAIR

One way to measure the effectiveness of an 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.

Emissions Changes as a Result of Repair

The average emissions of all vehicles in this analysis of the Texas I/M program that received repairs are shown in Table IV-2 and Table IV-3. There were insufficient data to calculate the average before and after emissions for the TSI test results. In Table IV-2, ASM5015 and ASM2525 test results for HC, CO, and NO_X are presented for pre-OBD vehicles with model years between 1990 and 1995, broken down by the most common repair slates (groups of common types of repairs). Average before and after repair emissions levels were calculated for each repair category to determine the emissions effects of different combinations of repair types. Table IV-3 shows these data for the pre-1995 (i.e., pre-OBD) model years. Average emissions for both inspections prior to and following repair cycles are shown, along with the average change between the two.

Table IV-2. Model Years 1990-1995 (Pre-OBD) Average Emissions Before and After Repairs by Repair Category, ASM Mode

Repair Category	ASM Mode	No.	HC (ppm)				CO (%)				NOx (ppm)			
			Before Repair	After Repair	Change		Before Repair	After Repair	Change		Before Repair	After Repair	Change	
					Conc	(%)			Conc	(%)			Conc	(%)
Miscellaneous	5015	2,968	179.90	104.42	-75.48	-42%	0.97	0.40	-0.57	-59%	1,435.10	743.51	-691.59	-48%
Engine Mechanical	5015	105	214.46	83.90	-130.55	-61%	1.24	0.32	-0.92	-74%	1,526.03	617.32	-908.70	-60%
Emissions System	5015	3,972	165.00	69.59	-95.41	-58%	0.86	0.27	-0.59	-68%	1,645.04	621.86	-1,023.18	-62%
Emissions System & Misc	5015	194	122.27	81.89	-40.39	-33%	0.74	0.38	-0.36	-49%	1,793.57	916.98	-876.58	-49%
Ignition/Electrical System	5015	968	267.99	110.15	-157.85	-59%	1.35	0.56	-0.79	-58%	1,134.69	586.86	-547.83	-48%
Fuel System	5015	1,085	193.78	96.22	-97.56	-50%	1.11	0.39	-0.72	-65%	1,308.30	686.51	-621.80	-48%
Fuel System & Emissions System	5015	100	154.46	66.71	-87.75	-57%	0.81	0.25	-0.56	-69%	1,675.03	789.87	-885.16	-53%
All Repairs	5015	9,392	183.21	88.24	-94.97	-52%	0.98	0.36	-0.62	-63%	1,489.25	672.00	-817.25	-55%
Miscellaneous	2525	2,968	158.88	88.12	-70.76	-45%	0.90	0.38	-0.52	-58%	1,288.06	634.05	-654.01	-51%
Engine Mechanical	2525	105	186.85	59.96	-126.89	-68%	1.11	0.23	-0.88	-80%	1,360.19	502.96	-857.23	-63%
Emissions System	2525	3,972	145.72	55.94	-89.79	-62%	0.79	0.24	-0.56	-70%	1,481.54	519.00	-962.54	-65%
Emissions System & Misc	2525	194	115.97	68.25	-47.72	-41%	0.88	0.44	-0.44	-50%	1,581.94	763.53	-818.41	-52%
Ignition/Electrical System	2525	968	238.10	86.96	-151.14	-63%	1.25	0.52	-0.74	-59%	1,021.73	488.06	-533.67	-52%
Fuel System	2525	1,085	172.95	80.56	-92.39	-53%	1.00	0.37	-0.63	-63%	1,183.92	573.41	-610.51	-52%
Fuel System & Emissions System	2525	100	135.20	53.66	-81.54	-60%	0.85	0.16	-0.70	-82%	1,449.99	665.66	-784.33	-54%
All Repairs	2525	9,392	162.28	72.42	-89.86	-55%	0.91	0.33	-0.58	-64%	1,339.00	564.89	-774.12	-58%

Table IV-3. Model Years 1990-1995 (Pre-OBD) Average Emissions Before and After Repairs by Repair Category and Model Year Group, TSI Mode

Repair Category	TSI Mode	N	HC (ppm)				CO (%)			
			Before Repair	After Repair	Change		Before Repair	After Repair	Change	
					Conc.	(%)			Conc.	(%)
Miscellaneous	curb idle	369	350.9322	215.0271	-135.905	-39%	1.15	0.67	-0.48	-42%
Engine Mechanical	curb idle	21	368	148.9524	-219.048	-60%	0.86	0.22	-0.64	-75%
Emissions System	curb idle	319	439.1505	123.4326	-315.718	-72%	1.36	0.31	-1.05	-77%
Emissions System & Misc	curb idle	25	445.6	151.16	-294.44	-66%	1.63	0.68	-0.96	-59%
Ignition/Electrical System	curb idle	187	469.1497	175.5936	-293.556	-63%	1.46	0.41	-1.04	-72%
Fuel System	curb idle	235	398.4298	181.7787	-216.651	-54%	1.48	0.50	-0.98	-66%
Fuel System & Emissions System	curb idle	8	364.5	106.75	-257.75	-71%	0.58	0.15	-0.43	-74%
All Repairs	curb idle	1,164	406.1246	173.5696	-232.555	-57%	1.32	0.48	-0.84	-63%
Miscellaneous	high idle	369	175.49	124.90	-50.59	-29%	1.02	0.64	-0.37	-37%
Engine Mechanical	high idle	21	206.62	70.43	-136.19	-66%	0.85	0.26	-0.58	-69%
Emissions System	high idle	319	275.04	79.36	-195.68	-71%	1.22	0.34	-0.88	-72%
Emissions System & Misc	high idle	25	321.96	90.04	-231.92	-72%	1.07	0.58	-0.49	-46%
Ignition/Electrical System	high idle	187	303.94	99.02	-204.93	-67%	1.32	0.44	-0.88	-67%
Fuel System	high idle	235	250.17	100.75	-149.41	-60%	1.26	0.50	-0.75	-60%
Fuel System & Emissions System	high idle	8	201.00	46.50	-154.50	-77%	0.43	0.17	-0.26	-60%
All Repairs	high idle	1,164	242.37	101.12	-141.25	-58%	1.16	0.49	-0.68	-58%

C. ISSUES WITH THE REPAIR DATA IN THE TIMS DATASET

There are several issues with the repair data contained in the TIMS dataset 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 previous reports.

The repair data in the TIMS is entered by the inspector performing the inspection; however, the motorist often does not bring the vehicle repair form for the re-inspection and this leads to the inspector leaving this information blank. Usually, most repair entries in the TIMS are made by inspectors that either work in the same facility where the re-inspection takes place or made the repairs themselves.

The TIMS repair data includes only five different repair types, 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 IV-1, "miscellaneous" repairs make up over 40 percent 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 the TCEQ believed that a large fraction of inspectors did not fill out the repair list correctly, the TCEQ adopted the simpler list which was used during this evaluation period. Accuracy and completeness of repair data are common issues in I/M programs that attempt to collect repair data.

It is recommended that the TCEQ consider increasing the number of repair categories in the analyzer software, and eliminating the "Miscellaneous" category since that does not provide any useful information. Ideally, the repair choices that inspectors see and choose from would be only those that apply to the technology of the vehicle being inspected, although that does involve an increase in program complexity.

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 exist in the dataset, along with some extremely high (e.g. 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.

D. 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 trouble codes followed by an OBD pass (readiness criteria met, MIL commanded off and no DTCs) as an indicator that the I/M program is resulting in OBD repairs. In this analysis, it is assumed that an OBD fail result followed by an OBD pass result is due to vehicle repairs, although it is possible that some of the OBD fails followed by an OBD pass could result from intermittent problems, self-correcting problems (such as a loose gas cap that is tightened upon a vehicle refuel) or an OBD problem that is masked by unset readiness monitors (e.g., through a battery disconnect) on a subsequent passing re-test. This "masking" issue is analyzed later in this section. This analysis is analogous to the tailpipe emissions changes observed with repairs in Section IV-B.

Since OBD test pass/fail results are not enforced on HD vehicles, Class 2 vehicles were excluded from this analysis. This left a dataset of 17,097,005 OBD inspection records available for the analysis.

Overall Success of Repairs to Vehicles Failing OBD

For this task, ERG analyzed vehicle inspection records to identify tests with OBD failures and then determined how many of those failures were subsequently corrected. In addition, ERG created very specific definitions of OBD "fail" and "pass" to exclude initial test failures associated with readiness, such as failures due to OBD/analyzer communication problems, OBD test failures associated with inspector-entry and bulb-illumination checks, and OBD tests converted to ASM tests. 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 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.). These tests for which the OBD test was passed but the overall I/M test was failed were excluded from this analysis.

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 or until the vehicle received a waiver. 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, until a waiver was granted, or until the end of the evaluation period. Once the vehicle passed its inspection, 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 October 1, 2017, 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 December 31, 2017, and there would be no information for those inspections. Using these criteria, the dataset contained 14,315,164 OBD I/M cycles (including single-OBD-test passes) that started before October 1, 2017.

After grouping by I/M cycle for vehicles with OBD failures (as previously defined), 134,416 I/M cycles were seen to include at least one failed OBD test. Of these cycles, 113,163 (84.2 percent) had a final OBD test disposition of "pass," which for purposes of this analysis was defined as a test with a commanded MIL status of "pass" (MIL commanded off) and an OBD test disposition of "pass." The remaining 21,253 vehicles never passed a subsequent OBD test; for these vehicles it was learned that 16,036 of them received the initial failing result but did not ever report for a re-inspection. Additional re-inspections may have occurred after December 31 2017, which would increase the overall "repaired" numbers. Additionally, 529 of these vehicles received waivers.

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 later in this section.

Success of Repairs to Specific Emission Control Systems Failing OBD

For this analysis, DTCs were categorized based on the type of monitored system, and using this categorization, ERG performed an analysis of repairs based on component categories, in order to determine if the program was resulting in effective emission control system repairs. This task was performed as a continuation of the analysis in Section C. It uses combinations of vehicles and I/M cycles defined in that section. However, for this task, failure modes were assigned based on the DTCs contained in the failed test records.

Specifically, the analysis was performed on vehicles with DTC failures associated with oxygen sensors (O_2 Sensor), exhaust gas recirculation systems (EGR System), secondary air injection systems (AI System), catalytic converter efficiency (Catalyst), and evaporative emissions control system (Evap System) components[4]. The O_2 Sensor, EGR System, AI System, and Catalyst were included with this analysis because the readiness status of these systems, as well as the evaporative system, are specifically monitored by non-continuous monitors, and therefore the extent to which malfunctions may be masked by unset readiness monitors during a re-test (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 (as indicated by a fail test followed by a pass test).

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."

[4] A list of DTCs that were included in each of these groups is given in Appendix B.

To quantify the upper limit to which readiness may be masking unrepaired malfunctions during OBD re-tests, 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 evaporative system malfunction, then the evaporative system monitor is unset on the final "pass" test for this vehicle, thereby possibly masking an unrepaired evaporative system malfunction. Once this monitor becomes "ready," any unrepaired malfunction would result in a stored evaporative system DTC and MIL re-illumination.
- Confirmed Repaired – These are the vehicles whose monitors for which the initial failure occurred are "ready" in the final test, indicating that specific type of failure is not being masked by a "not-ready" monitor. 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." Because this subset of inspections were failed, it seems that incorrect reporting of monitor status is truly the cause as opposed to potential inspection fraud through clean-scanning.

With regard to criteria used for categorizing "pass" and "fail" tests, it should also be noted that historical or permanent DTCs without MIL illumination are trouble codes for previous malfunctions that don't necessarily indicate a current malfunction. In accordance with the EPA guidance, vehicles are not failed for historical or non-MIL permanent DTCs (stored DTCs but no MIL illumination) in the Texas I/M program. Pending DTCs are not collected in the Texas I/M program[5]. Results from this repair analysis 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's worthwhile to note that a failed OBD test record could contain more than one DTC. In the Texas I/M program, up to 10 DTCs may be stored in the test record,

[5] No state I/M program collects pending DTC data as per Mode $07 of SAE J1979. States only use Mode $03. DTCs read via Mode $03 have to be associated to MIL status, i.e. a DTC + MIL commanded on with a confirmed DTC.

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 IV-4 provides a summary of vehicle repairs (as indicated by OBD fails followed by OBD passes) performed over the period of evaluation. Since this analysis was performed on I/M data collected between January 1, 2016 through December 31, 2017, it is possible that some of the un-repaired vehicles were repaired in 2018. This would increase the "repaired" counts from the numbers shown in this table.

Table IV-4. 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	36,141	30,911	85.5%	14,156	39.2%	16,755	46.4%
O_2 Sensor	21,782	17,743	81.5%	379	1.7%	17,364	79.7%
EGR System	10,687	8,628	80.7%	621	5.8%	8,007	74.9%
AI System	1,862	1,465	78.7%	183	9.8%	1,282	68.9%
Catalyst	27,165	22,551	83.0%	3,402	12.5%	19,149	70.5%

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 IV-4 Also, only categories directly monitored with non-continuous monitors are tabulated in Table IV-4. Other failure categories for which readiness status would be more difficult to assess are excluded from the table. Table IV-5 indicates that readiness status may be masking malfunctions of 2 percent to 39 percent of vehicles that pass OBD re-tests based on MIL status with these types of failures. I/M program modifications that would require confirmation of specific failure-mode monitors being set to "ready" 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.

A comparison was also made between OBD evaporative system results and gas cap test results, on a by-test basis, for all OBD tests conducted during the period of evaluation. Table IV-5 presents a summary of these results.

Table IV-5. 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	16,536,025	98.5%	72,582	0.4%	16,608,607	16,536,025
Fail	184,538	1.1%	2,393	0.0%	186,931	184,538
Total	**16,720,563**	**99.6%**	**74,975**	**0.4%**	**16,795,538**	**16,720,563**

As can be seen from this table, approximately 1.1 percent of the tests had failed the OBD portion of the test with evaporative system DTCs, and gas cap failures were seen in 0.4 percent of the tests. The OBD evaporative system monitoring is designed to be a more comprehensive test since it assesses the integrity of the entire control system, but the OBD evaporative emissions control system fail rate may be lowered in part by unset evaporative system readiness monitors. Evaporative emissions control 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 (0.0 percent) failed both tests. Allowable pressure decay limits and enhanced OBD evaporative emissions control system test criteria may contribute to differences in fail rates of the two tests and the lack of overlap between the two tests.

Overall OBD / ASM / TSI Repair Slates

The most common repair slates for vehicles receiving each type of inspection (OBD, ASM, TSI) were also identified. The top six slates for each inspection type are listed in Table IV-6. The top set of repair slates was slightly different for each of the inspection types; since each inspection tests the vehicle somewhat differently, it would be expected that different types of repairs would result. The table also gives the total number of vehicles that received repairs (i.e., received one of the top six repairs or some other repair). It can be seen from Table IV-6 that substantially more repair data were available for ASM and OBD vehicles than for TSI vehicles due in part to the fewer number of TSI tests.

Table IV-6. Top Six Most Common Repair Slates for Each Inspection Test

Repair Description	OBD		TSI		ASM	
	Count	Percent	Count	Percent	Count	Percent
Miscellaneous	61,881	40.9%	483	33.3%	3,300	31.5%
Emissions System	35,570	23.5%	385	26.5%	4,214	40.2%
Fuel System	34,681	22.9%	297	20.5%	1,194	11.4%
Ignition/Electrical System	14,071	9.3%	216	14.9%	1,041	9.9%
Engine Mechanical	2,572	1.7%	26	1.8%	120	1.1%
Fuel System & Miscellaneous	753	0.5%	N/A	N/A	N/A	N/A
Emissions System & Miscellaneous	N/A	N/A	15	1.0%	192	1.8%
Other repair slates	1,623	1.1%	30	2.1%	424	4.0%
Total	**151,151**	**100.0%**	**1,452**	**100.0%**	**10,485**	**100.0%**

For OBD inspections, a failed inspection includes one or more DTCs that are set. The DTCs give information about what type of problem(s) the vehicle has that may necessitate repairs. When an OBD inspection is passed, no DTCs will be set. Therefore, the DTCs that are initially set and then finally unset (turned off) were compared to the repairs for OBD vehicles. Since there are far too many possible combinations of DTCs to create a "DTC slate" analogous to the repair slates (where all DTCs that were turned on during an inspection sequence are considered as a group, and the analysis is done on these groups), repairs were correlated with DTCs on an individual basis rather than as slates for the OBD repair analysis.

In Table IV-7, the five repair types are listed horizontally across the header row. Each row of the table represents one DTC. The number of times that each DTC was "turned off" in the same inspection cycle as each repair is given in the cells of the table. For example, in row 1 of the table, it can be seen that DTC P0420 (a catalyst system DTC) was most frequently turned off by "Emissions System" repairs (2,675 times), followed by "Miscellaneous" repairs (1,808 times). Rows with DTCs that relate to similar components or problems are grouped together in the table. The DTCs listed in Table IV-7 are the most commonly recorded DTCs, representing about two-thirds of the total DTC repair counts.

Table IV-7. Most Common OBD DTCs and Associated Repairs

DTC Name	Repair Description	Repair Type										Total
		Fuel System		Ignition/ Electrical System		Emissions System		Engine Mechanical		Miscellaneous		
		N	%	N	%	N	%	N	%	N	%	N
P0420	Catalyst System Efficiency Below Threshold (Bank 1)	1,216	19%	466	7%	2,675	43%	85	1%	1,808	29%	6,250
P0430	Catalyst System Efficiency Below Threshold (Bank 2)	459	19%	160	7%	1,016	43%	38	2%	689	29%	2,362
P0300	Random/Multiple Cylinder Misfire Detected	573	22%	514	20%	670	26%	84	3%	771	30%	2,612
P0301	Cylinder 1 Misfire Detected	274	21%	301	23%	337	25%	52	4%	366	28%	1,330
P0302	Cylinder 2 Misfire Detected	261	21%	300	24%	299	24%	53	4%	342	27%	1,255
P0303	Cylinder 3 Misfire Detected	258	21%	280	23%	285	24%	37	3%	351	29%	1,211
P0304	Cylinder 4 Misfire Detected	274	22%	276	22%	274	22%	46	4%	387	31%	1,257
P0305	Cylinder 5 Misfire Detected	176	23%	170	22%	171	22%	21	3%	223	29%	761
P0306	Cylinder 6 Misfire Detected	167	23%	153	21%	162	22%	24	3%	217	30%	723
P0440	Evaporative Emission Control System Malfunction	257	19%	103	8%	536	39%	27	2%	447	33%	1,370
P0441	Evaporative Emission Control System Incorrect Purge Flow	268	20%	92	7%	501	38%	27	2%	430	33%	1,318
P0442	Evaporative Emission Control System Leak Detected (small leak)	505	23%	154	7%	806	36%	38	2%	719	32%	2,222
P0446	Evap Emiss Control Sys. Vent Control Circuit Malfunction	323	21%	102	7%	605	40%	30	2%	459	30%	1,519
P0449	Evap Emiss Control Sys. Vent Valve/Solenoid Circuit Malfunction	221	21%	68	6%	434	40%	19	2%	333	31%	1,075
P0455	Evaporative Emiss Control Sys. Leak Detected (gross leak)	587	22%	170	6%	997	37%	44	2%	888	33%	2,686
P0457	Evaporative Emission System Leak Detected (fuel cap loose/off)	144	24%	28	5%	204	34%	13	2%	206	35%	595

Table IV-7. Most Common OBD DTCs and Associated Repairs

DTC Name	Repair Description	Repair Type: Fuel System N	%	Ignition/ Electrical System N	%	Emissions System N	%	Engine Mechanical N	%	Miscellaneous N	%	Total N
P0401	Exhaust Gas Recirculation Flow Insufficient Detected	362	17%	155	7%	929	44%	48	2%	621	29%	2,115
P0171	Fuel System too Lean (Bank 1)	1,043	24%	364	8%	1,322	31%	104	2%	1,454	34%	4,287
P0174	Fuel System too Lean (Bank 2)	629	23%	231	9%	829	31%	71	3%	927	34%	2,687
P0101	Mass Air Flow (MAF) Circuit Range/Performance	115	26%	32	7%	130	29%	14	3%	150	34%	441
P0102	Mass or Volume Air Flow Circuit Low Input	142	25%	52	9%	174	31%	14	2%	183	32%	565
P0135	O_2 Sensor Heater Circuit Malfunction (Bank 11 Sensor 1)	416	31%	113	8%	393	29%	24	2%	397	30%	1,343
P0139	O_2 Sensor Circuit Slow Response Bank 1 Sensor 2	48	38%	13	10%	37	29%	4	3%	24	19%	126
P0141	O_2 Sensor Heater Circuit Malfunction (Bank 11 Sensor2)	369	31%	91	8%	345	29%	30	3%	357	30%	1,192
P0325	Knock Sensor 1 Circuit Malfunction (Bank 1 or Single Sensor2)	144	21%	88	13%	209	31%	28	4%	212	31%	681
P0328	Knock Sensor 1 Circuit High, Bank 1 or Single Sensor	41	22%	21	11%	51	28%	6	3%	64	35%	183
P0121	Throttle Position Sensor/Switch A Circuit Malfunction	156	25%	54	9%	161	26%	16	3%	228	37%	615
P0128	Coolant Temperature Below Thermostat Regulating Temp.	320	18%	155	9%	488	28%	55	3%	730	42%	1,748
P0700	Transmission Control System Malfunction	108	20%	43	8%	132	25%	19	4%	225	43%	527

E. AVERAGE REPAIR COSTS

The TIMS dataset contains manually entered costs for I/M program repairs. This information was analyzed to provide a rough estimate of the cost of vehicle repairs as a result of the Texas I/M program.

In order to estimate repair costs based on type of repair, repair categories were developed for each vehicle for a given I/M cycle. A repair category is a concatenation of the set of repair types performed in a repair event. The five different repair types listed in Table IV-1 were combined to produce the seven most common repair categories, which account for approximately 99.1 percent of all vehicle and I/M cycle combinations. These categories are presented in Table IV-9.

Over one half (53.8 percent) of the repair costs in the TIMS were recorded as $0. There are several possible reasons for this, including inaccurate repair data entry during a vehicle re-inspection; motorists performing their own repairs; lack of repair data available during a vehicle re-inspection; or vehicles receiving a re-test without receiving repairs, such as vehicles that fail due to a readiness monitor and need to simply be driven until the monitors pass their readiness tests. 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 IV-8 presents the number of records with a cost of $0 by repair category. It was observed that most categories listed contained about 20-40 percent $0 repair costs, but fuel system and miscellaneous repairs contained a much higher percentage (about 54.8 percent and 67.6 percent, respectively). All these percentages are comparable to those in the 2014 and 2016 reports, but markedly higher than those observed in previous TIMS data analyses.

It was also noted than many of the repair costs 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 invalid data entry by inspectors during vehicle re-inspections. Figure IV-1 presents a histogram of repairs that cost more than $2000.

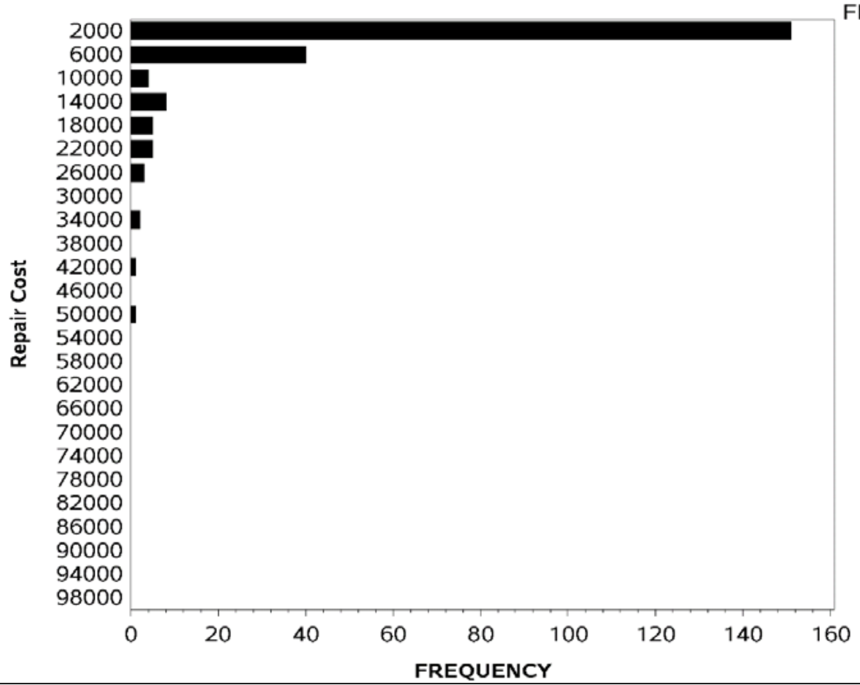
Table IV-8. TIMS Records with a Repair Cost of $0, by Category

Repair Category	Cost > 0	Cost = Zero	Total	% of Cost = 0
Fuel System and Emissions System	716	118	834	14.1
Emissions System & Miscellaneous	478	361	839	43.0
Engine Mechanical	1,988	726	2714	26.8
Ignition / Electrical System	9,902	5,406	15,308	35.3
Fuel System	16,337	19,813	36,150	54.8
Miscellaneous	23,570	16,578	40,148	41.3
Emissions System	21,246	44,383	65,629	67.6
Total	**74,237**	**87,385**	**161,622**	**54.1**

Table IV-9 presents median and mean repair costs for each of the repair types specified in the 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 161,000 repairs while spending approximately \$14.5 million. According to the edited dataset, which leaves out \$0 cost and greater than \$2,000 cost observations, vehicle owners performed 94,000 repairs while spending approximately \$13.3 million.

Figure IV-2 and Figure IV-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, entered repair costs as a whole have not increased from year to year. Due to the limited control in repair data entry and the large number of suspect values in the TIMS repair data, these results may be significantly different from true repair costs resulting from the Texas I/M program.

Figure IV-1. Repairs with Cost Greater than \$2000



Repair Cost	FREQ.	CUM. FREQ.	PCT.	CUM. PCT.
2000	151	151	68.64	68.64
6000	40	191	18.18	86.82
10000	4	195	1.82	88.64
14000	8	203	3.64	92.27
18000	5	208	2.27	94.55
22000	5	213	2.27	96.82
26000	3	216	1.36	98.18
30000	0	216	0.00	98.18
34000	2	218	0.91	99.09
38000	0	218	0.00	99.09
42000	1	219	0.45	99.55
46000	0	219	0.00	99.55
50000	1	220	0.45	100.00
54000	0	220	0.00	100.00
58000	0	220	0.00	100.00
62000	0	220	0.00	100.00
66000	0	220	0.00	100.00
70000	0	220	0.00	100.00
74000	0	220	0.00	100.00
78000	0	220	0.00	100.00
82000	0	220	0.00	100.00
86000	0	220	0.00	100.00
90000	0	220	0.00	100.00
94000	0	220	0.00	100.00
98000	0	220	0.00	100.00

Table IV-9. Average Repair Costs

Year of Inspection	Repair Category	Original Dataset			Costs Between $0 and $2000		
		Number of Repairs	Median Repair Cost	Mean Repair Cost	Number of Repairs	Median Repair Cost	Mean Repair Cost
2016	Fuel System and Emissions System	252	$162	$282	191	$260	$353
2016	Emissions System & Miscellaneous	469	$180	$223	408	$200	$256
2016	Engine Mechanical	1,445	$135	$243	1,038	$200	$287
2016	Ignition / Electrical System	8,018	$67	$117	5,138	$125	$174
2016	Fuel System	18,342	$0	$76	8,278	$100	$158
2016	Emissions System	21,479	$80	$162	12,873	$199	$255
2016	Miscellaneous	34,500	$0	$34	11,232	$40	$94
2017	Fuel System and Emissions System	232	$156	$239	165	$240	$324
2017	Emissions System & Miscellaneous	365	$180	$220	308	$210	$260
2017	Engine Mechanical	1,269	$135	$287	919	$200	$286
2017	Ignition / Electrical System	7,290	$85	$130	4,746	$143	$186
2017	Fuel System	17,808	$0	$86	8,020	$100	$172
2017	Emissions System	18,669	$50	$156	10,618	$199	$258
2017	Miscellaneous	31,129	$0	$36	9,973	$45	$94

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

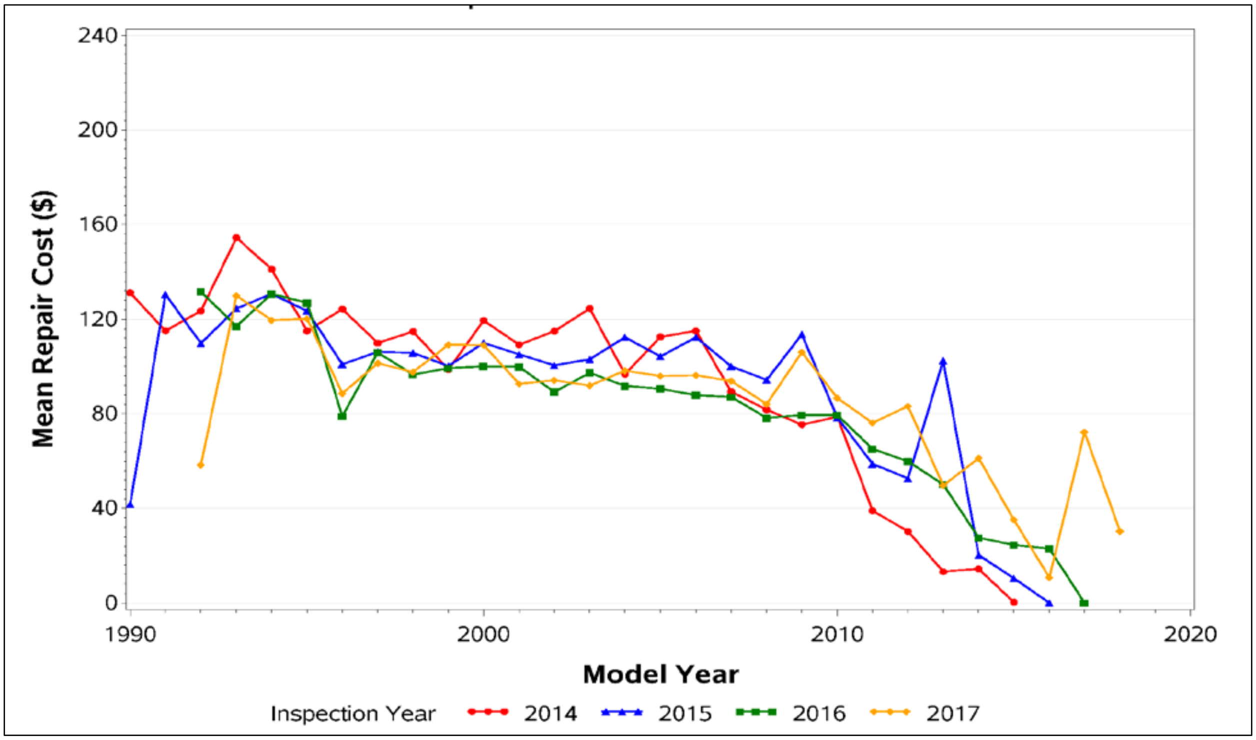


Figure IV-3. Mean Repair Costs by Model Year and Inspection Year (Edited Dataset)

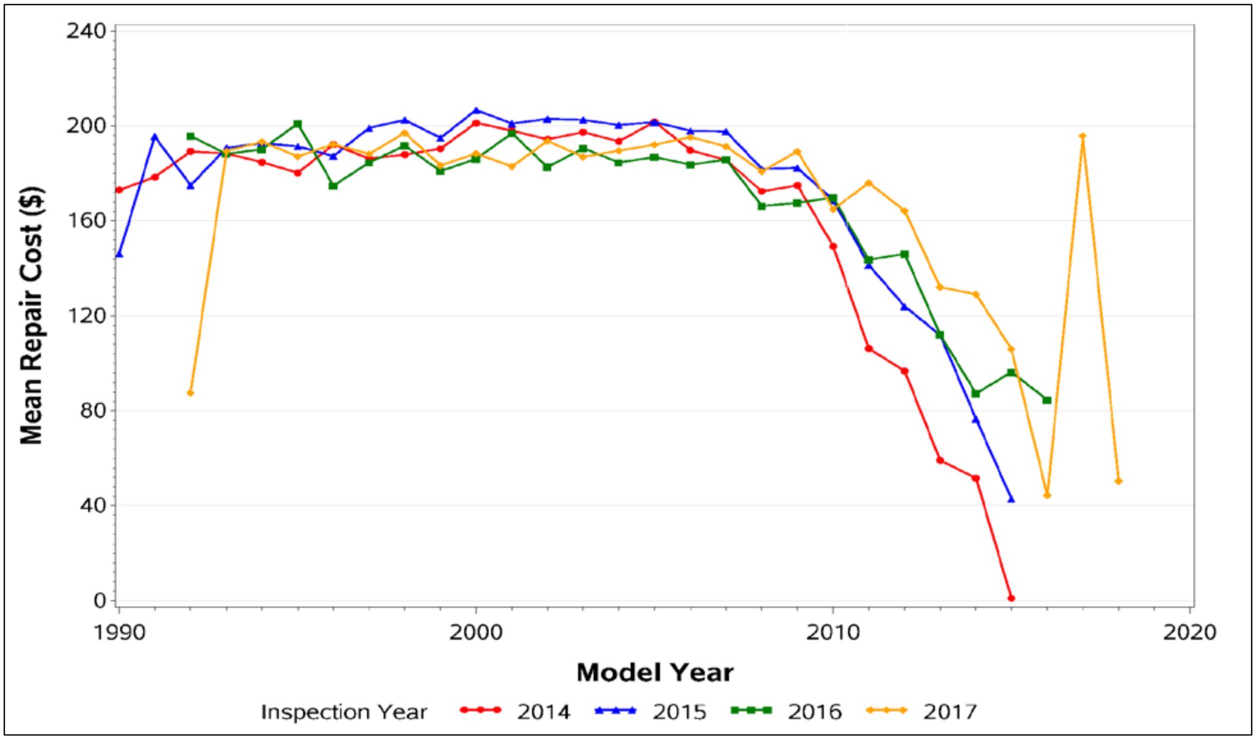


Figure IV-4 and Figure IV-5 present the percentile distribution of repair costs for the most common TIMS repair categories, for both the unedited and edited datasets. The unedited data contains repairs with an average cost of $0 for all repair slates, but miscellaneous repairs costing $0 extend close to the 70th percentile, considerably more than the other categories.

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 IV-4. Distribution of Repair Costs by Category (Unedited Dataset)

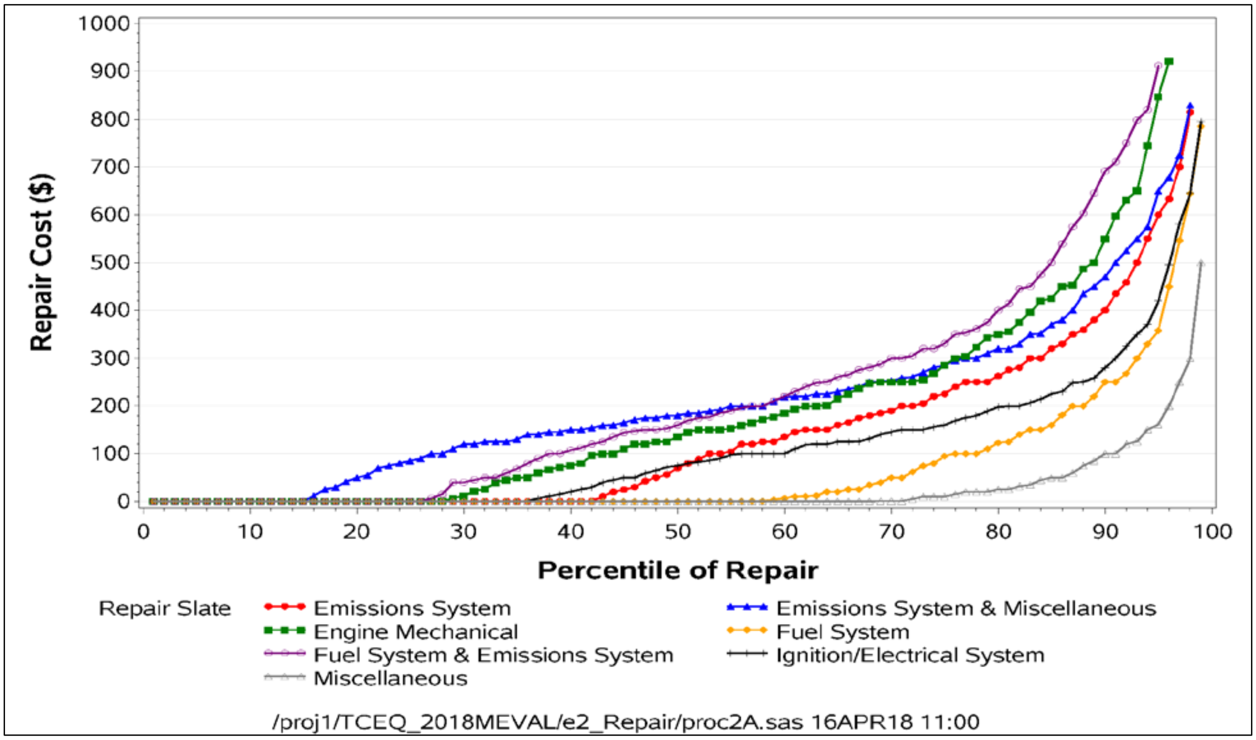
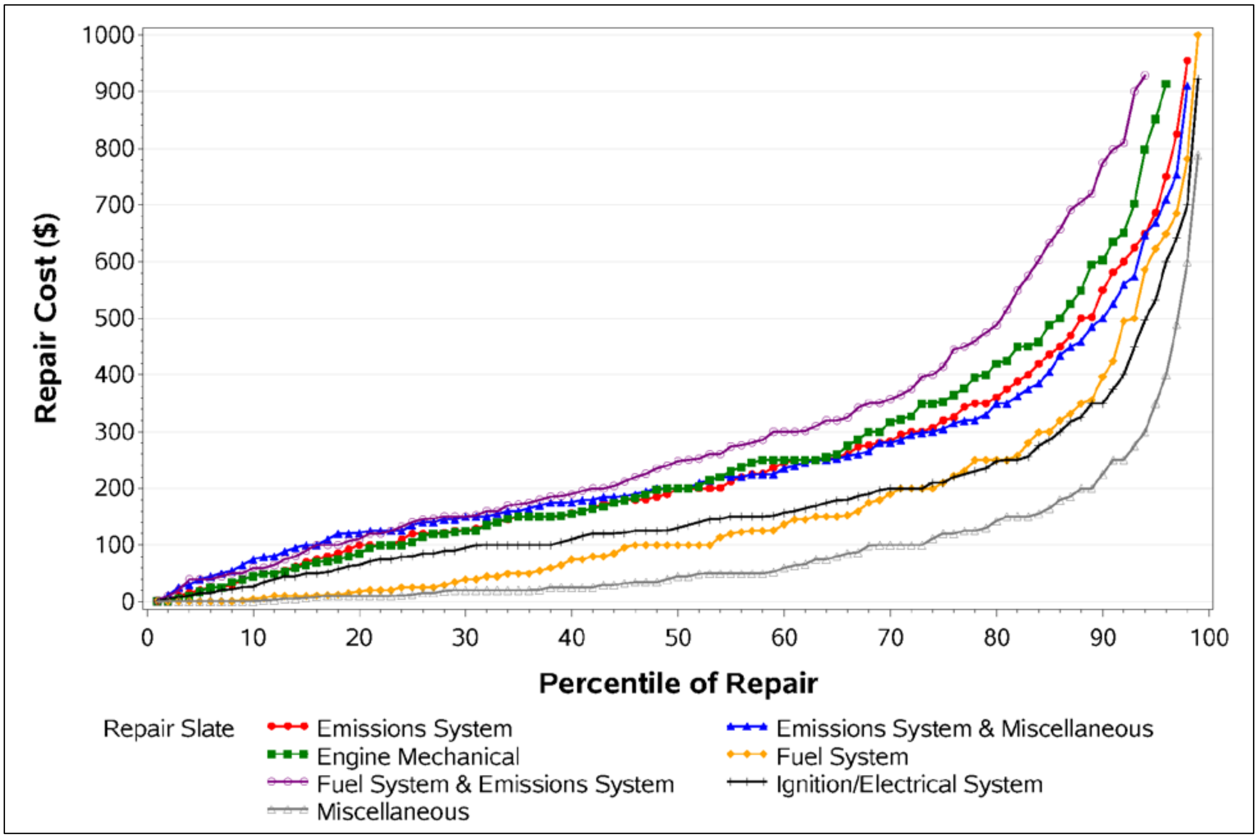


Figure IV-5. Distribution of Repair Costs by Category (Edited Dataset)



F. RERF ANALYSIS

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 because of the Texas I/M program. Table IV-10 shows the counts of repairs reported by stations participating in the RERF program. A total of 1,371 RERF repairs were provided to ERG for analysis. However, it should be noted that 9,123 records in the TIMS dataset include the identification number of a RERF that performed the repair. It is not clear why the RERF dataset available for this analysis only contains 1,371 of the 9,123 records recorded in the TIMS database.

Table IV-10. Repairs Performed at RERF Stations

Repair Type	Defective, Not Repaired	Repaired	% Repaired	Total Vehicles with This Defect	Defect % of Total
Catalyst	6	136	95.8	142	10.5
Camshaft	0	14	100.0	14	1.0
CylinderHead	0	14	100.0	14	1.0
EGR/VVT	2	68	97.1	70	5.2
EVAP	1	148	99.3	149	11.0
EmissionsSystem	3	43	93.5	46	3.4
Eng.Cooling	0	60	100.0	60	4.4
EngineBlock	0	1	100.0	1	0.1
EngineExhaust	0	9	100.0	9	0.7
EngineMechanical	3	26	89.7	29	2.1
FuelFilter	1	10	90.9	11	0.8
FuelPump	1	13	92.9	14	1.0
FuelSystem	3	25	89.3	28	2.1
Ignition/ElectricalSystem	1	39	97.5	40	3.0
Injectors	0	112	100.0	112	8.3
Miscellaneous	8	105	92.9	113	8.3
O2Sensor	6	161	96.4	167	12.3
PCM	1	24	96.0	25	1.8
PCV	0	16	100.0	16	1.2
SparkPlugWires	1	44	97.8	45	3.3
SparkPlugs	1	90	98.9	91	6.7
SparkTiming	2	40	95.2	42	3.1
TAC	0	2	100.0	2	0.1
ThrottleBody	0	51	100.0	51	3.8
Trans/FinalDrive	0	28	100.0	28	2.1
Valves(Mechanical)	1	19	95.0	20	1.5
Valves(OilSeals)	0	9	100.0	9	0.7
VehicleFluids	0	7	100.0	7	0.5
Total	41	1314	97.0	1355	100.0

RERF Costs

Analysis of the RERF data indicates vehicle owners spent over $464,000 on 786 repair events (some included the repair of more than one component) at RERFs, resulting in mean and median repair costs of $590 and $591, respectively. These results were obtained from data collected from repair summary data submitted to DPS by repair shops participating in the RERF program.

In order to estimate repair costs based on type of repair, repair categories (referred to as repair slates) were developed for each vehicle for a given I/M cycle. As with the TIMS data analysis, a repair category 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 IV-10 were combined to produce the fourteen most common repair slates – these are the 14 repair slates with at least ten repairs in the group. These 14 categories and the costs associated with repairs for each are given in Table IV-11.

Table IV-11. RERF Repair Category Average Costs

Repair Category	Number of Repairs	Median Repair Cost	Mean Repair Cost
EVAP	67	$464	$416
Catalyst	61	$664	$631
Miscellaneous	56	$343	$180
O2 Sensor	41	$427	$436
EGR/VVT	14	$567	$586
Injectors_CAT	14	$594	$617
Emissions System	13	$395	$300
Engine Mechanical	13	$486	$545
O2Sensor & Miscellaneous	13	$483	$426
Spark Plugs	11	$654	$597
Spark Timing	11	$733	$592
Eng. Cooling	10	$468	$463
O2Sensor & Catalyst	10	$650	$623
PCM	10	$658	$738

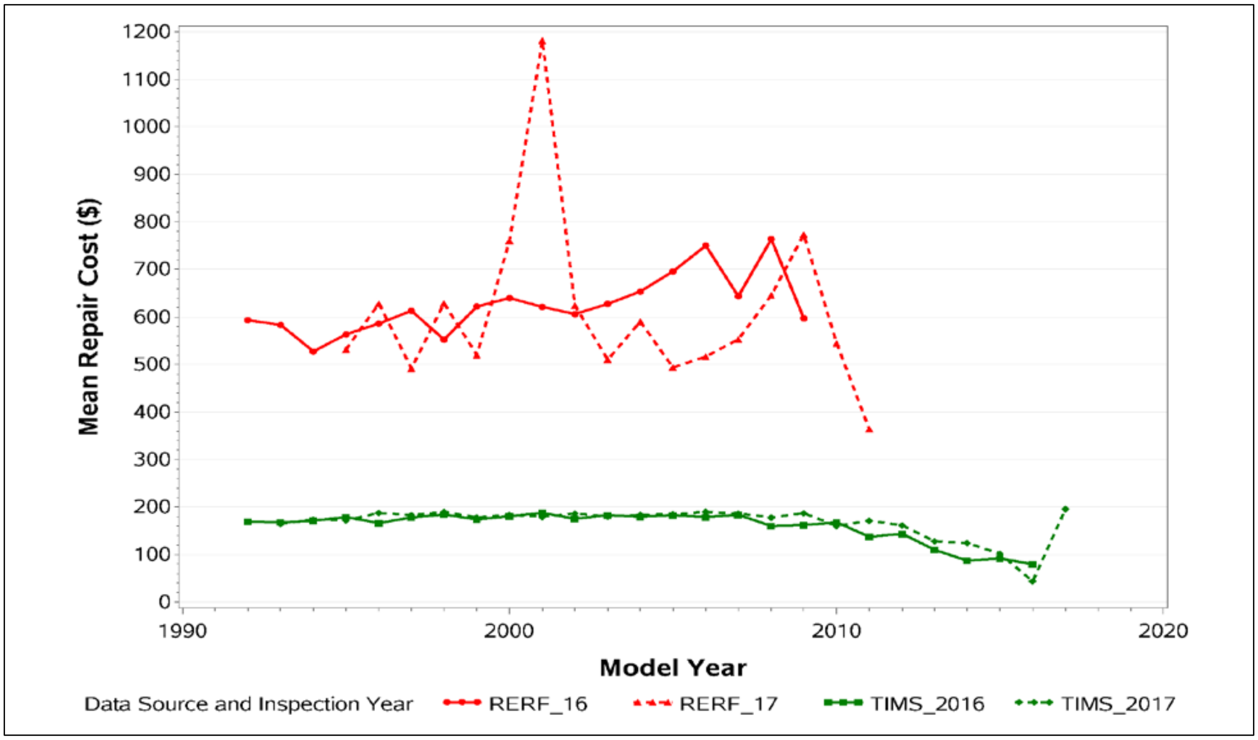
Figure IV-6 presents mean repair costs by inspection year and model year, for the RERF and TIMS datasets. Average repair costs for the RERF data tend to fall in the $500 - $700 range, which is significantly higher than the $150 - $200 range seen in the TIMS data[6]. Data points for model years with fewer than 10 repaired vehicles are not shown, as the means might not be representative. Even so, the RERF averages are somewhat noisy, with a particularly high spike for model year 2001.

There is a large difference in the TIMS versus RERF average repair cost data. As noted, obtaining accurate repair data is difficult and this certainly contributes to the problem. However, another explanation may be that the repair costs for RERF stations is higher than average repair stations since these stations voluntarily participate in the RERF

[6] This analysis uses the "edited" TIMS cost data, which excludes repair costs of $0 and repair costs greater than $2000 from the means.

program and, therefore, are more likely to make repairs that are more technically challenging and, more expensive. It is also possible that the inspection technicians are less likely to enter accurate repair cost data because unlike the RERF technicians they have no first-hand knowledge of the repair and the RERF technicians realize that repair cost data is used to rank their facility, and this motivates them to be more conscientious in filling out the repair form.

Figure IV-6. Mean Repair Costs by Data Source, Model Year and Inspection Year



In the 2014 I/M evaluation and earlier I/M evaluations, the distribution of repair costs by repair category was also presented. However, given the much smaller number of RERF records available in 2016 and 2018, the number of vehicles in even the largest repair slate categories resulted in plots too noisy to be informative in the 2016 or 2018 analyses.

V. 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 repair and then upward from emissions degradation before the next I/M cycle. The analyses presented in Sections V.1 and V.2 are annual benefits based on the TIMS data alone (Section V.A) or pairing the TIMS data with RS data (Section V.B).

A. ESTIMATE OF ANNUAL I/M BENEFIT FROM TIMS DATA

ERG used two years of the TIMS data to calculate the Annual Benefit of the Texas I/M program. This analysis only applies to estimating the benefits of the ASM and TSI test because the OBD test does not provide any emission measurement data. 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, which are described below. 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 Texas 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 from the end of the I/M sequence are used for estimating program benefits. 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-duration ASM value. Therefore, the TIMS ASM test values have not been corrected for fast passes. Accordingly, the calculated benefit of I/M-induced repairs from fast-pass ASM tests tends to underestimate the program's true 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 data 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 measurements 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 III.C were combined into these four categories for the purposes of calculating the Annual I/M Benefit. 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. Waivers are flagged separately, but are not removed from these calculations.
- 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 89 percent of all sequences. The FP sequences are the next most common and make up about 10 percent of all sequences. The 1F and FF sequences are less common and make up the remaining 1 percent 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 present the results in various ways. Table V-1 and Table V-2 document the average emission concentration values for ASM and TSI tests, respectively, in both the DFW and HGB program areas during this evaluation period (i.e., the 2018 report covering 2016 and 2017 program years). The values also show the measured average change in emissions concentrations at the inspection events. In the last row of each table, it can be seen that ASM HC decreased 13 to 18 percent, ASM CO decreased 24 to 27 percent, ASM NO_X decreased 15 to 18 percent, TSI HC decreased 17 to 19 percent, and TSI CO decreased 19 to 22 percent. As described above, these changes are confounded by the effects of the fast-pass algorithm (which tends to underestimate the program's emission reduction) and by regression toward the mean (which tends to overestimate the program's emission reduction). These averages include all four of the I/M sequence categories of 1P, 1F, FF and FP, but the focus of the analysis below is on the 1P and FP categories as they constitute the great majority of the data.

The second block of data in each of Table V-1 and Table V-2 shows the emissions averages for the DFW and HGB program areas categorized by the two major I/M sequence categories, 1P and FP. These two categories make up 99 percent of the I/M sequences in the datasets. The table shows that, of course, for the 1P category the change in emissions is 0 percent since these vehicles simply initially pass. However, for the FP category, the ASM measurements and TSI measurements show large emissions decreases from 57 to 83 percent. These are emission reductions of 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 the DFW and HGB program areas have approximately the same values.

Another observation that can be made from the data in Table V-1 and Table V-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 complicates this comparison is that the technologies of the 1P vehicles and FP vehicles are probably quite different. Table V-3 and Table V-4 contain these same values from the 2016 Report (covering 2014 and 2015 program years) and are included here as a point of reference. Table V-5 and Table V-6 contain these same values from the 2014 report (covering 2012 and 2013 program years), and Table V-7 and Table V-8 contain these same values from the 2012 report (covering 2010 and 2011 program years). The new results in this current report are very similar to the 2016, 2014, and 2012 results, or slightly lower for some pollutants. It is possible this could be because the Texas I/M program has been effectively encouraging owners to maintain their vehicles over the years but has possibly reached a plateau in the achievement of additional reductions. As stated in the Recommendations, one way to address this more thoroughly would to collect RS data from a non-program area such as San Antonio, which would help quantify the affect of the I/M program in DFW and HGB.

Table V-1. 2018 Report Annual I/M Benefit Using TIMS Data for ASM Emissions

ASM HC (ppm)								
			5015			2525		
Area	Seq.	Count	Initial	Final	% Change	Initial	Final	% Change
DFW	1P	71,465	65.5	65.5	0.0%	43.1	43.1	0.0%
	FP	10,733	149.1	64.3	-56.9%	126.9	47.2	-62.8%
	1P+FP	85,007	81.5	70.8	-13.1%	58.8	48.9	-16.9%
HGB	1P	67,778	58.1	58.1	0.0%	39.0	39.0	0.0%
	FP	8,700	149.7	58.7	-60.8%	128.9	42.2	-67.2%
	1P+FP	77,819	70.7	60.7	-14.1%	51.6	42.1	-18.4%
DFW & HGB	1P	139,243	61.9	61.9	0.0%	41.1	41.1	0.0%
	FP	19,433	149.4	61.8	-58.6%	127.8	45.0	-64.8%
	1P+FP	162,826	76.3	66.0	-13.5%	55.4	45.6	-17.6%
ASM CO (%)								
DFW	1P	71,465	0.200	0.200	0.0%	0.151	0.151	0.0%
	FP	10,733	0.757	0.199	-73.7%	0.687	0.166	-75.9%
	1P+FP	85,007	0.302	0.233	-22.8%	0.250	0.186	-25.7%
HGB	1P	67,778	0.185	0.185	0.0%	0.147	0.147	0.0%
	FP	8,700	0.804	0.190	-76.3%	0.742	0.157	-78.8%
	1P+FP	77,819	0.271	0.204	-24.5%	0.231	0.168	-27.4%
DFW & HGB	1P	139,243	0.192	0.192	0.0%	0.149	0.149	0.0%
	FP	19,433	0.778	0.195	-74.9%	0.712	0.162	-77.2%
	1P+FP	162,826	0.287	0.219	-23.6%	0.241	0.177	-26.5%
ASM NOx (ppm)								
DFW	1P	71,465	483	483	0.0%	365	365	0.0%
	FP	10,733	1284	512	-60.1%	1130	415	-63.3%
	1P+FP	85,007	617	521	-15.5%	493	405	-17.9%
HGB	1P	67,778	421	421	0.0%	326	326	0.0%
	FP	8,700	1141	444	-61.1%	1019	356	-65.1%
	1P+FP	77,819	516	440	-14.8%	418	345	-17.3%
DFW & HGB	1P	139,243	453	453	0.0%	346	346	0.0%
	FP	19,433	1220	482	-60.5%	1080	388	-64.1%
	1P+FP	162,826	568	482	-15.2%	457	376	-17.7%

Table V-2. 2018 Report Annual I/M Benefit Using TIMS Data for TSI Emissions

TSI HC (ppm)								
			Curb			High		
Area	Seq.	Count	Initial	Final	% Change	Initial	Final	% Change
DFW	1P	18,120	84.3	84.3	0.0%	46.9	46.9	0.0%
	FP	1,847	414.8	95.4	-77.0%	253.0	53.5	-78.9%
	1P+FP	20,262	110.8	93.3	-15.7%	63.6	52.4	-17.5%
HGB	1P	13,852	74.2	74.2	0.0%	40.7	40.7	0.0%
	FP	1,380	385.5	86.8	-77.5%	226.5	47.5	-79.0%
	1P+FP	15,414	101.5	82.7	-18.5%	56.9	45.3	-20.4%
DFW & HGB	1P	31,972	79.9	79.9	0.0%	44.2	44.2	0.0%
	FP	3,227	401.1	91.7	-77.1%	240.6	50.9	-78.8%
	1P+FP	35,676	106.7	88.7	-16.9%	60.7	49.4	-18.7%
TSI CO (%)								
DFW	1P	18,120	0.212	0.212	0.0%	0.228	0.228	0.0%
	FP	1,847	1.410	0.251	-82.2%	1.251	0.272	-78.2%
	1P+FP	20,262	0.303	0.242	-20.3%	0.306	0.253	-17.2%
HGB	1P	13,852	0.190	0.190	0.0%	0.198	0.198	0.0%
	FP	1,380	1.305	0.224	-82.8%	1.141	0.243	-78.7%
	1P+FP	15,414	0.282	0.214	-24.4%	0.276	0.219	-20.7%
DFW & HGB	1P	31,972	0.202	0.202	0.0%	0.215	0.215	0.0%
	FP	3,227	1.361	0.239	-82.4%	1.199	0.260	-78.3%
	1P+FP	35,676	0.294	0.230	-22.0%	0.293	0.238	-18.6%

Table V-3. 2016 Report Annual I/M Benefit Using TIMS Data for ASM Emissions

ASM HC (ppm)								
			5015			2525		
Area	Seq.	Count	Initial	Final	% Change	Initial	Final	% Change
DFW	1P	135,052	64.8	64.8	0.0%	42.9	42.9	0.0%
	FP	18,496	156.7	64.5	-58.8%	132.9	47.7	-64.1%
	1P+FP	157,331	78.9	68.3	-13.5%	56.8	46.9	-17.4%
HGB	1P	122,112	61.0	61.0	0.0%	40.7	40.7	0.0%
	FP	15,446	141.0	60.8	-56.9%	120.9	43.6	-64.0%
	1P+FP	139,786	72.3	63.6	-12.0%	52.0	43.5	-16.2%
DFW & HGB	1P	257,164	63.0	63.0	0.0%	41.8	41.8	0.0%
	FP	33,942	149.6	62.8	-58.0%	127.5	45.8	-64.1%
	1P+FP	297,117	75.8	66.1	-12.9%	54.5	45.3	-16.9%
ASM CO (%)								
DFW	1P	135,052	0.20	0.20	0.0%	0.15	0.15	0.0%
	FP	18,496	0.83	0.20	-75.5%	0.78	0.17	-78.1%
	1P+FP	157,331	0.30	0.22	-24.4%	0.25	0.18	-28.1%
HGB	1P	122,112	0.19	0.19	0.0%	0.15	0.15	0.0%
	FP	15,446	0.81	0.19	-76.6%	0.75	0.15	-79.6%
	1P+FP	139,786	0.27	0.21	-24.3%	0.23	0.16	-28.2%
DFW & HGB	1P	257,164	0.20	0.20	0.0%	0.15	0.15	0.0%
	FP	33,942	0.82	0.20	-76.0%	0.76	0.16	-78.8%
	1P+FP	297,117	0.29	0.22	-24.3%	0.24	0.17	-28.1%
ASM NOx (ppm)								
DFW	1P	135,052	456	456	0.0%	348	348	0.0%
	FP	18,496	1319	482	-63.5%	1157	391	-66.2%
	1P+FP	157,331	582	485	-16.6%	466	378	-19.0%
HGB	1P	122,112	426	426	0.0%	328	328	0.0%
	FP	15,446	1122	443	-60.5%	986	352	-64.3%
	1P+FP	139,786	518	445	-14.2%	415	346	-16.5%
DFW & HGB	1P	257,164	442	442	0.0%	338	338	0.0%
	FP	33,942	1230	464	-62.3%	1079	373	-65.4%
	1P+FP	297,117	552	466	-15.5%	442	363	-17.9%

Table V-4. 2016 Report Annual I/M Benefit Using TIMS Data for TSI Emissions

TSI HC (ppm)								
			Curb			High		
Area	Seq.	Count	Initial	Final	% Change	Initial	Final	% Change
DFW	1P	26,985	81.6	81.6	0.0%	45.5	45.5	0.0%
	FP	2,789	434.7	95.2	-78.1%	255.3	53.0	-79.3%
	1P+FP	30,131	109.7	90.3	-17.7%	61.9	50.4	-18.5%
HGB	1P	21,925	77.1	77.1	0.0%	43.6	43.6	0.0%
	FP	2,221	350.8	87.5	-75.1%	215.1	48.3	-77.5%
	1P+FP	24,440	102.8	84.6	-17.7%	60.3	48.8	-19.1%
DFW & HGB	1P	126,950	76.9	76.9	0.0%	42.6	42.6	0.0%
	FP	12,609	322.3	92.3	-71.4%	190.6	50.3	-73.6%
	1P+FP	141,470	103.4	85.3	-17.5%	58.8	47.7	-18.8%
TSI CO (%)								
DFW	1P	26,985	0.20	0.20	0.0%	0.22	0.22	0.0%
	FP	2,789	1.44	0.24	-83.5%	1.28	0.26	-79.7%
	1P+FP	30,131	0.30	0.23	-23.4%	0.30	0.24	-19.2%
HGB	1P	21,925	0.19	0.19	0.0%	0.21	0.21	0.0%
	FP	2,221	1.27	0.24	-81.4%	1.06	0.25	-76.5%
	1P+FP	24,440	0.29	0.22	-24.1%	0.29	0.23	-18.7%
DFW & HGB	1P	126,950	0.18	0.18	0.0%	0.21	0.21	0.0%
	FP	12,609	1.07	0.22	-79.3%	0.99	0.26	-73.8%
	1P+FP	141,470	0.28	0.21	-23.9%	0.29	0.24	-19.2%

Table V-5. 2014 Report Annual I/M Benefit Using TIMS Data for ASM Emissions

ASM HC (ppm)								
			5015			2525		
Area	Seq.	Count	Initial	Final	% Change	Initial	Final	% Change
DFW	1P	312,423	65.4	65.4	0.0%	42.4	42.4	0.0%
	FP	32,878	162.8	63.6	-60.9%	143.0	46.6	-67.4%
	1P+FP	352,673	77.3	68.3	-11.7%	54.6	45.9	-16.0%
HGB	1P	281,083	61.6	61.6	0.0%	40.5	40.5	0.0%
	FP	23,765	170.0	60.8	-64.3%	150.8	44.2	-70.7%
	1P+FP	309,856	71.9	63.7	-11.4%	51.0	43.0	-15.6%
DFW & HGB	1P	593,506	63.6	63.6	0.0%	41.5	41.5	0.0%
	FP	56,643	165.9	62.4	-62.4%	146.3	45.6	-68.9%
	1P+FP	662,529	74.8	66.2	-11.5%	52.9	44.5	-15.9%
ASM CO (%)								
DFW	1P	312,423	0.20	0.20	0.0%	0.15	0.15	0.0%
	FP	32,878	1.02	0.20	-80.1%	0.96	0.16	-82.8%
	1P+FP	352,673	0.30	0.23	-24.8%	0.25	0.17	-29.7%
HGB	1P	281,083	0.19	0.19	0.0%	0.14	0.14	0.0%
	FP	23,765	1.07	0.19	-82.7%	1.03	0.15	-85.1%
	1P+FP	309,856	0.27	0.21	-24.3%	0.23	0.16	-28.9%
DFW & HGB	1P	593,506	0.20	0.20	0.0%	0.15	0.15	0.0%
	FP	56,643	1.04	0.20	-81.2%	0.99	0.16	-83.8%
	1P+FP	662,529	0.29	0.22	-24.6%	0.24	0.17	-29.3%
ASM NOx (ppm)								
DFW	1P	312,423	473	473	0.0%	355	355	0.0%
	FP	32,878	1485	492	-66.9%	1320	397	-70.0%
	1P+FP	352,673	586	495	-15.5%	463	379	-18.2%
HGB	1P	281,083	443	443	0.0%	336	336	0.0%
	FP	23,765	1422	455	-68.0%	1278	360	-71.8%
	1P+FP	309,856	530	457	-13.7%	419	350	-16.4%
DFW & HGB	1P	593,506	459	459	0.0%	346	346	0.0%
	FP	56,643	1459	476	-67.3%	1303	381	-70.7%
	1P+FP	662,529	560	477	-14.7%	443	366	-17.4%

Table V-6. 2014 Report Annual I/M Benefit Using TIMS Data for TSI Emissions

TSI HC (ppm)								
			Curb			High		
Area	Seq.	Count	Initial	Final	% Change	Initial	Final	% Change
DFW	1P	51,466	79.8	79.8	0.0%	42.6	42.6	0.0%
	FP	4,680	534.3	93.6	-82.5%	337.6	54.6	-83.8%
	1P+FP	56,888	107.8	88.6	-17.9%	61.3	49.1	-19.9%
HGB	1P	37,458	78.8	78.8	0.0%	42.3	42.3	0.0%
	FP	2,734	562.0	89.5	-84.1%	323.1	51.7	-84.0%
	1P+FP	40,687	106.8	86.5	-19.0%	58.6	47.1	-19.6%
DFW & HGB	1P	88,924	79.4	79.4	0.0%	42.5	42.5	0.0%
	FP	7,414	545.8	92.1	-83.1%	331.6	53.5	-83.9%
	1P+FP	97,575	107.4	87.7	-18.3%	60.2	48.3	-19.8%
TSI CO (%)								
DFW	1P	51,466	0.19	0.19	0.0%	0.21	0.21	0.0%
	FP	4,680	1.87	0.24	-87.3%	1.61	0.25	-84.7%
	1P+FP	56,888	0.29	0.22	-24.5%	0.29	0.23	-20.5%
HGB	1P	37,458	0.20	0.20	0.0%	0.21	0.21	0.0%
	FP	2,734	2.11	0.24	-88.5%	1.68	0.24	-85.7%
	1P+FP	40,687	0.30	0.22	-26.7%	0.29	0.23	-21.5%
DFW & HGB	1P	88,924	0.19	0.19	0.0%	0.21	0.21	0.0%
	FP	7,414	1.97	0.24	-87.9%	1.64	0.24	-85.1%
	1P+FP	97,575	0.30	0.22	-25.4%	0.29	0.23	-20.9%

Table V-7. 2012 Report Annual I/M Benefit Using TIMS Data for ASM Emissions

Area	Seq.	Count	5015 Initial	5015 Final	5015 % Change	2525 Initial	2525 Final	2525 % Change
ASM HC (ppm)								
DFW	1P	477,748	64.76	64.76	0.0%	42.10	42.10	0.0%
	FP	51,133	166.90	62.92	-62.3%	146.87	45.91	-68.7%
	1P+FP	540,337	77.43	67.79	-12.4%	54.91	45.57	-17.0%
HGB	1P	409,231	61.98	61.98	0.0%	40.79	40.79	0.0%
	FP	38,895	161.94	60.12	-62.9%	144.67	43.59	-69.9%
	1P+FP	457,187	72.97	64.44	-11.7%	52.07	43.62	-16.2%
DFW & HGB	1P	886,979	63.48	63.48	0.0%	41.49	41.49	0.0%
	FP	90,028	164.75	61.71	-62.5%	145.91	44.91	-69.2%
	1P+FP	997,524	75.38	66.26	-12.1%	53.61	44.67	-16.7%
ASM CO (%)								
DFW	1P	477,748	0.203	0.203	0.0%	0.147	0.147	0.0%
	FP	51,133	1.060	0.204	-80.8%	1.036	0.165	-84.1%
	1P+FP	540,337	0.305	0.226	-26.0%	0.253	0.172	-31.9%
HGB	1P	409,231	0.193	0.193	0.0%	0.145	0.145	0.0%
	FP	38,895	1.106	0.188	-83.0%	1.080	0.156	-85.6%
	1P+FP	457,187	0.289	0.212	-26.6%	0.244	0.167	-31.7%
DFW & HGB	1P	886,979	0.198	0.198	0.0%	0.146	0.146	0.0%
	FP	90,028	1.080	0.197	-81.8%	1.055	0.161	-84.7%
	1P+FP	997,524	0.298	0.219	-26.3%	0.249	0.170	-31.8%
ASM NOx (ppm)								
DFW	1P	477,748	472.77	472.77	0.0%	355.73	355.73	0.0%
	FP	51,133	1467.22	491.20	-66.5%	1,306.02	393.42	-69.9%
	1P+FP	540,337	584.82	494.10	-15.5%	462.93	378.18	-18.3%
HGB	1P	409,231	461.37	461.37	0.0%	351.51	351.51	0.0%
	FP	38,895	1441.50	472.61	-67.2%	1,292.90	378.06	-70.8%
	1P+FP	457,187	559.31	477.93	-14.6%	445.48	368.69	-17.2%
DFW & HGB	1P	886,979	467.51	467.51	0.0%	353.78	353.78	0.0%
	FP	90,028	1456.08	483.17	-66.8%	1,300.34	386.78	-70.3%
	1P+FP	997,524	573.13	486.69	-15.1%	454.93	373.83	-17.8%

Table V-8. 2012 Report Annual I/M Benefit Using TIMS Data for TSI Emissions

TSI HC (ppm)								
			Curb			High		
Area	Seq.	Count	Initial	Final	% Change	Initial	Final	% Change
DFW	1P	65,371	81.65	81.65	0.0%	43.76	43.76	0.0%
	FP	6,137	544.39	93.74	-82.8%	325.24	54.17	-83.3%
	1P+FP	72,472	111.86	90.28	-19.3%	62.35	49.37	-20.8%
HGB	1P	50,582	79.34	79.34	0.0%	43.07	43.07	0.0%
	FP	3,845	560.32	90.86	-83.8%	332.93	52.79	-84.1%
	1P+FP	55,123	109.45	87.73	-19.8%	61.04	48.18	-21.1%
DFW & HGB	1P	115,953	80.64	80.64	0.0%	43.46	43.46	0.0%
	FP	9,982	551.21	92.64	-83.2%	328.53	53.64	-83.7%
	1P+FP	127,595	110.81	89.18	-19.5%	61.78	48.86	-20.9%
TSI CO (%)								
DFW	1P	65,371	0.203	0.203	0.0%	0.217	0.217	0.0%
	FP	6,137	2.028	0.254	-87.5%	1.678	0.263	-84.3%
	1P+FP	72,472	0.320	0.235	-26.5%	0.310	0.242	-21.7%
HGB	1P	50,582	0.205	0.205	0.0%	0.214	0.214	0.0%
	FP	3,845	2.061	0.263	-87.2%	1.699	0.252	-85.2%
	1P+FP	55,123	0.316	0.233	-26.4%	0.303	0.236	-22.2%
DFW & HGB	1P	115,953	0.204	0.204	0.0%	0.215	0.215	0.0%
	FP	9,982	2.042	0.258	-87.4%	1.687	0.259	-84.7%
	1P+FP	127,595	0.319	0.234	-26.4%	0.307	0.239	-21.9%

B. ESTIMATE OF THE ANNUAL I/M BENEFIT FROM PAIRED I/M AND RS DATA

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 period before the next I/M cycle. The analysis presented in this section estimates annual benefits based on pairing the TIMS data with RS data.

Although the effect of the Texas I/M program is to reduce emissions by repairing vehicles that fail an emissions test, these vehicles will then likely have increasing emissions until their next I/M test (or next I/M failure). This is also true for passing vehicles. RS data allows this slow increase in emissions to be observed as it can be seen that initially passing vehicles (89 percent of the fleet) go through the Texas I/M program and their emissions gradually increase each year. This is often called emission creep. Eventually, when their emissions have increased over the years to a high enough level, the I/M cutpoint is tripped and repairs are performed. During those previous years, the emissions of the initially-passing vehicles have gradually increased. More-stringent cutpoints would help reduce the number of vehicles that are allowed pass the Texas I/M program 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. Finally, it should be noted that increasing cutpoint stringency is only possible with tailpipe testing, not OBD.

ERG used RS data taken in the I/M program areas to determine the Annual I/M Benefit produced by the Texas I/M program. This was done by pairing RS data with the TIMS inspection data by vehicle license plate 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 Texas 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 RS emissions measurements, the average RS emissions versus time before and after I/M inspection will have a considerable amount of variability even when millions of RS observations are used. Nevertheless, the calculation provides an estimate of the benefits of the Texas I/M program that is independent of the program itself.

Preparation of RS Data – In this task, the RS data were collected in the DFW and HGB program areas to evaluate the Annual I/M Benefit. The goal was to use the RS data already being collected by the DPS as an independent means of measuring the benefit. The RS data provided by DPS started out with about 1.6 million records, collected between July 1, 2015, and February 28, 2018, in the HGB and DFW program areas, with approximately half of the records coming from either area.

The remote sensing contractor matched the RS records to registration records in the weeks after they were collected, so that matching process did not have to be performed for this analysis. The match of RS records to registration records provided a VIN (wherever a successful match was made) that ERG could then match to the TIMS dataset. The RS records provided to ERG also contained vehicle information from the match to the registration dataset, including model year, make, and model. This information, in addition to the vehicle information in the TIMS dataset, can be used to characterize the on-road fleet for the Comprehensive Method [Reference 2] calculations.

The RS records provided to ERG by the DPS were already checked for validity by the RS data collection contractor. Therefore, there was no additional check made for the validity of the values within each of the RS data fields. However, a filter on the vehicle specific power (VSP) was applied, to remove vehicles that happened to be observed while under very high or very low loads. Any records with a VSP outside the range of 0-35 kilowatt per ton were removed from the dataset. This left 1.3 million records in the dataset: 650,000 records in the DFW program area and 660,000 records in the HGB program area.

It has been found that the number of RS observations collected per year has decreased dramatically over the last several years, beginning in 2014, but continuing to decrease in 2017. Decreases in the number of available RS observations will result in much smaller groups of vehicles when the RS observations are paired with close-in-time I/M inspections.

Calculation of the Annual I/M Benefit – The calculation of the Annual I/M Benefit was done using the Comprehensive Method outlined by the EPA. [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 placed 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 the 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_X 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_X plots for the entire dataset are shown in Figure V-1 through Figure V-3 for the HGB program area and in Figure V-4 through Figure V-6 for the DFW program area. These figures show the RS averages (indicated by the dots) and the uncertainties associated with these averages at a 95 percent confidence level (indicated by the lines).

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

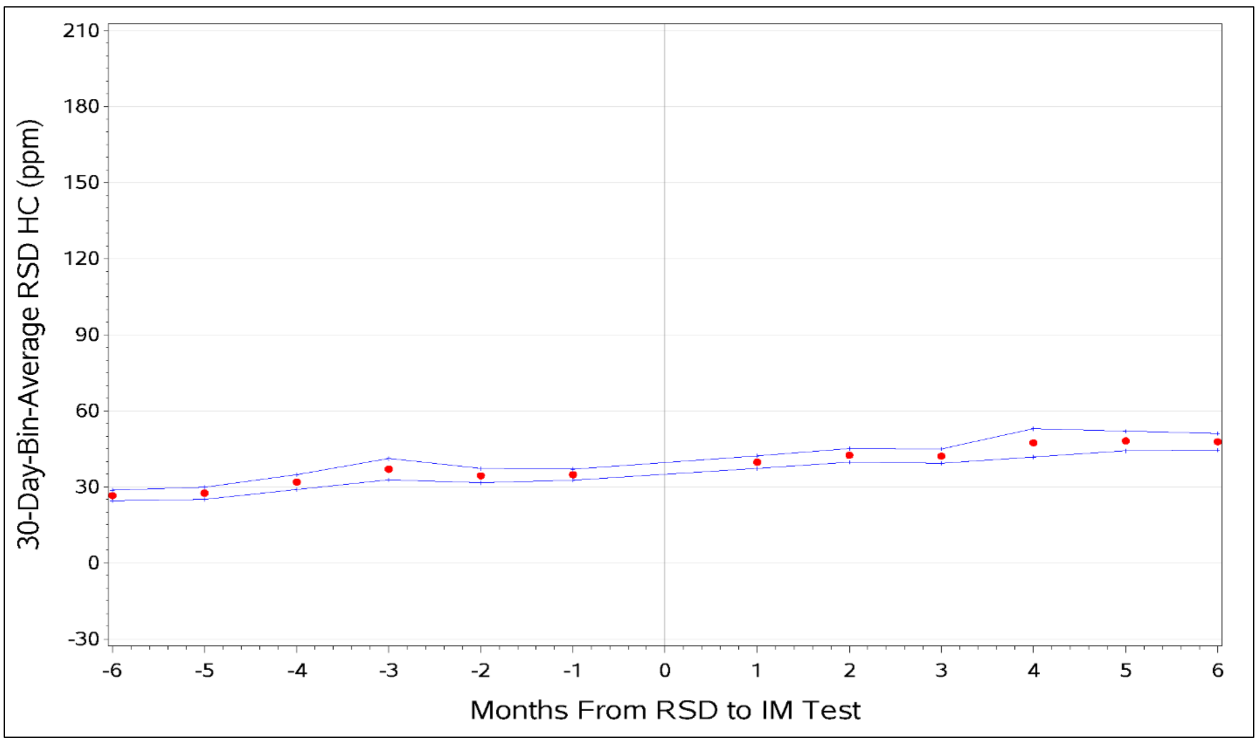


Figure V-2. Average RS CO Versus Month from the I/M Test RS Readings from the HGB Program Area

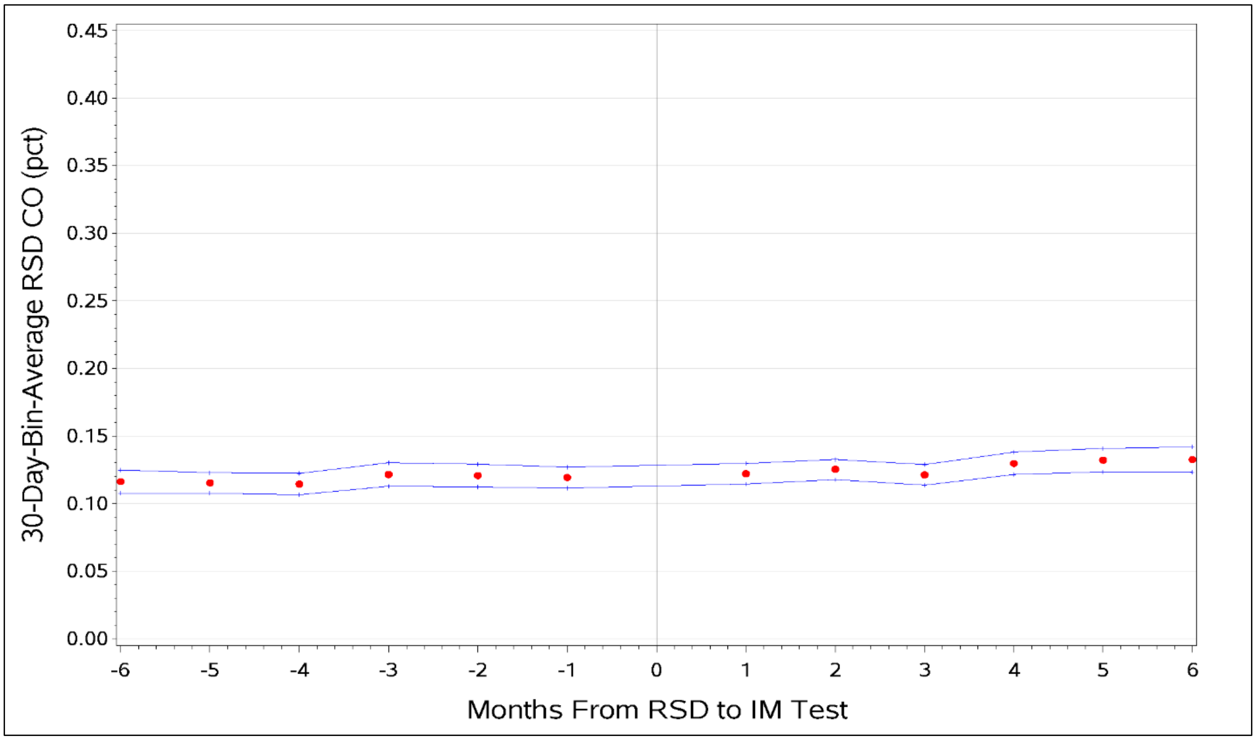


Figure V-3. Average RS NO_X Versus Month from the I/M Test RS Readings from the HGB Program Area

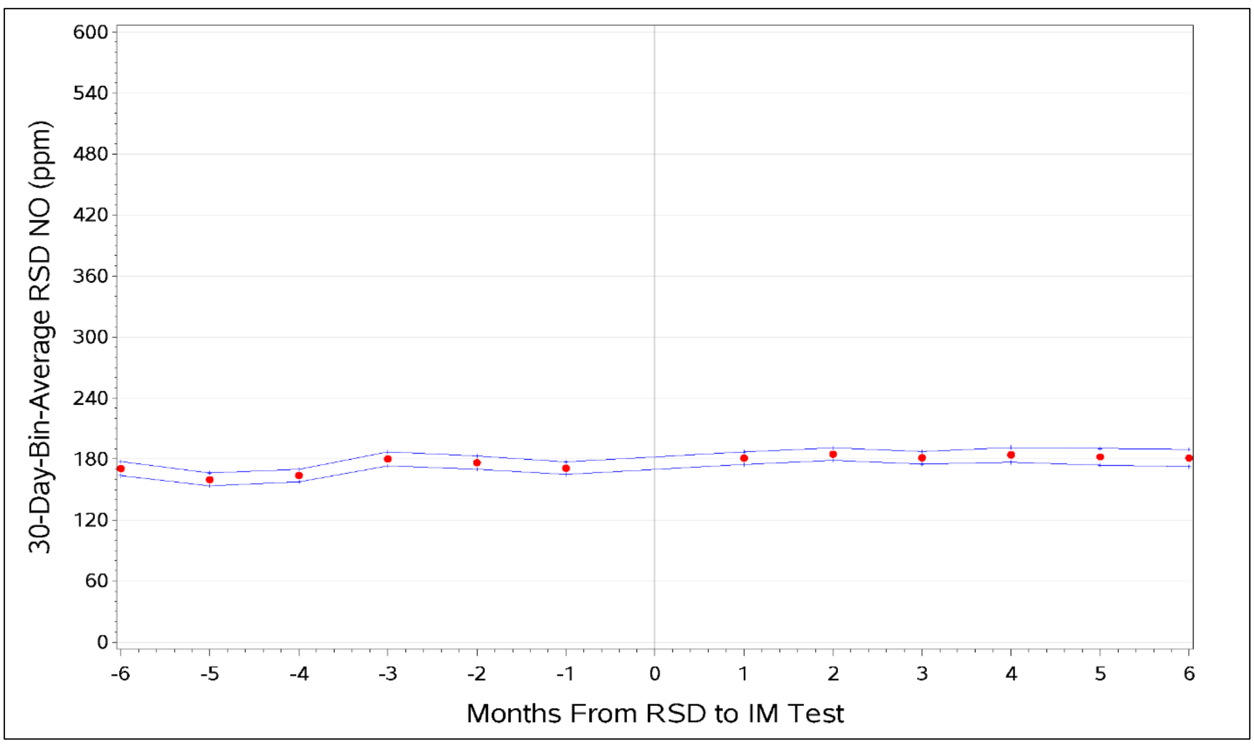


Figure V-4. Average RS HC Versus Month from the I/M Test RS Readings from the DFW Program Area

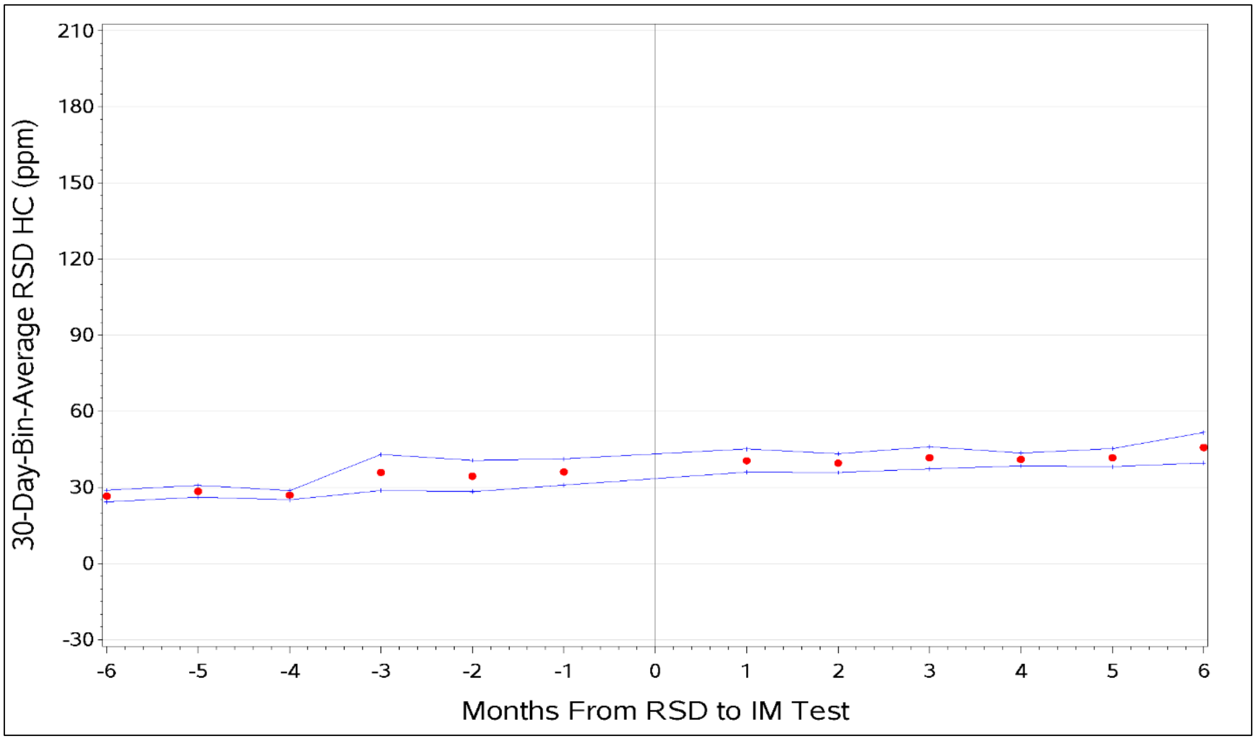


Figure V-5. Average RS CO Versus Month from the I/M Test RS Readings from the DFW Program Area

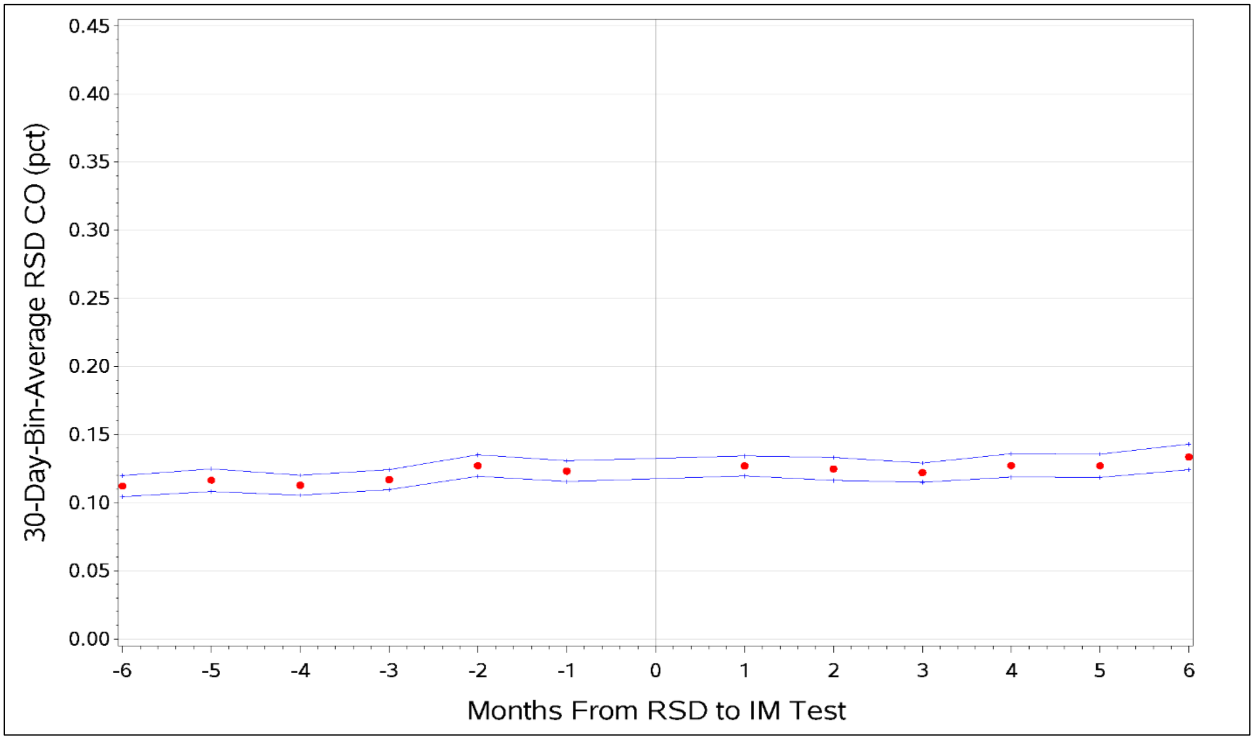
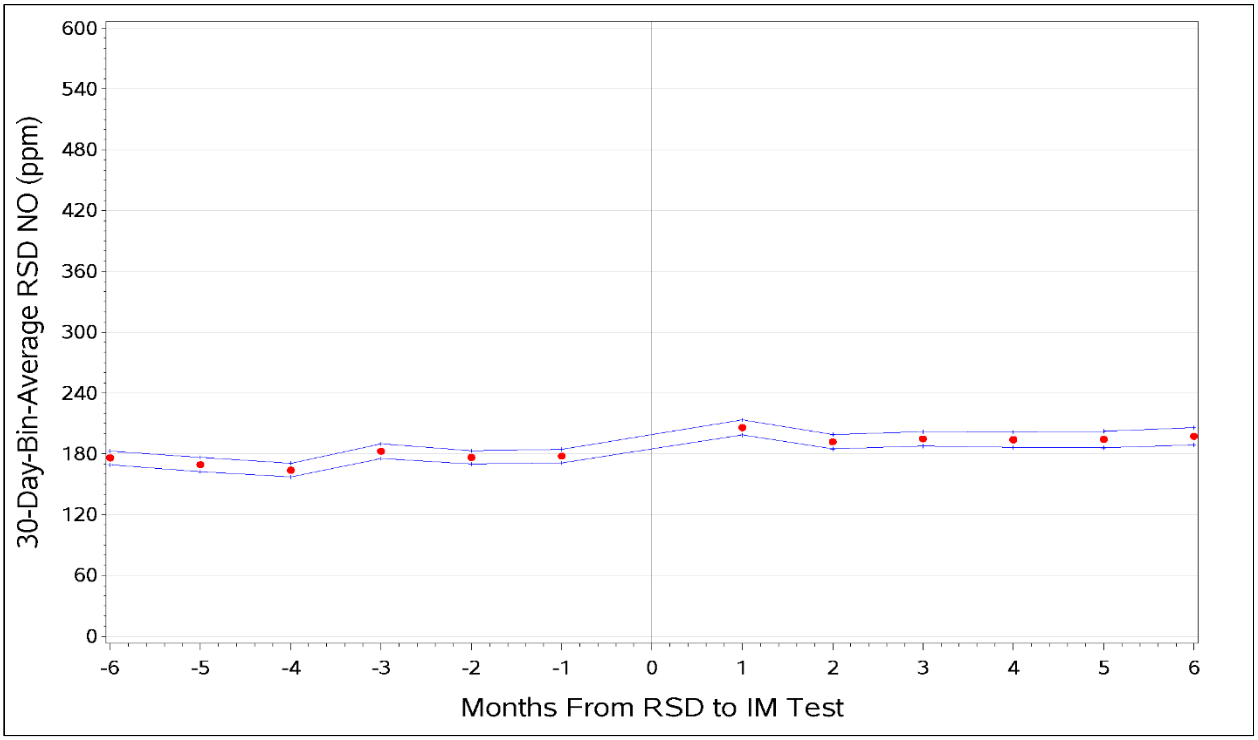


Figure V-6. Average RS NO_X Versus Month from the I/M Test RS Readings from the DFW Program Area



It is difficult to assess the impact of I/M testing from these figures as the HC readings are relatively constant around 30 ppm for both program areas, the CO readings are also similar in the HGB and DFW program areas in the range of 0.12-0.15 percent; however, the NO_X values are somewhat different with the HGB program area in the range of 230-300 ppm and the DFW program area between 300-360 ppm. 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 V-9 shows the number of records in the RS-matched-with-TIMS dataset (for both HGB and DFW program areas) that fall into each I/M sequence category. The sample sizes are for the total number of I/M vehicles matched to RS records, but they are not necessarily the same vehicle before and after the I/M test. The table clearly demonstrates that the 1P and FP I/M sequence categories dominate the Texas I/M program. At this point, the separate effects of the 1P and FP categories are examined.

Table V-9. 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)	127,204	95.2%	127,487	95.1%
Fail Initial (1F)	194	0.1%	224	0.2%
Fail Initial, Fail Final (FF)	25	0.0%	53	0.0%
Fail Initial, Pass Final (FP)	6,198	4.6%	6,271	4.7%
Other Misc. Sequences	9	0.0%	11	0.0%
Total	**133,630**	**100.0%**	**134,046**	**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. Figure V-7, Figure V-9, and Figure V-11 show the time trend of the monthly average RS HC, CO, and NO_X for the HGB program area for vehicles that passed initially (1P). Below these figures are Figure V-8, Figure V-10, and Figure V-12 for the corresponding vehicles that failed initially and then ultimately passed (FP).

The 1P plots, which describe 95 percent of the vehicles in the HGB program 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 4.6 percent of the vehicles in the HGB program area, show downward jogs in the emissions at the time of the I/M inspection, or just following the inspection. 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 Texas 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 Figure V-1, Figure V-2, and Figure V-3. This is because while the FP vehicles show substantial emissions decreases, they make up only 4.6 percent of the HGB fleet. An additional 95.2 percent of the fleet is made up of 1P vehicles that have slight emissions increases, as an expected result of general long-term degradation. There was no discernible difference in the plots for the emissions in the DFW program area; therefore, they were not included here to conserve space.

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

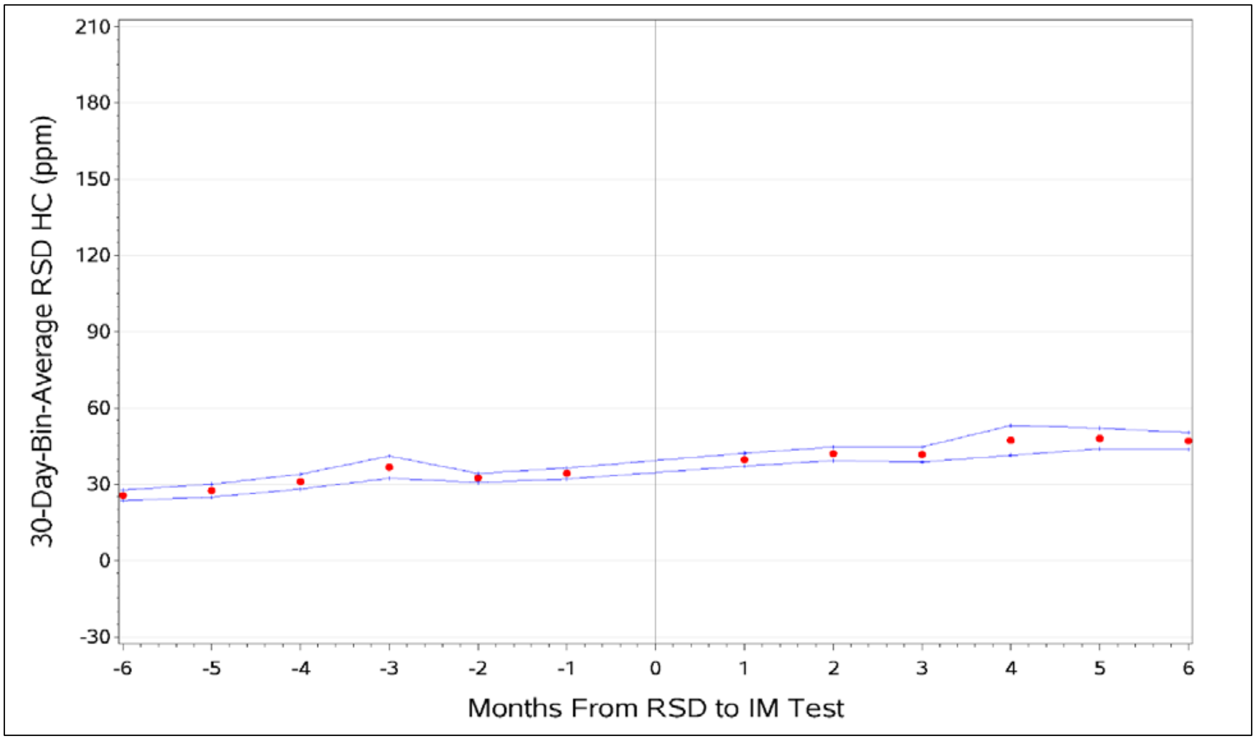


Figure V-8. Average RS HC vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = FP

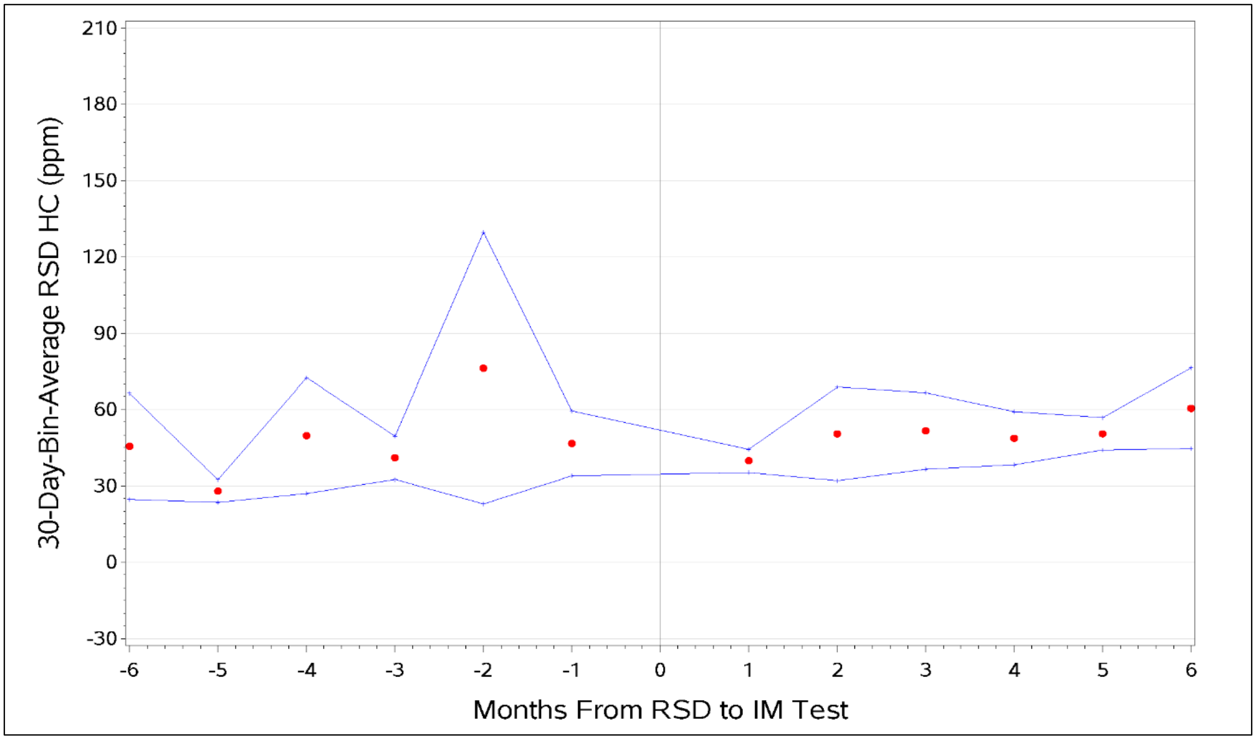


Figure V-9. Average RS CO vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = 1P

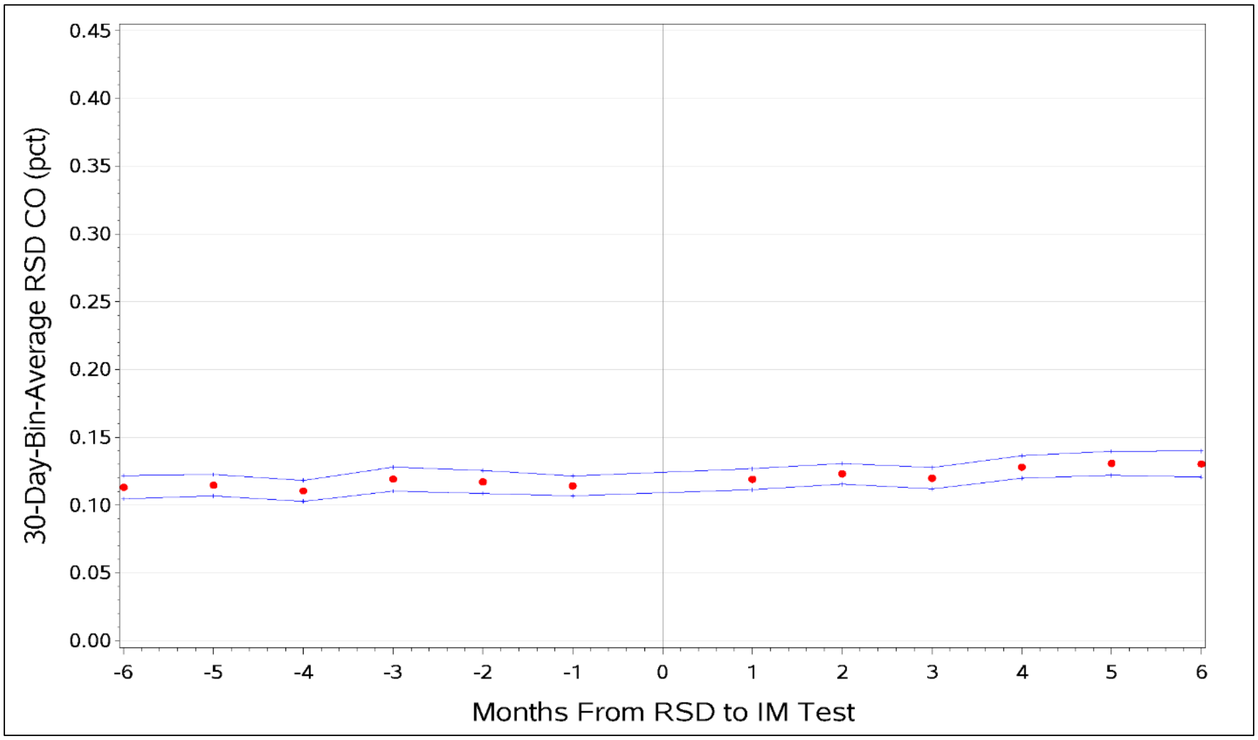


Figure V-10. Average RS CO vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = FP

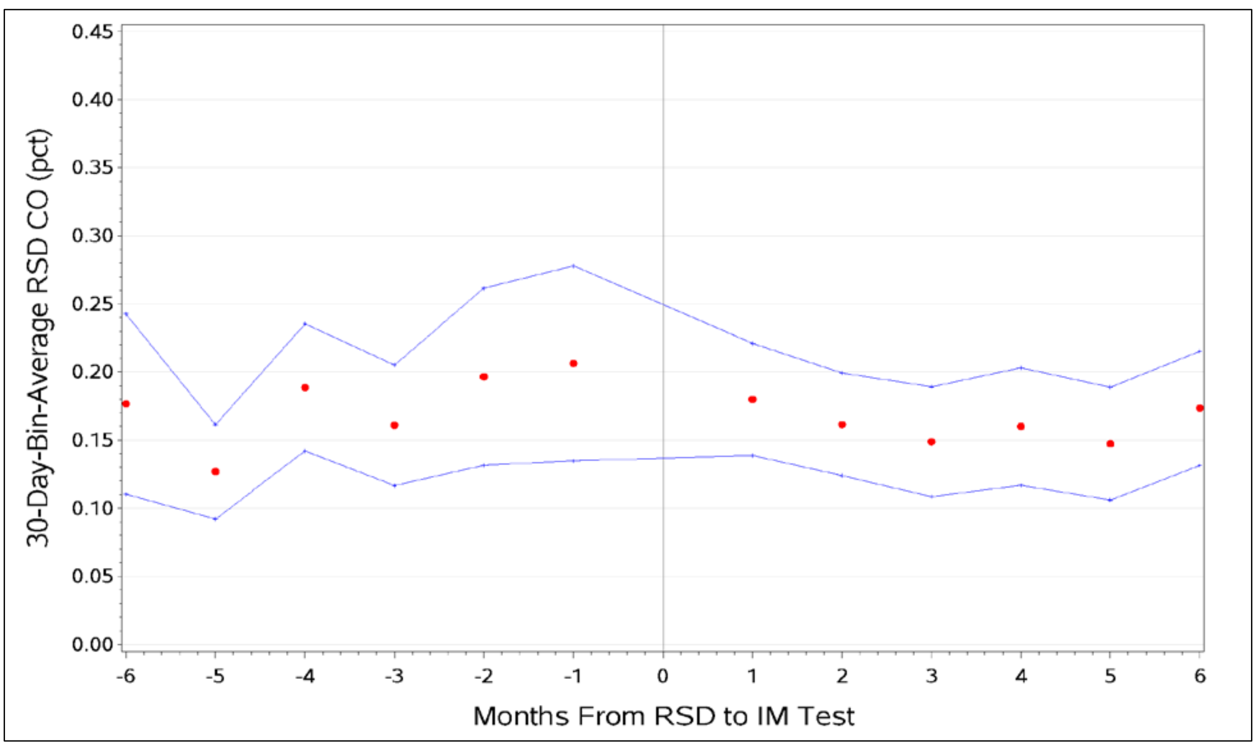


Figure V-11. Average RS NO_X vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = 1P

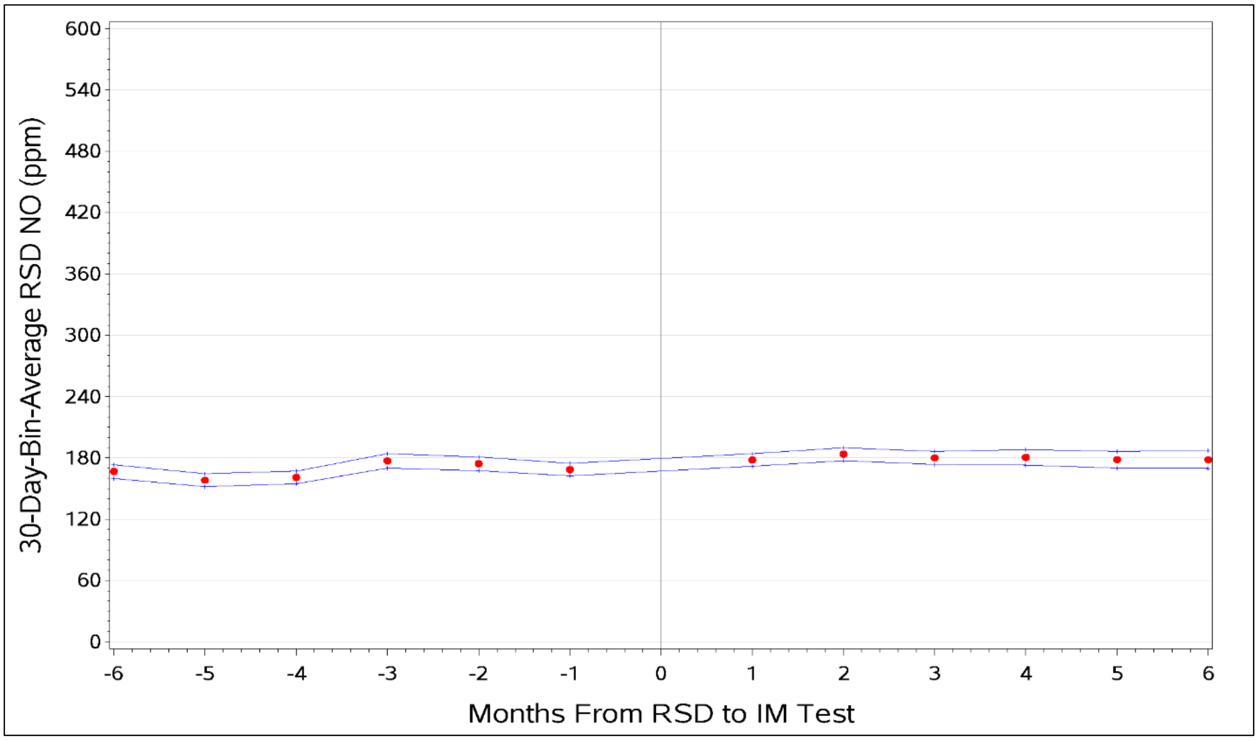
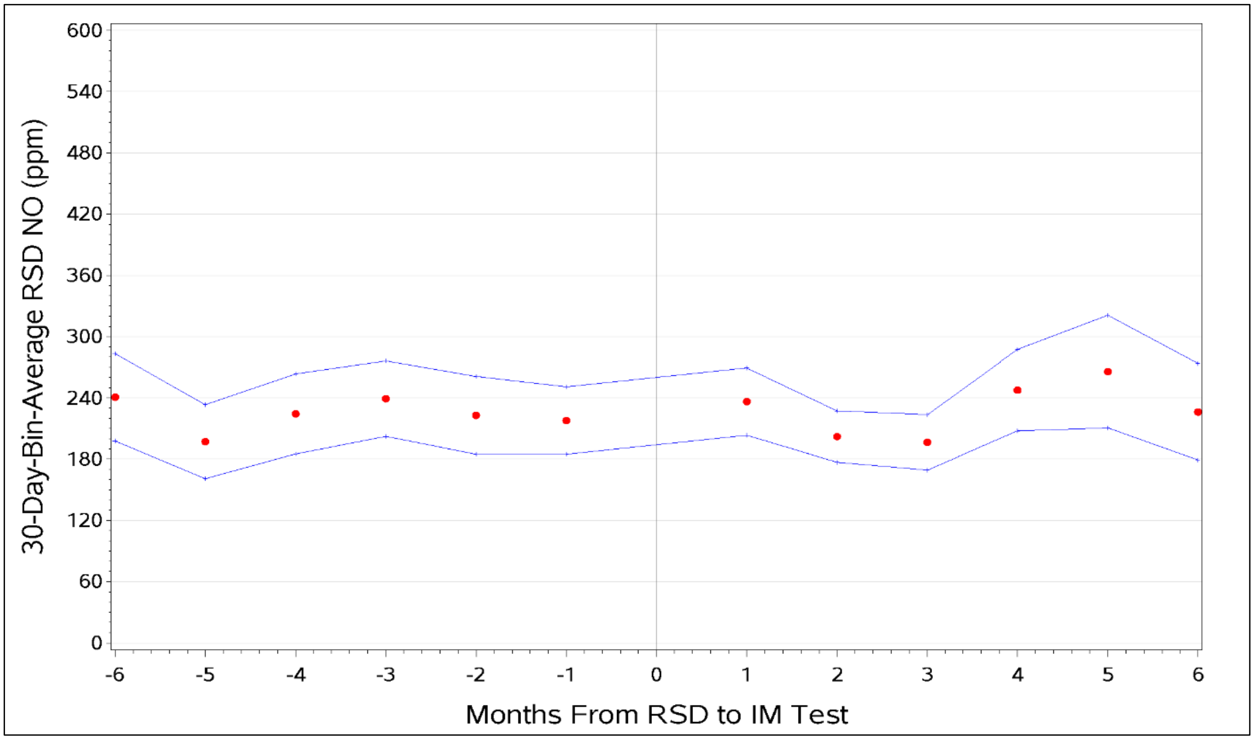


Figure V-12. Average RS NO_X vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = FP



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 120 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 the EPA in the documentation for the Comprehensive Method. The after bin contains all RS tests that happened between 1 and 120 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 TIMS dataset for each of the two major I/M sequence categories, FP and 1P, and averages were calculated separately 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 matched set of RS vehicles, 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 program areas in Figure V-13 through Figure V-24. The bars show the mean emissions levels and the error bars show the 95 percent confidence level uncertainties for the respective averages. There are two groups of vehicles shown on each plot. The first labeled “1 RSD Before I/M” is comprised of vehicles that were observed by RS prior to their I/M inspection, and the second, “2 RSD After I/M” is comprised of those vehicles that were observed by RS after their I/M inspection.

The plots for the FP vehicles show that in most cases the emissions of FP vehicles decrease, especially for the older model year groups; however, in many cases the decrease is not statistically significant – even with thousands of RS observations in the FP category. The plots for the 1P vehicles show that in some cases the emissions of 1P vehicles increase across the I/M inspections; however, in many cases the increase is not statistically significant even with tens of thousands of RS observations in the 1P category.

Figure V-13. Average 1P RS HC by Model Year Group Before and After I/M Test for HGB Vehicles

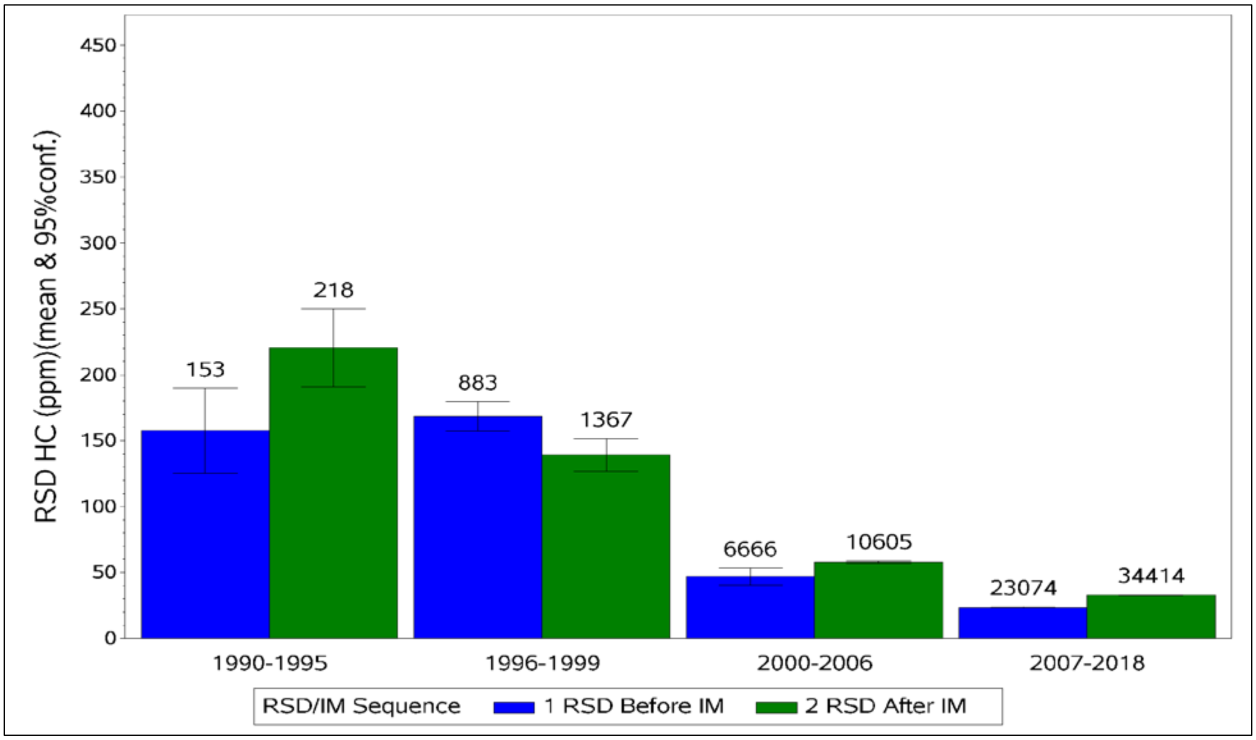


Figure V-14. Average FP RS HC by Model Year Group Before and After I/M Test for HGB Vehicles

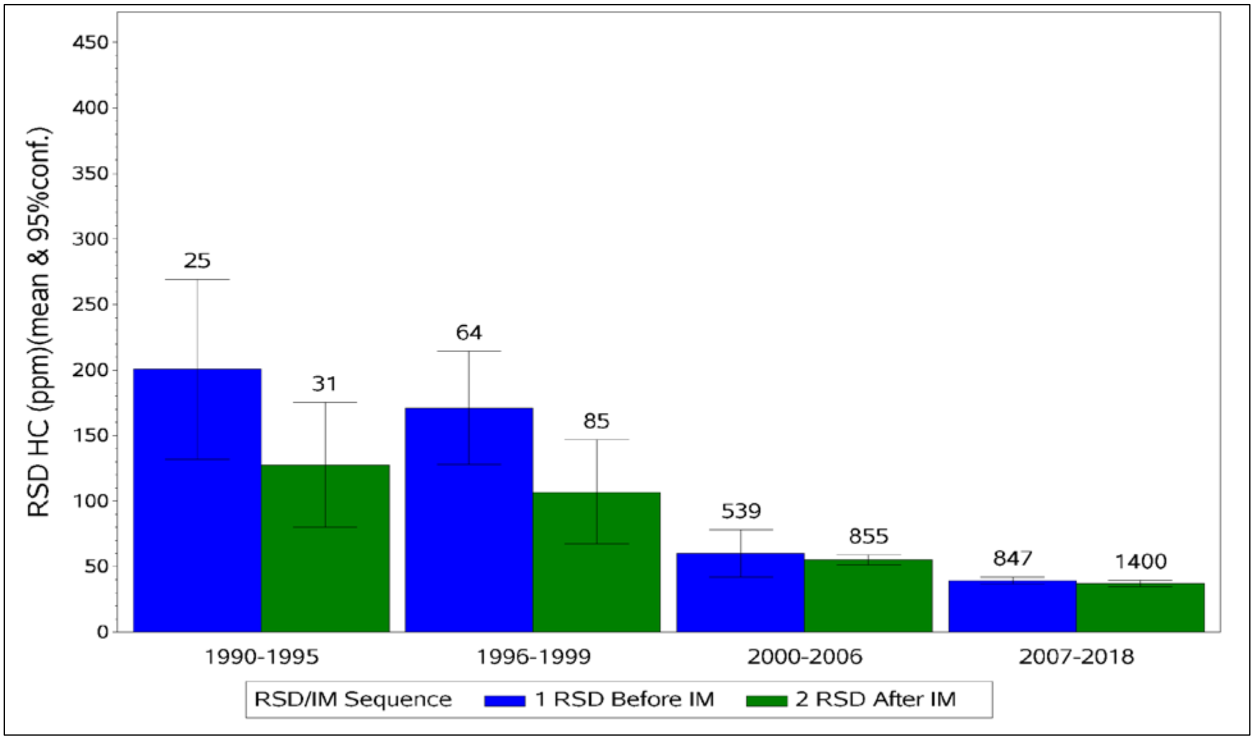


Figure V-15. Average 1P RS HC by Model Year Group Before and After I/M Test for DFW Vehicles

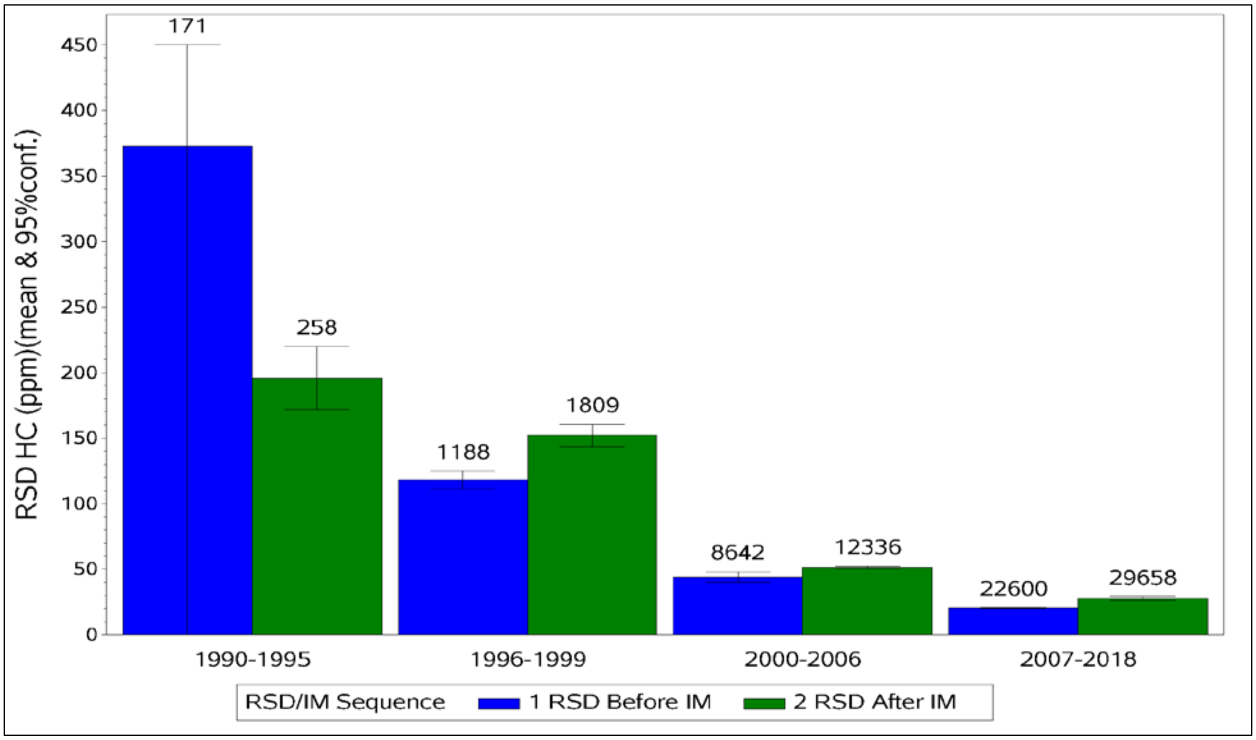


Figure V-16. Average FP RS HC by Model Year Group Before and After I/M Test for DFW Vehicles

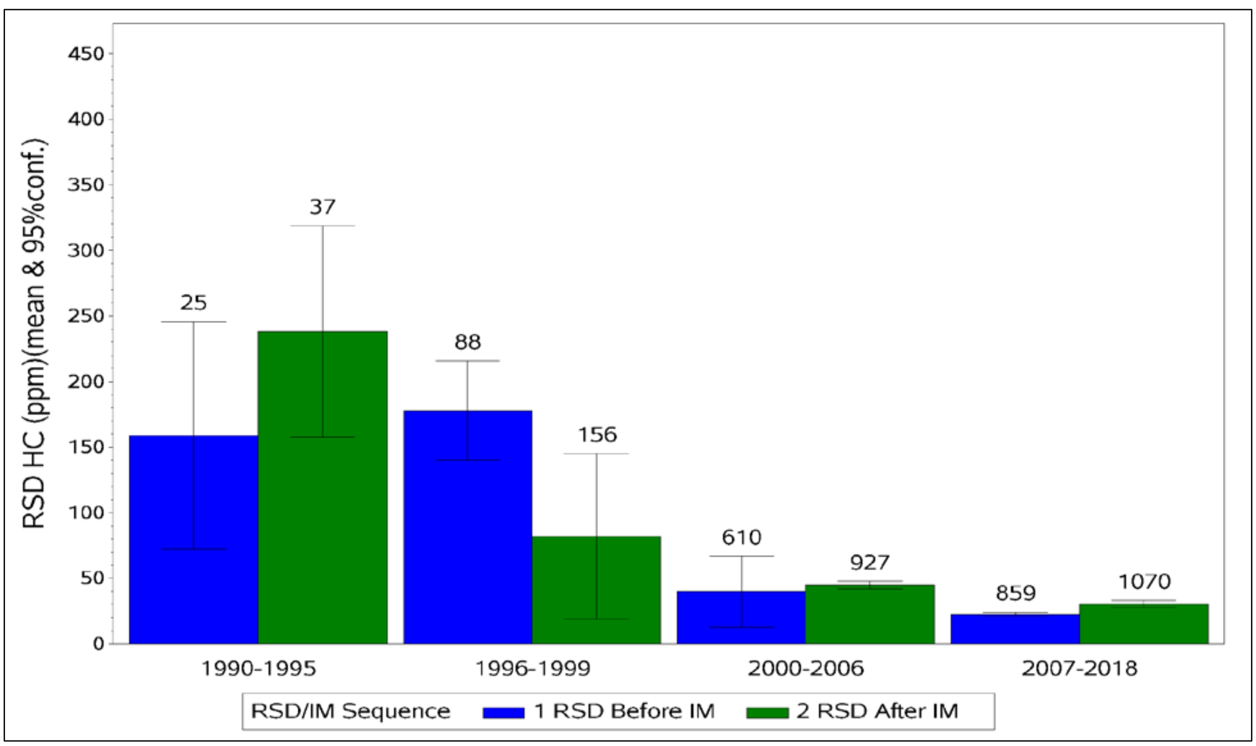


Figure V-17. Average 1P RS CO by Model Year Group Before and After I/M Test for HGB Vehicles

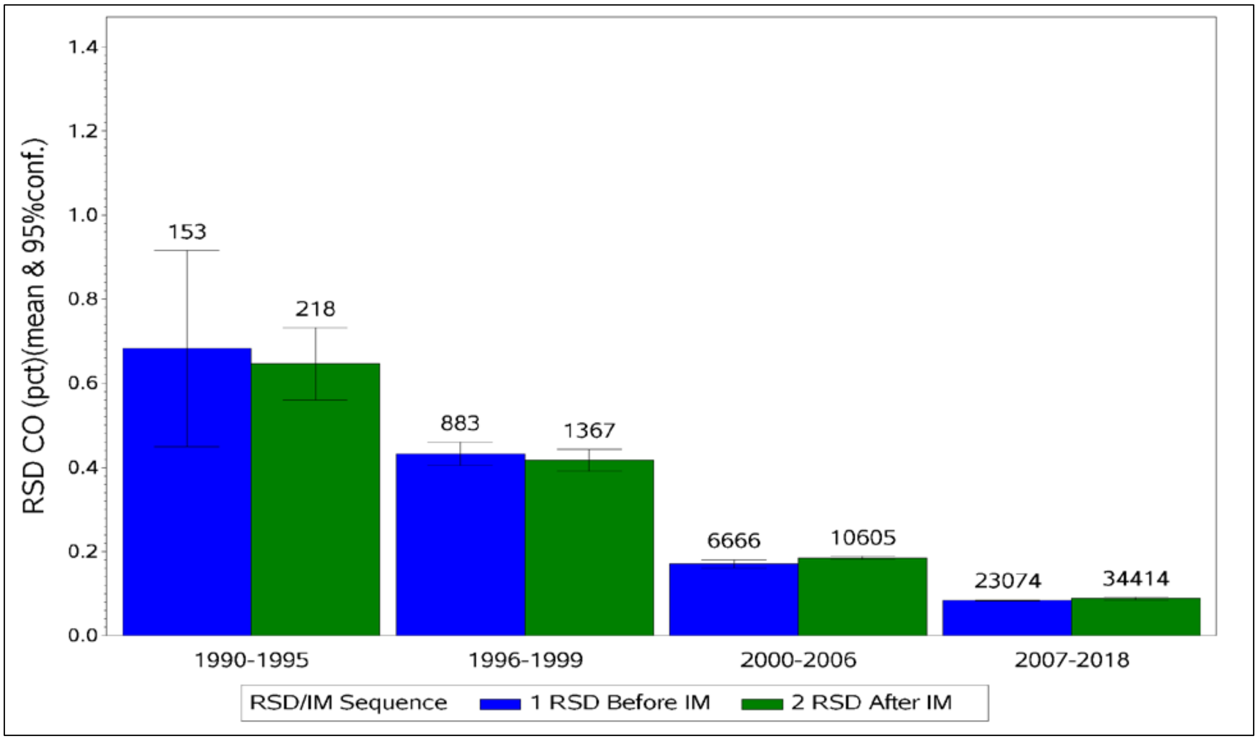


Figure V-18. Average FP RS CO by Model Year Group Before and After I/M Test for HGB Vehicles

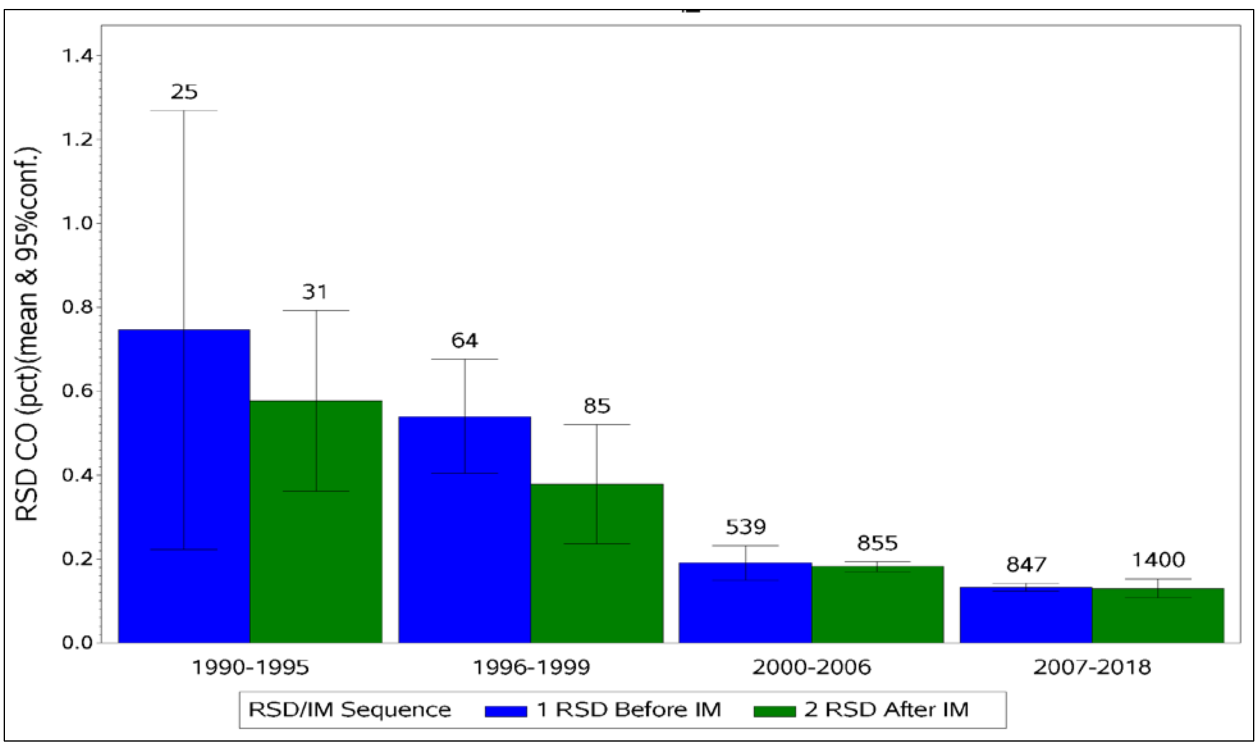


Figure V-19. Average 1P RS CO by Model Year Group Before and After I/M Test for DFW Vehicles

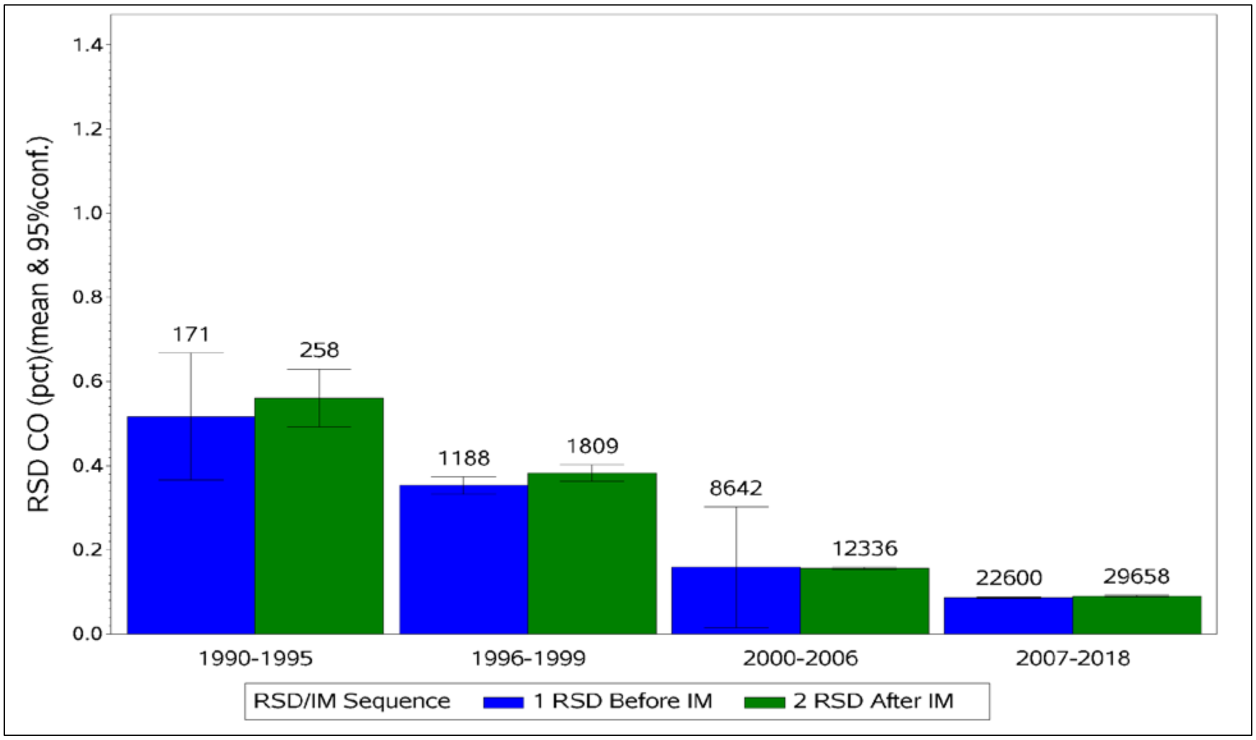


Figure V-20. Average FP RS CO by Model Year Group Before and After I/M Test for DFW Vehicles

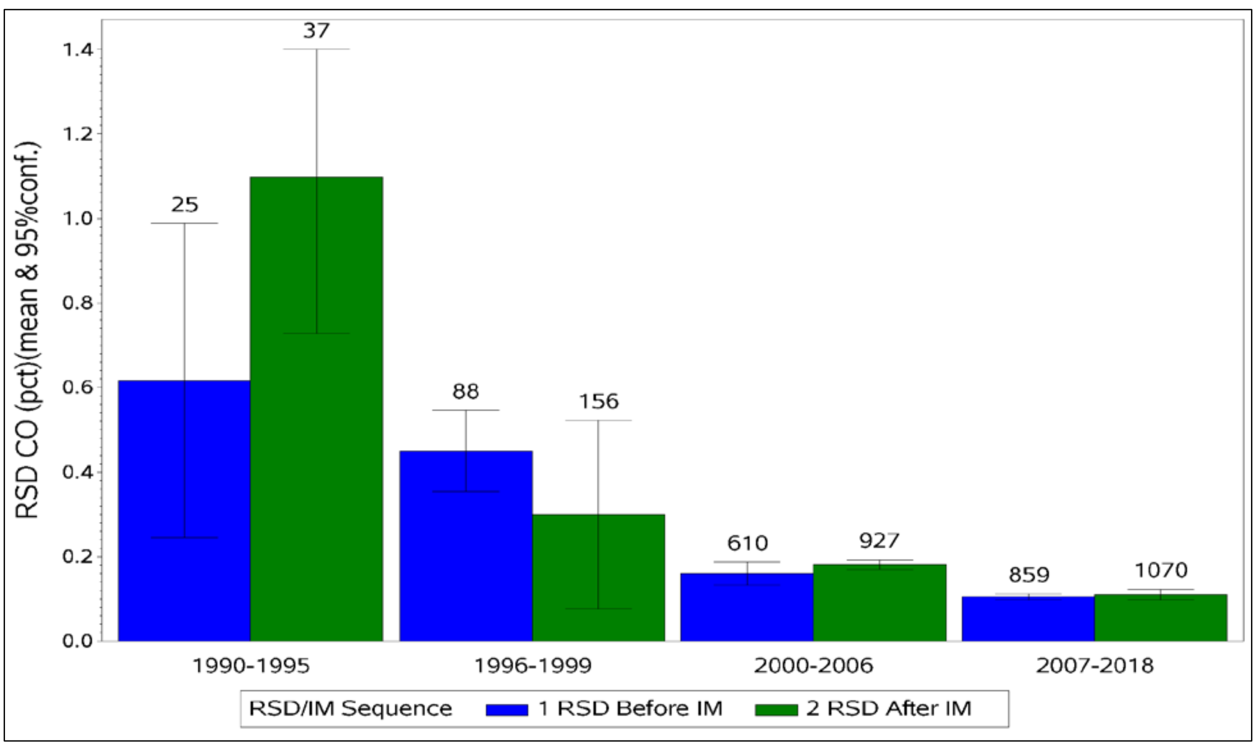


Figure V-21. Average 1P RS NO_X by Model Year Group Before and After I/M Test for HGB Vehicles

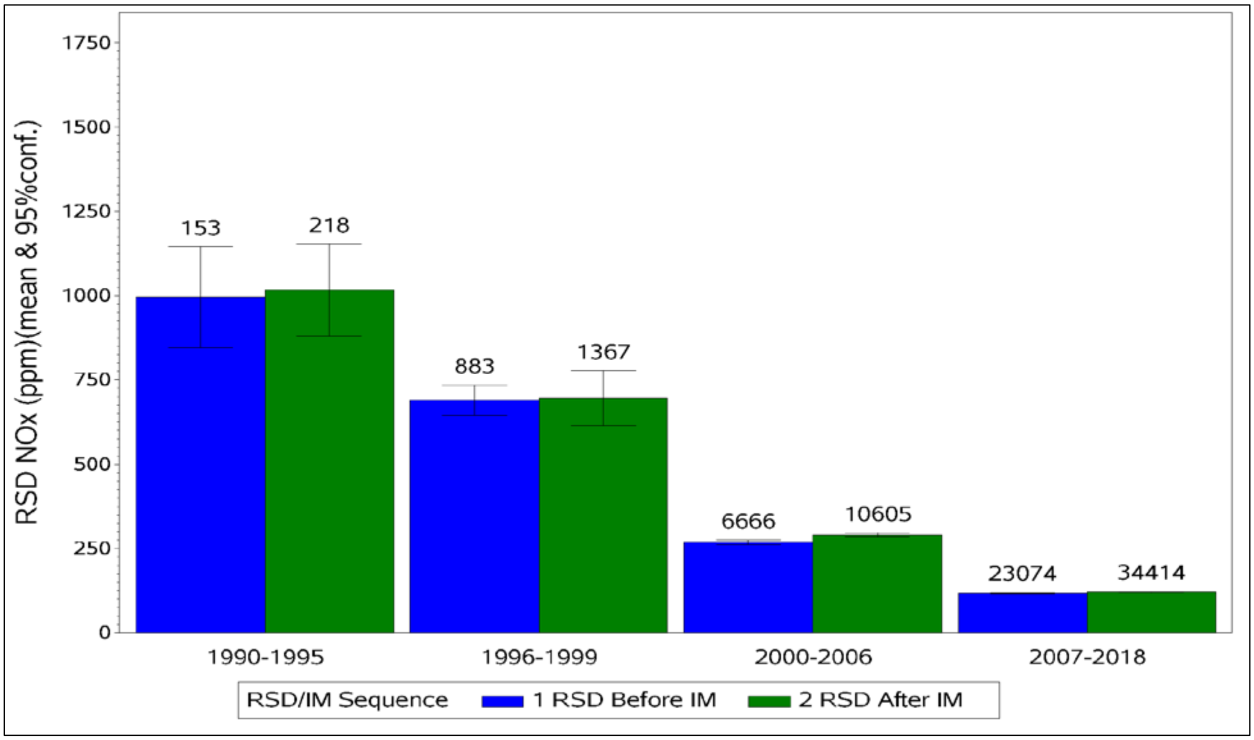


Figure V-22. Average FP RS NO_X by Model Year Group Before and After I/M Test for HGB Vehicles

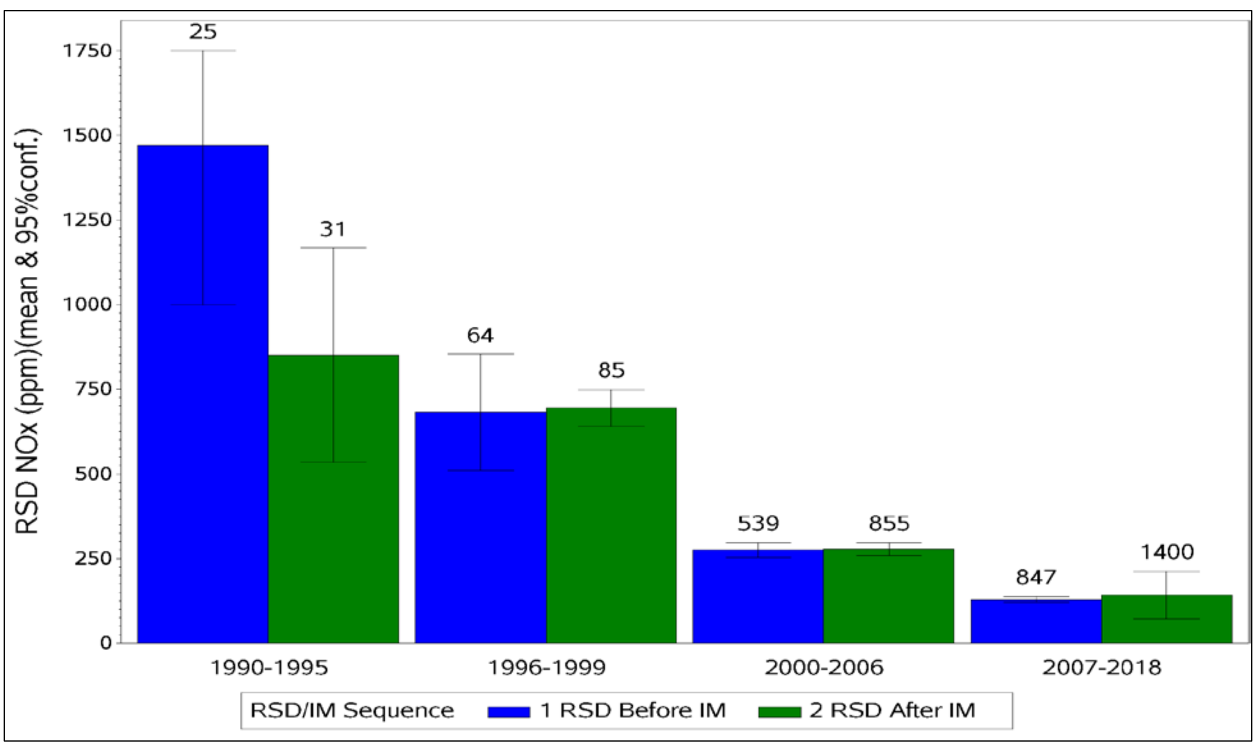


Figure V-23. Average 1P RS NO_X by Model Year Group Before and After I/M Test for DFW Vehicles

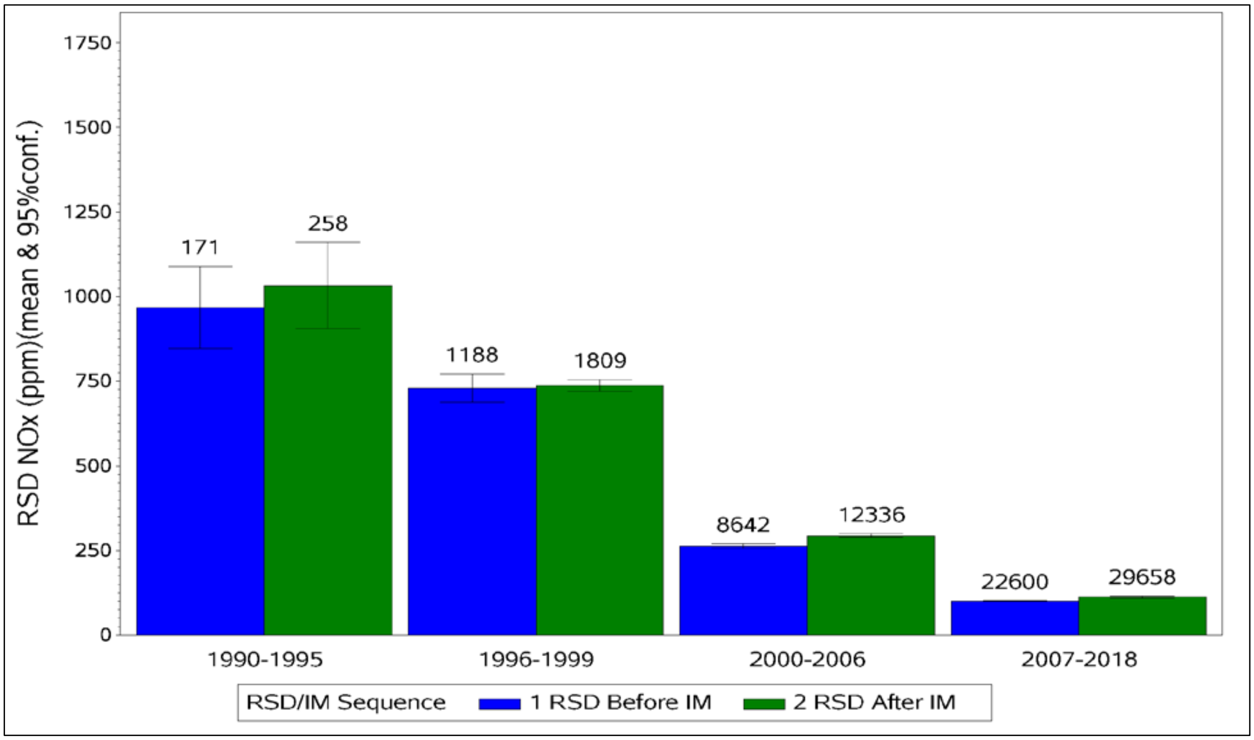
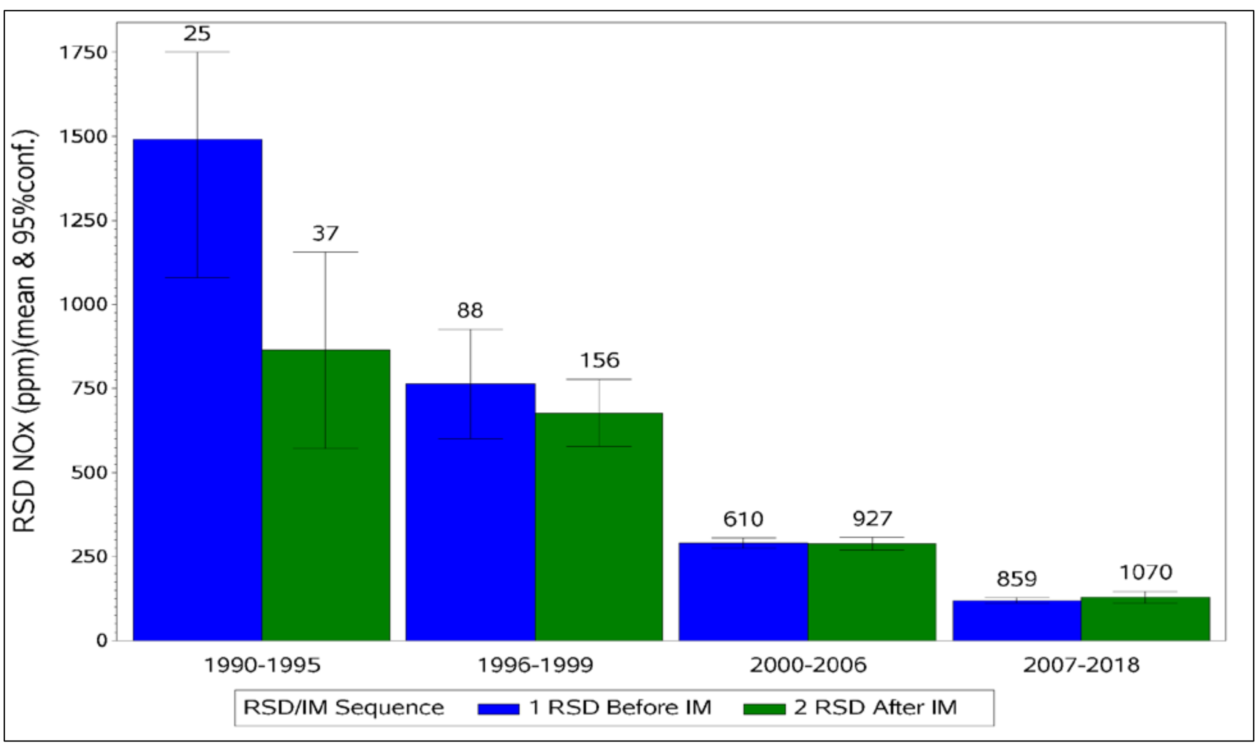


Figure V-24. Average FP RS NO_X by Model Year Group Before and After I/M Test for DFW Vehicles



The RS average concentrations shown in the figures above are summarized in Table V-10 and Table V-11. The values in Table V-10 show that for vehicles that failed and then passed, HC emissions remained fairly constant, while CO and NO_X levels were somewhat reduced from before to after the I/M inspection. Changes were largest for the oldest model year groups. Table V-11 shows that for 1P vehicles, there was generally a slight increase in emissions levels from before to after the I/M inspection. However, looking back at Figure V-13 through Figure V-18, it can be seen that the changes are almost always within the error bars, and therefore, not statistically significant.

Table V-10. RS Averages Before and After an I/M Test for HGB and DFW for I/M Sequence Category = FP

HGB Program Area						
	RS HC (ppm)		**RS CO (%)**		**RS NOx (ppm)**	
MY Group	**Before I/M**	**After I/M**	**Before I/M**	**After I/M**	**Before I/M**	**After I/M**
1990-1995	201	128	0.746	0.577	1469	850
1996-1999	171	107	0.540	0.378	681	694
2000-2006	60	55	0.191	0.182	275	278
2007-2016	39	37	0.133	0.130	129	142
DFW Program Area						
	RS HC (ppm)		**RS CO (%)**		**RS NOx (ppm)**	
MY Group	**Before I/M**	**After I/M**	**Before I/M**	**After I/M**	**Before I/M**	**After I/M**
1990-1995	159	238	0.617	1.099	1491	864
1996-1999	178	82	0.450	0.300	763	677
2000-2006	40	45	0.160	0.181	289	288
2007-2016	23	30	0.105	0.110	119	129

Table V-11. RS Averages Before and After an I/M Test for HGB and DFW for I/M Sequence Category = 1P

HGB Program Area						
	RS HC (ppm)		RS CO (%)		RS NOx (ppm)	
MY Group	Before I/M	After I/M	Before I/M	After I/M	Before I/M	After I/M
1990-1995	158	220	0.682	0.646	995	1017
1996-1999	168	139	0.432	0.417	689	695
2000-2006	47	58	0.171	0.184	268	290
2007-2016	23	33	0.084	0.088	117	121
DFW Program Area						
	RS HC (ppm)		RS CO (%)		RS NOx (ppm)	
MY Group	Before I/M	After I/M	Before I/M	After I/M	Before I/M	After I/M
1990-1995	373	196	0.517	0.560	968	1033
1996-1999	118	152	0.353	0.382	730	737
2000-2006	44	51	0.158	0.156	263	293
2007-2016	20	28	0.086	0.089	100	112

The results in Table V-10 and Table V-11 show the difference in average RS concentrations between before and after I/M observations, for different model year groups. These results are then combined to calculate the net overall effect on emissions of the I/M program. Because RS measurements are primarily taken on freeway on-ramps, it is generally assumed newer vehicles are driven on the highways; therefore, the average vehicle observed by RS is somewhat newer than the average vehicle in the I/M fleet. This difference is shown in Table V-12, 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. The overall fleet results for the annual I/M benefit are shown in Table V-13. It should be noted that in the absence of an I/M program, fleet emissions are expected to increase as motorists are less likely to make emission repairs in order to pass an upcoming I/M test; therefore, the actual emission reductions are likely greater than those reported below.

Table V-12. Model Year Distributions for RS-Matched-to-I/M Fleet and I/M Tested Fleet

Model Year Group	DFW				HGB			
	RS-Matched-to-I/M Fleet		I/M Tested Fleet		RS-Matched-to-I/M Fleet		I/M Tested Fleet	
	Number	%	Number	%	Number	%	Number	%
1990-1995	832	0.6%	220,518	3.3%	715	0.5%	187,580	3.0%
1996-1999	5,214	3.9%	572,203	8.5%	3,979	3.0%	516,572	8.2%
2000-2006	37,333	27.9%	2,607,682	38.7%	30,752	23.0%	2,384,310	37.8%
2007-2016	90,667	67.6%	3,335,359	49.5%	98,184	73.5%	3,213,170	51.0%
Total	**134,046**	**100.0%**	**6,735,762**	**100.0%**	**133,630**	**100.0%**	**6,301,632**	**100.0%**

Table V-13. RS Average Concentrations to Evaluate the Annual I/M Benefit

I/M Program Area	I/M Sequence	RS wrt I/M	Number of Obs	RS HC (ppm) Mean	RS HC (ppm) UCLM	RS HC (ppm) LCLM	RS HC (ppm) Change (%)	RS CO (%) Mean	RS CO (%) UCLM	RS CO (%) LCLM	RS CO (%) Change (%)	RS NOx (ppm) Mean	RS NOx (ppm) UCLM	RS NOx (ppm) LCLM	RS NOx (ppm) Change (%)
DFW+HGB	1P+FP	Before	66,434	33.4	35.3	31.5		0.119	0.122	0.116		174	176	171	
	1P+FP	After	95,226	41.6	42.9	40.3	24.7%	0.125	0.127	0.122	4.8%	189	192	187	8.9%
	1P	Before	63,377	32.7	34.7	30.8		0.116	0.120	0.113		171	173	168	
	1P	After	90,665	41.4	42.8	40.1	26.7%	0.122	0.125	0.120	5.1%	187	189	184	9.5%
	FP	Before	3,057	47.4	58.7	36.2		0.167	0.186	0.148		236	252	219	
	FP	After	4,561	45.7	49.9	41.5	-3.7%	0.166	0.181	0.152	-0.4%	233	246	221	-1.0%
DFW	1P+FP	Before	34,183	32.5	35.8	29.2		0.119	0.123	0.115		174	178	170	
	1P+FP	After	46,251	40.6	42.6	38.6	24.9%	0.125	0.129	0.121	5.0%	196	200	193	12.9%
HGB	1P+FP	Before	32,251	34.4	36.3	32.4		0.119	0.123	0.114		173	177	169	
	1P+FP	After	48,975	42.6	44.4	40.9	24.1%	0.124	0.128	0.120	4.7%	182	186	179	5.2%
DFW	1P	Before	32,601	32.1	35.5	28.7		0.117	0.122	0.113		171	175	167	
	1P	After	44,061	40.4	42.5	38.4	25.8%	0.123	0.127	0.119	4.5%	194	198	190	13.6%
	FP	Before	1,582	40.0	52.2	27.8		0.153	0.177	0.130		242	266	218	
	FP	After	2,190	43.8	48.7	38.8	9.4%	0.170	0.191	0.150	11.1%	248	267	228	2.2%
HGB	1P	Before	30,776	33.4	35.2	31.5		0.116	0.120	0.111		171	174	167	
	1P	After	46,604	42.4	44.2	40.6	27.1%	0.122	0.126	0.118	5.8%	180	184	177	5.7%
	FP	Before	1,475	55.5	74.7	36.2		0.182	0.212	0.152		229	251	207	
	FP	After	2,371	47.5	54.1	40.8	-14.4%	0.163	0.183	0.143	-10.4%	220	236	204	-3.7%

wrt- with respect to
Obs- observations
UCLM/LCLM- upper/lower confidence limit

VI. MEASURES FOR EVALUATING STATION PERFORMANCE

For an I/M program to function as designed, 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. 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 VI.A)
    - VIN from vehicle doesn't match OBD-downloaded VIN (VI.A.1)
    - Powertrain Control Module (PCM), Parameter ID (PID), VIN, and/or not ready status changes between inspections (VI.A.2)
  - — Tailpipe Inspection Manipulation (Section VI.B)
    - Clean-piping: a passing re-test follows a failed inspection within only a few minutes (VI.B.1)
    - Switching vehicle from ASM to TSI in order to pass inspection (VI.B.2)
    - Switching from light-duty (LD) (<8,500 GVWR) to HD (>8,500 GVWR) in order to pass inspection (VI.B.3)
    - Stations with an average very high or very low ASM or OBD fail rates relative to peers (VI.B.4)
- Errors of Omission:
  - — Use of analyzers of less-than-optimal functionality (Section VI.C)
    - Performing inspections on analyzers with a high degree of drift (VI.C.1)
    - Performing inspections right before failing a span gas audit (VI.C.2)
    - Performing only one of the four calibrations that are required every 72-hours, instead of all four (VI.C.3)
  - — Data entry issues (Section VI.D)
    - Consistently entering repair type as "Misc" (VI.D.1)
    - Consistently entering repair cost as $0 (VI.D.2)
    - VIN Check digit errors (VI.D.3)
    - Anomalous inspection sequences (other than 1P or FP) (VI.D.4)
  - — Anomalous test results (Section VI.E)
    - ASM or TSI Inspection results with greater than 16 percent CO_2 (VI.E.1)
    - ASM or TSI Inspection results with greater than 20.5 percent O_2 (VI.E.2)
    - ASM or TSI inspections with high DCF values (VI.E.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 did not match the downloaded OBD VIN, the downloaded VIN did not match the entered VIN (which can legitimately happen for several reasons), etc. However, the goal of this section is to identify those stations where these events are frequent (search for statistical outliers), suggesting that their occurrence is not accidental, and these events are much more common than at other stations.

A percentile rank was assigned to each station for its performance on each bullet in the previous 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 results were a compilation of the ranks for each station on each of the measures of errors of commission and each of the measures of errors of omission. These compiled ranks are discussed in Section VI.F.

Inspection stations that are operated by the state tend to exhibit a substantially different range of results than the majority of privately-operated stations, skewing the distribution of the results. These stations may be identified by the "G" within the station identification number and were excluded from all of the following analysis[7].

A. 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 tailpipe test 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 in an attempt to receive a passing test result. Information downloaded from the OBD system during an inspection may be used to identify possible clean-scanning activities. Parameters collected during an OBD inspection establish an electronic signature. If test parameters do not match the parameters expected for the vehicle under test, it's possible that clean-scanning has occurred.

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

A majority of the vehicles receiving OBD tests report the vehicle identification number (VIN) electronically. These VINs downloaded with a Mode $09 request from the ECM are referred to as eVINs. All 2005 and newer vehicles are required to report eVINs; a large number of 2004 and older models also report eVINs. A comparison of the inspector-entered VIN against the vehicle-downloaded VIN via the OBD connection can

[7] Fleet and government stations were included in this analysis, but they only account for 0.3% and 0.4% of all inspections; therefore, their inclusion is unlikely to impact the results.

help verify that all OBD inspections are performed on the correct vehicle. Both the inspector-entered VIN and the vehicle-downloaded VIN (or "eVIN") are recorded in each vehicle inspection record of the TIMS.

For this analysis, all 18 million OBD inspection records for the 2-year evaluation period were used. For each of these records, the OBD-downloaded eVINs were compared with VINs entered (either via keyboard or barcode scan) during the vehicle inspection. Of these, about 24 percent, or 4 million records, contain no valid eVIN (either the eVIN is entirely blank, is entered as "N/A", or is less than 17 digits long)[8]. Of the remaining 14 million, approximately 1 percent of these records (136,507 records) were found to have VIN-to-eVIN discrepancies. Manual investigation of these records showed a number of the OBD eVINs or entered VINs were invalid (for example, the VIN contained characters that are not allowed in a VIN, or combinations of characters not expected to be in a VIN, such as "XXXX"), and some mismatches were also due to VIN errors in the vehicle test record. An investigation of the VIN discrepancies, shown in Table VI-1, revealed that vehicles from the early years of OBD (1996-1999) had very high rates of discrepancies, with as many as 89 percent of vehicle records containing a discrepancy. Rates were very low for the later model years, in part due to federal requirements for the OBD system to provide the OBD eVIN on model year 2005 and newer vehicles. 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.

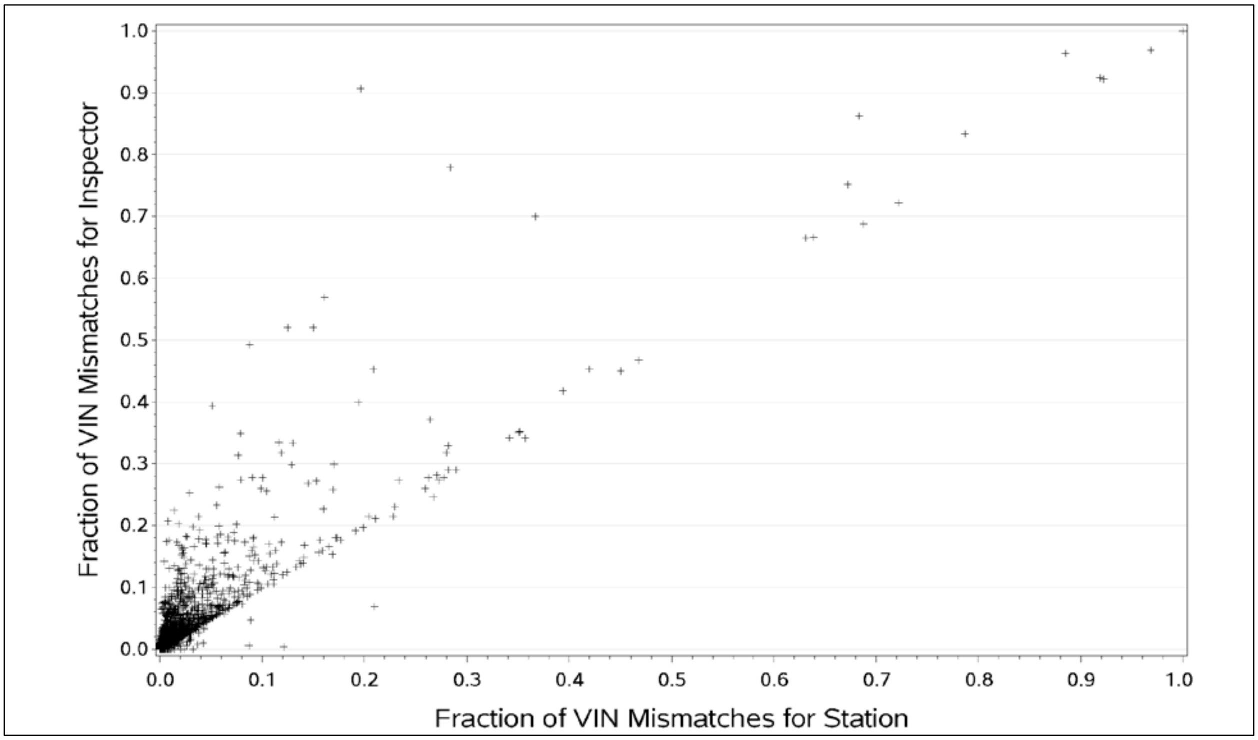
[8] The US EPA requirement for the eVIN to be standardized and available through the OBD system applies to all model year 2005 and newer vehicles, but not to model year 1996 through 2004.

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

Model Year	Number of OBD Inspections with valid eVIN but VIN Mismatch	Percent of OBD Inspections with VIN Mismatch	Total Inspections With valid OBD VINs
1996	1,569	88.8%	1,767
1997	2,321	87.5%	2,652
1998	2,786	86.1%	3,235
1999	3,522	78.4%	4,495
2000	6,195	11.6%	53,262
2001	7,946	3.9%	203,384
2002	8,502	3.2%	266,667
2003	8,537	2.6%	323,930
2004	9,304	2.2%	425,534
2005	11,163	1.4%	782,318
2006	10,730	1.2%	883,785
2007	10,118	0.9%	1,080,417
2008	8,504	0.8%	1,116,547
2009	4,623	0.6%	770,854
2010	4,411	0.5%	934,905
2011	4,238	0.4%	1,058,511
2012	4,310	0.3%	1,259,259
2013	4,247	0.3%	1,495,292
2014	3,993	0.3%	1,524,544
2015	2,521	0.3%	969,717
2016	449	0.3%	170,429
2017	83	0.3%	23,949
2018	3	0.5%	632
Total	**120,075**	**0.9%**	**13,356,085**

The rate at which VIN discrepancies were recorded was calculated for each station that performed OBD inspections, and for each inspector. These are compared graphically in Figure VI-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 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 in part result from practices other than clean-scanning, such as careless data entry when the VIN is manually entered, or vehicles with an invalid OBD VIN (earlier model years or PCM replacements).

Figure VI-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 eVIN hundreds of 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 VI-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 table also shows the maximum number of times a single VIN was tested at each station.

Table VI-2. Stations with Highest 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:				
1P49394	100.0	592	564	100.0
1P50083	96.9	413	372	100.0
2P39842	92.2	232	91	100.0
2P50940	91.9	148	135	99.9
1P49682	88.5	295	255	99.9
1P49197	78.7	108	83	99.9
2P49941	72.2	820	140	99.9
2P48665	68.8	314	58	99.9
1P43010	68.4	771	522	99.8
2P48689	67.2	1218	347	99.8

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 re-tests 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 re-test were used, and only records where monitor readiness values were non-missing were used, reducing the dataset from 14 million OBD inspections to 1.4 million inspections. This includes 810,000 initial inspections, and 890,000 re-tests.

In previous years of performing this I/M Evaluation (2016 and earlier), three variables were used to create the first "electronic profile" for each vehicle: the OBD-downloaded VIN, the PCM ID, and the PID Count. For this current 2018 analysis, three additional variables are added: the Communications Protocol (COMM_PROT), the calibration ID (CAL_ID) and the CVN (calibration verification number). The downloaded values for these six 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 70 percent of the test records. The OBD VIN or the manually entered VIN was null in the remaining 30 percent of the OBD test records. The 30 percent that did not download correctly is likely due to vehicles age, i.e. older vehicles with non-standard eVINs. Because of this, use of the OBD VIN in itself would not be sufficient to positively identify clean-scanning.

- PCM ID: The PCM ID was available in all but 40 of the test records. 51 unique PCM IDs were seen, but 40 percent of all PCM IDs had a value of "10". One other PCM ID represented another 39 percent of records, three other PCM IDs each comprised an additional 2 to 4 percent of the test records, and the remaining test records were distributed among the other PCM IDs. Because of this, as with the OBD VIN, use of PCM 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 most common PCM IDs).
- PID Count: 82 unique PID Count values were seen, and all but 749 OBD test records contained a value for PID Count. Seven PID Count values were seen in 38 percent of all OBD test records, while the remaining test records contained one of the remaining PID Count values.
- COMM_PROT: 7 unique values were seen, and all but 77 OBD test records contained a value for the COMM_PROT. Two COMM_PROT values were used for 67 percent of records, so the use of COMM_PROT along would not be sufficient to positively identify clean-scanning.
- CVN and CAL_ID each contain hundreds of unique values. These variables could be quite specific for identifying changes from one inspection to the next, except that they are only populated for about half of the OBD records, meaning that about 50 percent of OBD records have the same values (missing) for these variables.
- When the PCM ID, PID Count, COMM_PROT, CAL_ID, and CVN are looked at in combination, the three most common combinations comprise 6, 4, and 3 percent of inspections, with many hundreds of combinations making up the remainder of inspections. Thus, the combination of these five variables 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 "supported" and "not supported," 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, evaporative 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: 37 percent not monitored, 63 percent monitored;
- Evaporative systems: 4 percent not monitored, 96 percent monitored;
- Heated O2 systems: 2 percent not monitored, 98 percent monitored;

- Secondary air systems: 93 percent not monitored, 7 percent monitored; and
- When the status of the four monitors is looked at together, two combinations of monitor status dominated the dataset, with 58 percent and 30 percent of vehicles. Smaller numbers of vehicles comprised the remaining 14 combinations and 12 percent 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 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 re-test 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 808,000 initial inspections and 894,000 re-tests. Retests that took place on an analyzer from a different manufacturer than the initial test were excluded from the results, leaving 797,000 re-tests for analysis. The results of the analysis were:

- 656,849 (82.4 percent) of re-tests had matches for both the electronic profile and the readiness profile between initial test and subsequent re-tests on the same analyzer. These tests very likely indicate compliant testing.
- 34,087 (4.3 percent) of re-tests had a mismatch for both the electronic profile info and the readiness profile, between the initial test and at least one re-test 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).
- 717 (0.1 percent) of re-tests had a "readiness profile" mismatch between the initial test and at least one re-test on the same analyzer, but the electronic profile

matched between the initial test and all subsequent re-tests on the same analyzer. This scenario is difficult to interpret, since the readiness profile is based on "monitored versus 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.

- 105,817 (13.3 percent) of re-tests had an electronic profile mismatch info between the initial test and at least one re-test on the same analyzer, but the "readiness profile" matched between the initial test and all subsequent re-tests on the same analyzer. Since the computer ID serves as a unique identifier for any vehicle, this information should always match for re-tests on the same vehicle. A mismatch could occur only in the following scenarios:
  - — if another vehicle was substituted for a re-test (clean-scanning);
  - — if an anomaly in the analyzer software interpreted the computer ID info two different ways on subsequent re-tests for the same vehicle; or
  - — 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.

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

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

Re-test Match Scenario	Re-test-only Dataset
All match (compliant)	82.4 %
Readiness mismatch (ambiguous)	0.1 %
PCM ID info mismatch (fraud likely)	13.3 %
Both mismatch (fraud very likely)	4.3 %
Estimated % of clean-scanning	4% to 13%

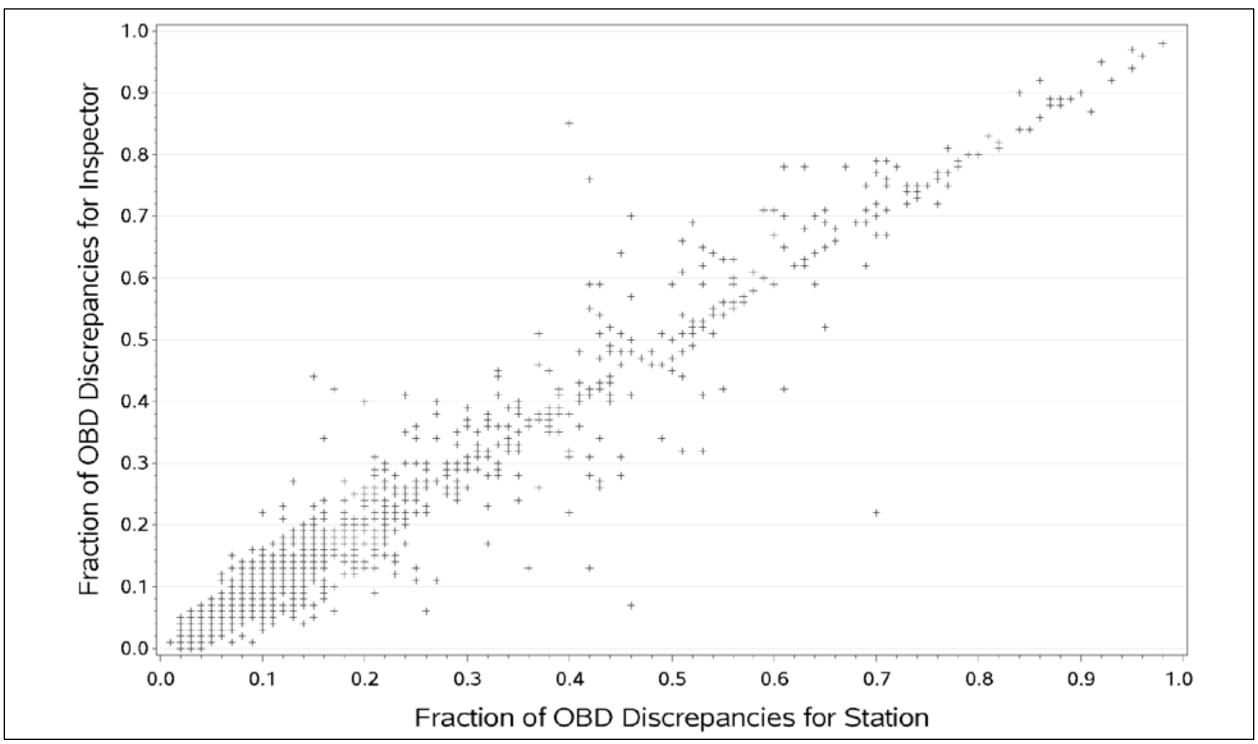
Next, using the complete dataset, which includes tests classified as initial tests, the following general statistics were seen for stations and inspectors with computer ID information or "readiness profile" mismatches.

- Over the two-year evaluation period, 95 percent of the 5,487 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 re-test records for any one station was 1,056 records over the two-year period, and another 53 stations had more than 200 records with a mismatch. Some stations had mismatch rates as high as 90 percent.

- Over the two-year evaluation period, 62 percent of the 31,197 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 re-test records for any one inspector was 751 records over the two-year period, while an additional 22 inspectors had more than 200 mismatch re-test records. Inspector mismatch rates as high as 85 percent were identified.

The distribution of station and inspector mismatch rates is shown in Figure VI-2. The horizontal axis shows the fraction of re-test 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 re-test 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 VI-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 re-test inspections performed at that station that included both an electronic profile mismatch and a readiness profile mismatch. Stations with fewer than 100 OBD re-test 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 are listed in Table VI-4. Some electronic profile and/or readiness mismatches are to be expected, and as mentioned above, 95 percent of stations had at least one case of a mismatch. However, most of those stations had only one or a few mismatches. Overall, about 4.3 percent of re-test inspections resulted in a readiness profile and electronic profile mismatch. When stations with a mismatch in as many as 90 percent of their inspections are seen, one can start to suspect that something beyond the expected occasional difference is taking place.

Table VI-4. Stations with Highest Percent 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:			
1P49394	85.0	120	100.0
2P44831	83.7	172	100.0
1P49139	81.4	102	99.9
1P49119	79.5	185	99.9
1P49388	78.6	159	99.8
2P49508	75.9	145	99.8
1P44321	75.2	149	99.8
1P50083	74.9	207	99.7
2P42264	74.7	269	99.7
1P50375	71.8	110	99.6

B. 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 warm-up or 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 is followed by a re-test 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 NO_X levels (NO_X 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.

Short Time Interval Between Inspections

For inspection cycles that begin with a failing inspection, a re-test (or re-tests) 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 re-test. The dataset shows that many stations have one or a few cases of a passing re-test 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, or from retesting a vehicle that previously had not been properly warmed-up. Some vehicles which failed with emissions levels very near the cutpoints might also be retested after no repair, and then 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 OBD, TSI, and ASM inspections were considered. This left 17.9 million observations in the dataset. In addition, only time differences on re-test inspections that were conducted at the same inspection station as the initial inspection were used. This resulted in a dataset of about 738,882 re-test observations.

The distribution of the number of times that a failed initial inspection was followed by a passing re-test within 15 minutes at a given station over a 2-year period is listed in Table VI-5. The table shows that this happened rarely or never for most stations.

However, for 88 stations, it happened 20 or more times (up to 90 times for the highest station, not shown in the table).

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

Number of Close-In-Time Retests	Number of Stations	Percent of Stations
0	1884	34.5
1	1087	19.9
2	672	12.3
3	474	8.7
4	318	5.8
5	211	3.9
6	154	2.8
7	120	2.2
8	85	1.6
9	63	1.2
10	68	1.3
11	52	1.0
12	37	0.7
13	35	0.6
14	32	0.6
15	26	0.5
16	18	0.3
17	13	0.2
18	14	0.3
19	9	0.2
20 or more	88	1.6
Total	**5460**	**100.0**

The ten stations with the highest rate of close-in-time re-tests are listed in Table VI-6. The percentage was calculated from the number of close-in-time re-tests and the total number of re-tests, at that station. Stations that performed fewer than 100 re-test inspections over the 2-year period are excluded from the results. From the table, the highest ranked stations performed a third of their re-test inspections within the short time period of 15 minutes or less after the initial passed inspection.

Table VI-6. Percent of Close-In-Time Retest Inspections for 10 Highest Ranking Stations

Station ID	Percent of Close-In-Time Retests	Number of Close-In-Time Retests	Total Number of Retest Inspections	Percentile Rank for Station
2P37659	44.4%	84	189	100.0
2P48438	27.7%	31	112	100.0
1P37540	18.6%	21	113	99.9
1P35260	17.7%	25	141	99.9
2P03057	17.5%	20	114	99.8
1P49943	17.3%	23	133	99.8
2P45952	17.0%	25	147	99.7
2P39249	16.0%	16	100	99.7
1P38854	15.8%	32	203	99.6
2P37904	15.4%	35	227	99.6

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 ASM inspection measures NO_X, but the TSI inspection does not, 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 280,000 observations in the dataset. Only inspection cycles where the initial inspection and the re-test inspection were conducted at the same station were used. This left about 30,000 re-tests in the dataset.

Overall, it was found that for ASM inspections that were failed for HC and/or CO, but where NO_X was passed, 2.3 percent of re-tests were TSI instead of ASM. For ASM inspections that included a NO_X failure, 2.4 percent of re-tests were TSI instead of ASM. These percentages are similar, but the fact that the percentage is slightly higher when a NO_X failure is present may indicate that some intentional test-type switching is taking place to avoid the stricter ASM standards. Table VI-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 NO_X. Stations that performed fewer than 100 re-test inspections were excluded from the results. The table shows that this happened 12 times at the station with the highest frequency of occurrences. The stations in Table VI-7 had rates of 1-10 percent of all re-tests being switches from ASM to TSI inspections.

Table VI-7. Percent of Retest Inspections Switched from ASM to TSI for 10 Highest Ranking Stations

Station ID	Percent of Retests Switched from ASM to TSI	Number of Switched Retests	Total Number of Retest Inspections	Percentile Rank for Station
2P42274	9.9	12	121	100.0
1P39598	1.8	2	112	97.9
1P25057	1.5	2	136	95.7
2P39188	1.5	2	137	93.6
1P27190	1.2	2	171	91.5
1P27747	0.9	1	107	89.4
2P40646	0.9	1	112	87.2
1P38551	0.9	1	116	85.1
1P01856	0.8	1	121	83.0
1P45927	0.8	1	124	80.9

Changing 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 re-test inspection were conducted at the same station were used. This left 740,000 re-test inspections in the dataset.

Overall, it was found that only 0.23 percent of inspections that were initially failed as a light-duty vehicle were followed by a passing re-test as a heavy-duty vehicle. However, these inspections were clustered at a handful of stations, shown below in Table VI-8. The table shows the ten inspection stations with the highest frequency of re-tests that involved a vehicle that failed as a light-duty vehicle on the initial inspection, followed by a passed re-test of the same vehicle as a heavy-duty vehicle. At the first station on the list, about 15 percent of vehicles that failed as a light-duty vehicle were switched to a heavy-duty vehicle, and then passed.

Table VI-8. Percent of Retest Inspections Switched from Light-Duty to Heavy-Duty, for 10 Highest Ranking Stations

Station ID	Percent of Retests Switched from LD to HD	Number of Switched Retests	Total Number of Retest Inspections	Percentile Rank for Station
2P42851	15.0%	74	492	100.0
2P03057	11.4%	13	114	100.0
1P02394	10.5%	30	287	99.9
1P35260	7.1%	10	141	99.9
1P36822	6.5%	18	279	99.8
2P45952	6.1%	9	147	99.8
2P35149	5.7%	19	333	99.7
2P30447	5.7%	25	441	99.7
1P45494	4.3%	16	369	99.6
2P48728	4.3%	5	116	99.6

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 the DPS. 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 for 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 percent rank for the station at the mean and the 100 percent 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 percent rank for the station at the mean, and the 100 percent 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 VI-9, with failure rates for OBD and ASM inspections listed separately. The lowest failure rate stations are listed in Table VI-10, with failure rates for OBD and ASM inspections listed separately. Stations with fewer than 100 inspections are excluded from the results.

Table VI-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:				
2P08599	44.8	47	105	100.0
1P51290	30.4	45	148	100.0
2P50603	29.2	33	113	99.9
2P32154	27.8	919	3305	99.9
2P02227	27.0	161	597	99.8
1P48662	26.8	188	701	99.8
2P51334	26.5	30	113	99.7
1P50869	23.9	72	301	99.7
1P50894	23.0	64	278	99.6
1P48176	22.7	1263	5562	99.6
ASM Inspection Results:				
1P39751	21.9	44	201	100.0
2P40519	21.7	26	120	97.0
2P10346	19.6	53	270	93.9
1P27190	14.7	16	109	90.9
2P37054	14.5	23	159	87.9
1P45927	14.5	23	159	84.8
1P41466	13.7	16	117	81.8
1P29906	13.3	34	256	78.8
2P31365	13.2	28	212	75.8
2P03889	12.8	15	117	72.7

Table VI-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:				
2P51308	0.0	0	255	100.0
2P50735	0.0	0	457	100.0
2P50701	0.0	0	298	99.9
2P50593	0.0	0	164	99.9
2P49045	0.0	0	110	99.9
2P48709	0.0	0	1233	99.8
2P48264	0.0	0	374	99.8
2P47655	0.0	0	783	99.8
2F21189	0.0	0	115	99.7
1P51624	0.0	0	161	99.7
ASM Inspection Results:				
2P44855	0.0	0	125	100.0
1P49119	0.0	0	339	97.3
1P44321	0.0	0	188	94.6
1P27564	0.0	0	157	91.9
1P49388	0.1	1	1201	89.2
1P45845	0.4	1	283	86.5
2P40941	0.4	1	225	83.8
2P45787	0.6	1	168	81.1
2P48668	0.6	1	158	78.4
1P36835	1.3	2	154	75.7

C. 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.

High Degree of Drift

In Section III.D, 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 desired. 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, NO_X, 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, 98 percent of 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 VI-11 had all or almost all calibrations on out-of-tolerance analyzers.

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

Station ID	Analyzer ID	Percent of Calibrations that Began with Out-of-Tolerance Analyzer	Number of Calibrations that Began Out-of-Tolerance	Total Number of Calibration Events	Percentile Rank for Station
1P43255	ES213311	100.0	115	115	99.9
1P31757	ES315050	100.0	121	121	99.8
1P33222	ES315471	99.5	220	221	99.8
1P11532	ES213104	99.2	117	118	99.7
1P35824	ES315484	98.2	56	57	99.6
2P50899	ES520628	97.8	44	45	99.5
1P48737	ES317057	97.5	39	40	99.4
1P45268	ES324317	97.0	128	132	99.4
1P49119	ES417531	96.9	157	162	99.3
2P33169	ES315210	96.3	156	162	99.2

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 III.D. Here, the audit failure rate for each station was calculated. Stations with fewer than six 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 VI-12.

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

Station ID	Analyzer ID	Percent of Audits that were Failed	Number of Audits that were Failed	Total Number of Audits for Station	Percentile Rank for Station
2P29944	ES212945	100.0	8	8	100.0
1P43010	SE500603	100.0	7	7	99.9
1P49028	ES214102	88.9	8	9	99.8
1P29892	ES212800	88.9	8	9	99.7
1P17329	ES213022	88.9	8	9	99.6
2P40421	ES314779	85.7	12	14	99.5
2P43221	ES213195	83.3	5	6	99.4
2P40673	ES212970	83.3	5	6	99.3
1P48619	WW510146	83.3	5	6	99.2
1P48273	WW510437	83.3	5	6	99.1

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 III.D, 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 highest ranking stations are shown in Table VI-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 VI-13. Percent of Inspections When Analyzer Should Have Been Locked Out

Station ID	Analyzer 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
2P40428	SE400004	100.0	137	137	100.0
2P40148	WW510619	100.0	516	516	96.9
2P34825	WW510719	100.0	177	177	93.8
2P32854	WW510575	100.0	245	245	90.6
2P18859	SE400002	100.0	132	132	87.5
2P11251	WW510627	100.0	177	177	84.4
2P03889	WW510490	100.0	320	320	81.3
2P03723	WW510538	100.0	275	275	78.1
1P49388	WW510656	100.0	212	212	75.0
1P49203	WW510515	100.0	453	453	71.9

D. DATA ENTRY ISSUES

Several TIMS 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.

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 42 percent of the repairs recorded in the TIMS during the most recent analysis period. At certain stations, miscellaneous repairs account for much more than that. The ten stations with the highest percentages of miscellaneous repairs are presented in Table VI-14. Stations that performed fewer than 100 inspections following repairs are excluded from the results.

Table VI-14. Miscellaneous Repair Percentage

Station ID	Percent of "Misc" repairs	Number of "Misc" repairs	Total Repairs	Percentile Rank for Station
1P35686	100.0	127	127	100.0
1P49693	100.0	497	497	100.0
1P31791	99.6	282	283	99.9
2P50486	99.6	262	263	99.9
2P12877	99.4	513	516	99.8
2P40123	99.4	153	154	99.8
1P37937	99.3	138	139	99.7
1P39423	99.3	266	268	99.7
2P18261	99.2	118	119	99.6
1P38521	99.1	115	116	99.6

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-half 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 VI-15. Stations that performed fewer than 100 inspections following repairs are excluded from the results.

Table VI-15. Zero-Cost Repair Percentage

Station ID	Percent of $0 Repairs	Number of $0 Repairs	Total Number of Repairs	Percentile Rank for Station
2P49348	100.0	181	181	100.0
2P48259	100.0	240	240	99.8
2P48055	100.0	317	317	99.6
2P42090	100.0	355	355	99.3
2P41757	100.0	188	188	99.1
2P41331	100.0	157	157	98.9
2P40123	100.0	154	154	98.7
2P39828	100.0	201	201	98.5
2P39191	100.0	184	184	98.3
2P39008	100.0	117	117	98.0

VIN Check Digit Errors

In the 2009 Texas I/M Program Evaluation Report, about 1.5% of VINs on record contained a bad check digit or an invalid character. More recently, in the 2012, 2014, and 2016 reports, fewer than 0.1% of VINs contained a bad check digit, representing such a small portion of total inspections that this metric was not used for the 2012, 2014, or 2016 analysis. This year, records with a bad check digit in the VIN comprise fewer than 0.001 percent of inspections (483 total bad check digits out of 9.6 million inspections). Most VINS are likely pre-populated through the record retrieval during the analyzer's initial "get-info" call or are scanned by the bar-code reader, so the VIN is entered correctly. TCEQ is aware that there have been prior instances of inspectors intentionally entering an incorrect VIN as a route to OBD inspection fraud. However, ERG examined the dataset and found that in the list of the stations with the highest frequency of bad check digits, the top ten worst performing stations had 3, 2, or 1 instances of bad check digits during the two-year period. The use of invalid VINs for OBD inspections may happen very occasionally but it is clearly not systematic, and ERG does not think that this metric remains useful as an indicator of an inspection problem.

Anomalous Inspection Sequences (other than 1P or FP)

Each vehicle that participates in the Texas I/M program produces a brief history when it is inspected, repaired, and retested. 99.5 percent of the vehicles that participate in the program have a repair sequence of either pass (P) or fail-repair-pass with three or fewer re-tests before the ultimate pass (FP group). The remaining portion of the fleet consists of vehicles with histories that contain multiple passes or fails. Table VI-16 lists stations that were in contact at some point with vehicles that had anomalous inspection sequences. Stations that performed fewer than 100 inspections are excluded from the results.

Table VI-16. Anomalous Inspection Sequence Percentage

Station ID	Percent of Inspections with Odd Sequence	Number of Inspections with Odd Sequence	Total Inspections	Percentile Rank for Station
1P48662	17.0	63	371	100.0
1P50667	7.4	21	285	100.0
2P50590	7.3	20	274	100.0
2P50328	7.1	36	504	99.9
1P50685	6.6	8	122	99.9
2P50838	6.4	7	109	99.9
2P02227	6.4	23	359	99.9
2P50570	6.2	12	193	99.9
1P50710	6.0	8	134	99.8
2P50751	5.6	7	125	99.8

E. ANOMALOUS TEST RESULTS

In Section III.D, 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 percent, O_2 levels near ambient concentrations, and high DCFs. In this section, the rate of each of these anomalies by station is investigated.

Tailpipe Inspections with CO_2 Greater Than 16%

Table VI-17 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 VI-17. Percent of Inspections with CO_2 Greater Than 16 Percent

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
1P48905	81.9	118	144	100.0
1P49400	51.2	66	129	99.9
1P40852	46.1	89	193	99.7
2P32603	31.7	40	126	99.6
1P42459	30.1	31	103	99.5
2P37054	28.7	49	171	99.3
1P45345	28.5	35	123	99.2
2P36721	28.0	77	275	99.1
1P37089	27.8	85	306	99.0
1P45660	21.9	69	315	98.8

Tailpipe Inspections with O2 Greater than 20.5%

Table VI-18 presents stations with a high percentage of vehicles whose ASM or TSI tests produced O_2 readings greater than 20.5 percent, which is outside the normal combustion range and is very close to the ambient O_2 concentration of 20.9 percent. Stations that performed fewer than 100 inspections are excluded from the table.

Table VI-18. Percent of Inspections with O_2 Greater Than 20.5 Percent

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
2P30874	100.0	149	149	100.0
1P47573	100.0	346	346	99.9
2P35746	98.2	586	597	99.7
1P40011	98.1	208	212	99.6
1P04303	97.6	124	127	99.5
1P17553	93.1	282	303	99.3
1P17053	91.3	105	115	99.2
1P50020	90.6	163	180	99.1
1P47529	90.4	142	157	99.0
1P41962	89.8	176	196	98.8

F. TAILPIPE INSPECTIONS WITH HIGH DCF DIFFERENCES

Table VI-19 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 percent and O_2 greater than 20.5 percent), since the DCF is based on CO, CO_2, and O_2 measurements. 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 VI-19. 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
2P42253	100.0	182	182	100.0
2P40429	100.0	120	120	99.9
2P40428	100.0	159	159	99.7
2P40140	100.0	512	512	99.6
2P37660	100.0	160	160	99.5
2P36556	100.0	245	245	99.3
2P35746	100.0	597	597	99.2
2P31366	100.0	116	116	99.1
2P30874	100.0	149	149	99.0
2P18859	100.0	159	159	98.8

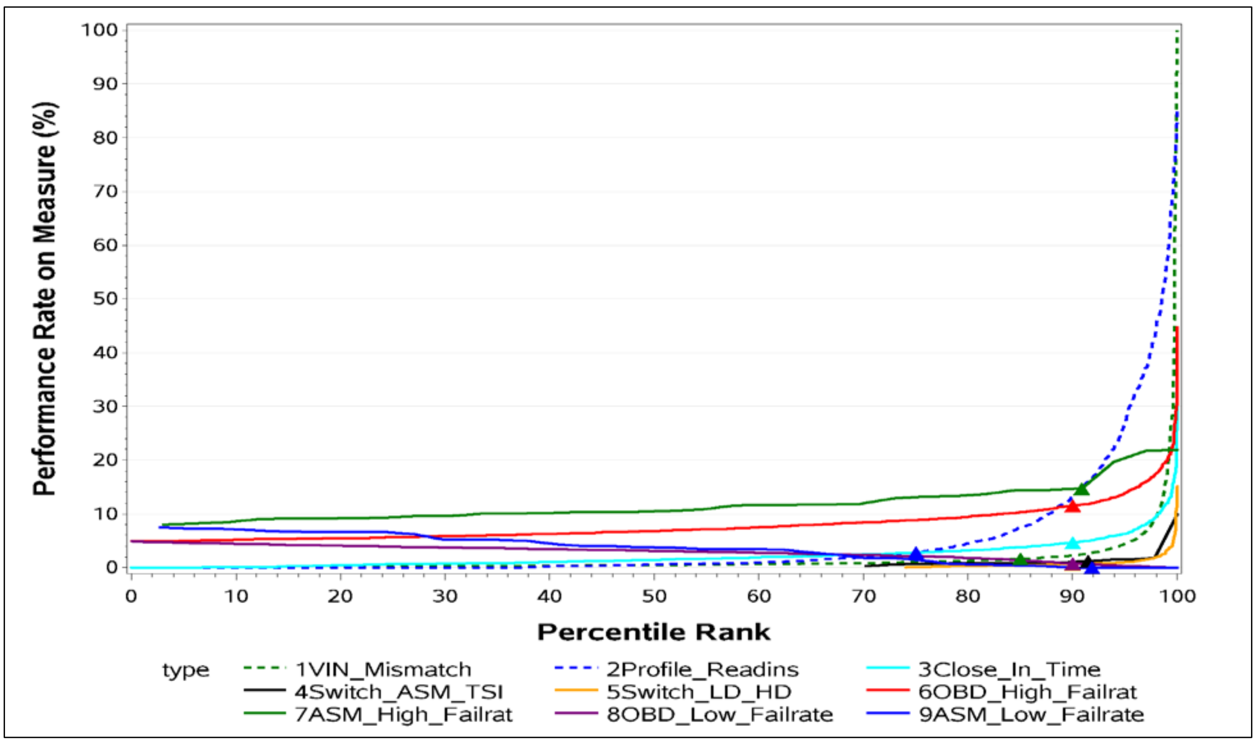
G. COMPILATION OF PERCENTILE RANKINGS

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 re-tests, 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 85 percent of stations had very low VIN mismatch rates. The remaining 15 percent had VIN mismatch rates that might be cause for concern, or about the top 15 percentiles in the ranking. In contrast, for the tailpipe inspection being switched from light-duty to heavy-duty in order to pass, at least 90 percent of stations had reasonably low rates of switching from ASM to TSI, and only the top 10 percent of stations would lead one to suspect possible fraud. Figure VI-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 dashed line for the OBD VIN mismatch shows that the stations from 0 to the 85th percentile had a very low percentage of mismatches. Above the 85th percentile, the mismatch rate quickly increases. Similarly, the blue dashed line for the OBD electronic readiness profile shows that stations up to the 75th percentile had a low rate of mismatches. For the other measures, the rate of overly close in time inspections, re-tests switched from ASM to TSI, and re-tests switched from light-duty to heavy-duty, the stations below about the 90th percentile had very low results. Above the 90th percentile, the rate of potentially fraudulent results rapidly increases. 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, and again the "break" for the low ASM failure rates is close to the 90th percentile.

Figure VI-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 VI-3, it is probably not likely that the station is performing that type of fraudulent activity that can be detected through this analysis. 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 VI-20. Table VI-21 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 have not already been, as a result of triggers or other audits). For example, the first station, 2P45952 had a very high rate of OBD VIN mismatches, and high rates of OBD readiness and electronic profile mismatches. This indicates a high possibility of OBD inspection fraud. However, this station also had a high rate of close-in-time retests, and switches from LD to HD. These results do not guarantee that this station is intentionally causing OBD vehicles to fail an initial inspection and performing unnecessary repairs, but the results do indicate that 2P45952 would be a good candidate for an audit. By contrast, in the fourth line, 1P42030 had high rates of OBD VIN mismatches, OBD readiness mismatches, and OBD electronic profile mismatches. This station also had a very low OBD failure rate, suggesting it is likely clean-scanning and would also be a good candidate for an investigation. If this table were to be used for identifying stations for investigations, audits, etc., the user would have to review the tables to 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 VI.3, VI.4, and VI.5 were used here. Figure VI-4 shows the distribution of the results versus 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 VI-4, the "break" percentiles were assigned at the 80th percentile for analyzers out of tolerance, the 80th percentile for span gas audit failures, the 95th percentile for performing inspections when the analyzer is not fully calibrated and should be locked out, 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 could 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 VI-22. Some of the rows do appear to show a clear picture of the inspectors at some stations having particular trouble entering data accurately and completely, with high scores for 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 percent and O_2 greater than 20.5 percent. Again, the table could be used to identify different types of enforcement that are indicated by the combinations of results on each line.

Finally, one new investigation for this section is a comparison of the potential-fraud rates by I/M program area. If fraud rates were higher in one area than the other, it might be possible that this would result in the Texas I/M program having a different degree of impact in the two program areas. The result of the investigation is shown below in Figure VI-5. Each of the nine different types of errors of commission is shown on the plot (this is the same group of categories as was shown in Figure VI-3). However, the plot now shows the fraction of stations that are from the DFW program area, for each decile of the ranks. For example, looking at the green dots on the dashed green line (VIN/eVIN mismatch), we can see that at the zero-percentile group, the fraction of stations in that group is 56 percent DFW (and by inference, 44 percent HGB). At the 10^{th} decile group, we see about 65 percent of stations are from the DFW program area (and so 35 percent from the HGB program area). By contrast, at the 90^{th} and 100^{th} decile groups, the percentage of stations from the DFW program area is about 40 percent (so the HGB program area would be 60 percent). This indicates that at the low end of the ranks (where fraud of this type is unlikely), there are more DFW stations, and at the high end of the ranks (where fraud of this type is much more likely) there are more HGB stations. A similar, and even more significant, trend can be seen for the squares on the blue dashed line, for the OBD electronic profile comparisons. For the other measures, it is much more difficult to see any sort of meaningful trend. However, it does appear that for the two major OBD fraud checks, the VIN/eVIN and the electronic profile, more stations are potentially committing fraudulent inspections in the HGB program area than in the DFW program area. Since OBD vehicles now dominate the fleet, fraudulent OBD inspections could significantly undermine the Texas I/M program’s effectiveness.

Table VI-20. 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
2P45952	4	99.8	92.0	95.6	99.7	.	99.8	69.7	.	.	.
1P42030	4	99.3	93.3	89.6	95.4	.	99.3	.	.	46.5	.
2P41186	4	99.0	99.0	95.8	94.8	.	98.8	63.4	.	.	.
1P39291	4	98.6	96.7	90.9	98.6	.	97.9	18.6	.	.	.
2P32413	4	98.6	78.5	85.7	98.6	.	90.6	.	.	94.6	.
1P00804	4	98.4	94.6	86.8	98.2	.	0.4	98.4	.	.	.
2P41310	4	98.1	90.6	85.8	98.1	.	97.7	.	.	16.4	.
2P34952	4	97.6	96.1	88.6	97.6	.	91.5	.	.	6.8	.
2P48393	4	97.5	86.4	85.1	94.8	.	97.5	.	.	28.2	.
2P45749	4	96.4	92.9	87.0	96.4	.	95.6	53.3	.	.	.
1P41027	4	96.3	96.3	76.5	13.7	34.0	90.8	94.7	.	.	.
1P38155	4	95.9	93.1	85.9	90.7	.	95.9	.	.	46.7	.
2P49341	4	92.6	87.5	92.3	33.2	.	92.6	90.1	.	.	.
2P36383	4	91.4	76.2	83.7	90.8	57.4	91.0	.	.	91.4	.
1P49394	3	100.0	100.0	100.0	.	.	.	.	.	96.6	.
2P42274	3	100.0	67.7	76.6	67.3	100.0	92.9	.	.	10.4	27.0
1P50083	3	100.0	100.0	99.7	.	.	.	.	.	97.6	.
2P03057	3	100.0	73.9	74.8	99.8	.	100.0	97.0	.	.	.
2P48438	3	100.0	98.9	94.8	100.0	.	69.3	25.7	.	.	.
1P49682	3	99.9	99.9	98.2	.	.	.	.	.	92.9	.
1P02394	3	99.9	88.4	0.8	97.8	.	99.9	66.0	.	.	35.1
1P37540	3	99.9	96.4	87.7	99.9	.	14.6	.	.	67.5	.
1P35260	3	99.9	75.9	90.2	99.9	.	99.9	.	.	80.7	.
1P44321	3	99.8	78.7	99.8	.	.	.	.	.	95.1	94.6
2P30447	3	99.7	94.2	86.4	85.4	.	99.7	41.4	.	.	.
2P39249	3	99.7	98.5	99.1	99.7	.	57.1	.	.	83.8	.
1P41458	3	99.5	83.3	81.9	97.5	.	99.5	27.2	.	.	.
2P36105	3	99.4	23.7	76.6	95.7	.	99.4	.	.	55.1	.
2P41978	3	99.4	79.2	97.0	99.4	.	90.1	.	.	75.5	.

Table VI-20. 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
2P49477	3	99.4	85.3	89.1	76.5	.	99.4	50.8	.	.	.
1P33099	3	99.3	93.3	98.1	99.3	.	9.6	.	.	39.2	.
2P40151	3	99.2	97.5	93.4	99.2	.	79.8	85.6	.	.	.
2P48849	3	99.2	99.0	88.4	.	.	.	99.2	.	.	.
2P42042	3	99.2	88.7	96.6	99.2	.	81.3	54.4	.	.	.
2P44075	3	99.1	97.9	87.8	99.1	.	64.0	9.6	.	.	.
2P36730	3	99.1	98.7	86.0	0.0	.	53.5	99.1	.	.	.
1P44369	3	99.1	60.4	88.7	92.3	.	99.1	35.4	.	.	.
1P49513	3	99.0	86.7	75.9	0.0	.	35.0	99.0	.	.	.
2P04004	3	98.9	98.9	85.7	92.4	.	38.4	10.7	.	.	.
2P44409	3	98.8	98.8	87.6	40.4	.	64.5	93.9	.	.	.
1P40619	3	98.8	91.0	98.8	.	.	.	.	.	92.0	.
2P44814	3	98.7	97.0	81.9	62.1	.	98.7	1.5	.	.	.
1P43051	3	98.7	98.7	92.5	69.6	.	24.0	94.7	.	.	.
2P48434	3	98.6	68.6	97.5	93.7	.	98.6	78.4	.	.	.
2P48676	3	98.5	98.5	80.4	51.2	.	91.4	83.1	.	.	.
1P35341	3	98.5	98.5	89.2	86.6	.	90.3	57.6	.	.	.
2P33043	3	98.4	65.7	82.2	98.4	.	94.6	.	.	90.0	.
2P40345	3	98.4	57.0	88.2	98.3	.	98.4	28.3	.	.	.
2P40988	3	98.2	98.2	87.1	82.5	.	79.8	91.8	.	.	.
2P01478	3	98.2	81.2	76.9	92.3	.	98.2	72.7	63.6	.	.

Table VI-21. 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
1P51530	0	78.8	.	.	.	.	.	.	.	78.8	.
1P41267	0	78.8	73.4	.	.	.	.	78.8	.	.	.
1P27629	0	78.8	78.8	.	.	.	.	.	.	63.2	.
1P31604	0	78.8	32.9	41.4	25.1	.	78.8	.	.	17.4	.
2P40122	0	78.8	78.8	32.2	0.0	.	58.2	.	.	11.2	.
1P51336	0	78.8	3.4	.	.	.	.	.	.	78.8	.
1P40489	0	78.7	78.7	56.4	.	.	.	52.7	.	.	.
1P11374	0	78.7	9.4	2.0	39.1	.	78.7	.	.	6.0	.
1P28729	0	78.7	66.4	39.0	16.3	78.7	6.2	76.9	.	.	.
2P49042	0	78.7	78.7	42.6	66.0	.	70.8	71.9	.	.	.
1P50463	0	78.7	48.0	.	.	.	.	78.7	.	.	.
1P28615	0	78.7	60.4	62.3	78.7	.	6.1	1.7	.	.	.
2P30388	0	78.7	36.5	27.0	20.5	.	78.7	.	.	39.0	.
2P48426	0	78.7	78.7	70.8	25.3	.	69.3	.	.	51.2	.
1P51057	0	78.7	48.7	.	.	.	.	.	.	78.7	.
1P17053	0	78.6	30.4	.	38.3	.	3.3	78.6	.	.	.
1P32504	0	78.6	24.3	5.8	55.6	.	78.6	.	.	11.1	.
1P26593	0	78.6	16.4	.	.	.	.	.	.	78.6	.
1P41008	0	78.6	78.6	.	.	.	.	.	.	67.6	.
2P38819	0	78.6	78.6	63.8	45.9	.	56.3	14.6	.	.	.
1P50667	0	78.6	61.6	23.2	18.3	.	36.7	78.6	.	.	.
2P39267	0	78.6	67.8	31.8	33.7	.	57.2	.	.	78.6	.
2P12626	0	78.6	55.4	25.3	44.3	.	78.6	.	.	34.3	.
2P47754	0	78.6	78.6	.	.	.	.	.	.	71.8	.
2P30964	0	78.6	77.0	.	.	.	.	.	.	78.6	.
1P39600	0	78.6	78.6	.	.	.	.	44.3	.	.	.
1P45726	0	78.5	78.5	.	.	.	.	72.0	.	.	.
2P41977	0	78.5	20.8	33.3	60.5	.	78.5	.	.	29.8	.
2P35472	0	78.5	78.5	46.5	47.8	.	51.1	69.8	.	.	.

Table VI-21. 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
2P12457	0	78.5	16.5	72.2	32.5	.	41.2	.	.	78.5	.
1P48907	0	78.4	34.2	65.9	78.4	.	32.8	.	.	18.2	.
1P33059	0	78.4	42.0	.	.	.	.	.	.	78.4	.
1P44723	0	78.4	78.4	70.4	72.0	.	26.4	.	.	6.6	.
1P49137	0	78.4	23.5	.	.	.	.	.	.	78.4	.
2P42273	0	78.4	56.1	73.0	46.4	.	78.4	.	18.2	20.5	.
1P45955	0	78.4	6.5	.	.	.	.	.	.	78.4	.
2P26712	0	78.4	78.4	69.7	48.3	.	43.4	.	.	72.6	.
1P04152	0	78.3	25.0	42.9	78.3	.	1.3	.	.	48.9	.
1P50687	0	78.3	45.4	.	.	.	.	.	.	78.3	.
2P18264	0	78.3	78.3	64.8	69.6	.	42.1	.	.	19.5	.
2P32931	0	78.3	17.7	43.2	78.3	.	47.3	.	.	51.2	.
2P29733	0	78.3	78.3	.	.	.	.	56.6	.	.	.
1P25243	0	78.3	7.7	3.4	77.1	.	4.3	.	.	78.3	.
2P37068	0	78.3	4.1	.	.	.	.	78.3	.	.	.
1P08796	0	78.3	24.3	41.9	78.3	.	2.3	.	.	65.8	.
2P34853	0	78.2	44.0	.	.	.	.	.	.	78.2	.
2P38617	0	78.2	78.2	31.2	47.0	.	56.1	41.5	.	.	.
1P43269	0	78.2	78.2	15.4	0.0	.	24.7	5.0	.	.	.
2P49859	0	78.2	14.9	45.8	78.2	.	72.6	.	.	69.4	.
2P48292	0	78.2	4.7	.	.	.	.	.	.	78.2	.

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

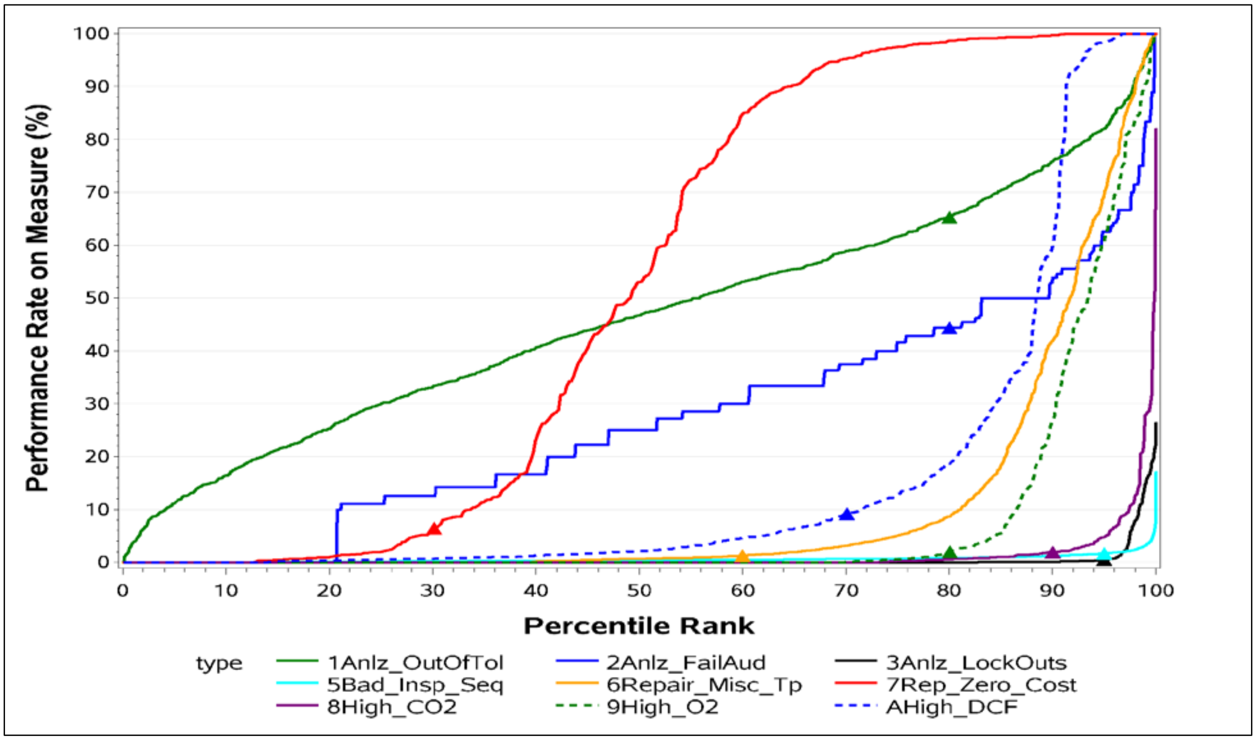


Figure VI-5. Fraction of Stations from the DFW Program Area, by Rank Decile, for VIN Mismatch and Profile Reading Errors of Commission

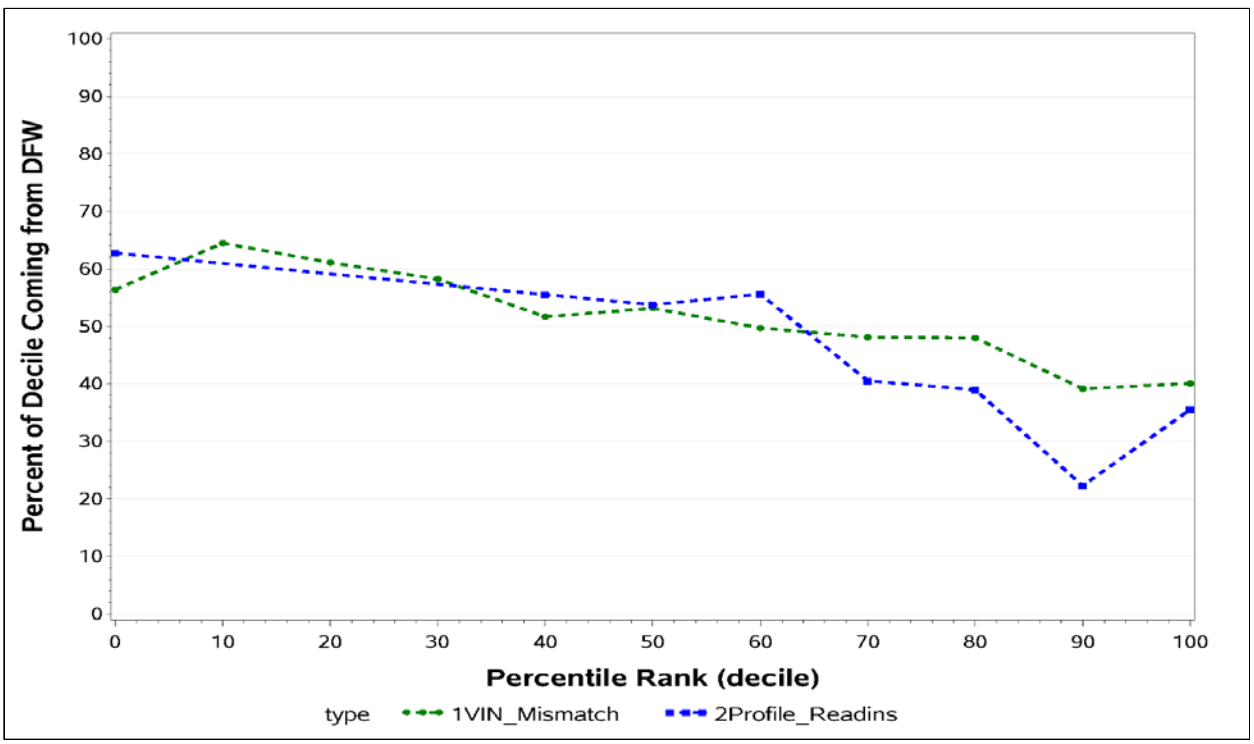


Figure VI-6. Fraction of Stations from the DFW Program Area, by Rank Decile, for Other Errors of Commission

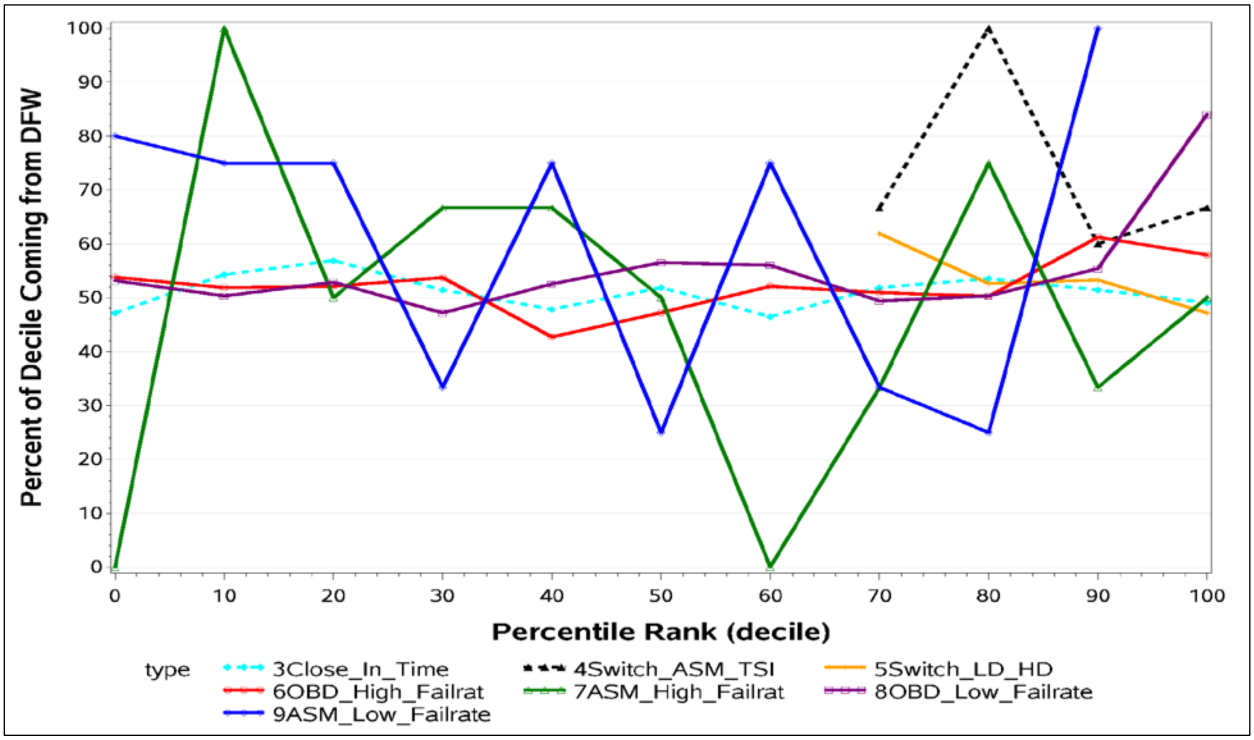


Table VI-22. Top 50 Stations with Errors of Omission

Station ID	Sum of Rank Flags	Max Rank for St.	Individual Ranks								
			Anlz Out of Tol	Anlz Locked Out	Anlz Fail Audits	Bad P/F Seq	Repair Type "Misc"	Repair Cost $0	CO_2 gt 16%	O_2 gt 20.5%	DCF Disagreement
1P32538	6	99.9	65.1	84.2	99.9	86.8	92.0	93.1	.	42.4	90.6
1P49028	6	99.8	96.4	99.8	94.2	77.9	90.0	85.7	.	97.0	67.5
1P42459	6	99.5	48.7	.	98.2	99.5	84.4	87.4	.	61.4	98.5
1P31631	6	99.3	21.6	84.1	99.3	10.1	95.8	97.1	.	90.9	94.6
2P34717	6	96.4	63.8	15.8	57.8	92.1	93.1	91.5	.	96.4	80.4
1P47573	5	99.9	8.8	43.4	97.8	35.4	99.9	98.0	.	43.5	84.1
2P48259	5	99.8	81.5	89.6	96.6	77.6	73.3	66.8	.	36.6	87.1
1P31834	5	99.2	8.5	82.6	99.2	10.7	95.7	95.7	.	71.3	46.2
2P36721	5	99.1	78.0	80.9	62.5	99.1	82.8	84.1	.	14.4	28.9
2P18859	5	98.8	2.4	13.5	98.2	45.9	89.3	98.8	.	81.9	93.4
1P38169	5	98.3	84.7	98.3	19.0	74.4	96.7	93.8	.	18.0	92.2
1P26940	5	98.3	56.5	91.0	97.2	6.0	98.3	93.7	.	33.1	71.3
2P50644	5	98.2	98.2	.	81.5	97.1	83.2	75.1	.	11.5	74.7
1P41468	5	98.1	62.3	98.1	24.6	27.4	89.9	88.3	.	38.3	73.9
1P40748	5	97.6	95.1	62.8	23.3	25.6	95.5	97.6	.	23.7	97.0
2P48512	5	97.5	66.5	74.8	77.3	97.5	88.2	88.2	.	75.5	80.7
1P06537	5	97.5	90.8	78.7	2.5	90.2	1.6	32.9	.	97.5	77.2
1P49436	5	97.2	93.5	.	38.7	94.9	97.2	95.8	.	4.5	89.8
1P26542	5	97.2	93.7	83.7	5.9	5.9	6.0	74.7	.	60.5	97.2
1P36995	5	96.7	87.1	62.2	17.1	96.7	86.4	82.0	.	88.9	76.4
2P32950	5	96.5	81.0	93.4	96.5	86.2	47.8	55.0	.	76.3	92.8
2P40989	5	95.1	19.8	18.9	95.1	82.6	80.7	73.1	.	83.7	81.9
2P01478	5	95.0	5.1	12.0	87.3	42.5	89.5	86.8	.	95.0	85.2
2P33028	5	95.0	87.9	80.3	86.1	95.0	48.0	76.3	.	49.0	71.9
2P35146	5	95.0	75.0	16.2	58.6	90.0	95.0	92.1	.	62.4	81.3
1P02394	5	93.3	92.4	25.3	90.1	0.8	93.2	90.8	.	63.9	93.3
2P48380	5	92.7	85.7	67.6	76.9	92.7	82.0	77.6	.	85.7	91.8
1P34604	5	92.4	83.2	81.6	13.9	15.7	92.4	89.8	.	33.7	75.9
1P39069	5	91.1	91.1	7.1	20.3	22.9	86.9	79.7	.	86.0	82.8
1P33509	5	90.6	62.0	84.4	90.6	14.0	85.7	89.4	.	73.7	76.1

Table VI-22. 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 P/F Seq	Repair Type "Misc"	Repair Cost $0	CO_2 gt 16%	O_2 gt 20.5%	DCF Disagreement
2P38823	5	88.9	29.7	88.9	65.5	61.1	88.6	82.4	.	37.3	67.2
1P50667	4	100.0	92.5	.	41.0	41.8	39.8	18.9	.	100.0	81.0
1P49400	4	99.9	51.8	.	38.5	99.9	38.0	79.3	.	19.6	74.6
2P50486	4	99.9	96.2	.	81.3	.	.	.	.	96.8	99.9
2P40428	4	99.7	40.9	.	98.0	80.7	94.5	99.7	.	74.6	79.0
1P40011	4	99.6	83.3	98.8	21.9	24.1	99.6	97.5	.	90.8	10.0
1P04303	4	99.5	12.2	57.9	2.0	0.9	99.5	96.7	.	96.9	93.0
2P37660	4	99.5	12.9	.	63.7	59.5	96.6	99.5	.	38.5	82.2
2P42090	4	99.3	59.1	.	71.2	66.8	97.1	94.1	.	15.6	98.9
1P50020	4	99.1	97.0	.	40.1	97.8	99.1	98.6	.	5.1	21.4
1P45660	4	98.8	82.2	.	31.5	98.8	32.2	71.8	.	86.6	15.8
1P39100	4	98.7	7.7	7.2	20.4	98.7	22.7	79.0	.	69.1	75.3
1P25057	4	98.6	38.9	21.7	4.9	98.6	4.8	81.1	.	85.3	88.9
1P36442	4	98.4	70.2	95.1	16.2	74.7	98.4	96.5	.	94.9	83.8
1P48872	4	98.2	73.3	.	36.4	38.4	92.1	91.1	.	12.3	98.2
2P37142	4	98.2	75.3	.	63.0	98.2	88.7	84.5	.	29.9	57.0
2P29429	4	98.2	98.2	.	51.1	85.7	81.3	88.1	.	48.3	75.2
1P25039	4	98.0	98.0	78.9	85.5	5.0	4.7	91.0	.	47.7	86.5
1P34790	4	97.9	.	.	96.7	81.3	97.9	97.4	.	79.7	82.3
2P10331	4	97.5	54.1	38.5	45.2	43.8	97.5	94.8	.	26.1	87.6

VII. REFERENCES

1. "Draft Guidance on Use of In-Program Data for Evaluation of I/M Program Performance," EPA420-P-01-003, www.epa.gov/otaq/regs/im/obd/p01003.pdf, August 2001.

2. "Guidance on Use of Remote Sensing for Evaluation of I/M Program Performance," EPA420-B-04-010, www.epa.gov/otaq/regs/im/obd/420b04010.pdf, July 2004.

3. T.H. DeFries, A.D. Burnette, S. Kishan, Y. Meng, "Evaluation of the Texas Motorist's Choice Program," ERG Report No. TNRCC-000531, May 31, 2000.

4. Evaluation of the Texas Inspection and Maintenance Programs in the Dallas/Fort Worth and Houston-Galveston-Brazoria Nonattainment Areas", Final Report, Eastern Research Group November 30, 2006.

5. Evaluation of the Texas Inspection and Maintenance Programs in the Dallas/Fort Worth and Houston-Galveston-Brazoria Nonattainment Areas", Final Report, Eastern Research Group November 30, 2009.

6. Evaluation of the Texas Inspection and Maintenance Programs in the Dallas/Fort Worth and Houston-Galveston-Brazoria Nonattainment Areas", Final Report, Eastern Research Group July 31, 2012.

7. Evaluation of the Texas Inspection and Maintenance Programs in the Dallas/Fort Worth and Houston-Galveston-Brazoria Nonattainment Areas", Final Report, Eastern Research Group November 7, 2014.

8. Evaluation of the Texas Inspection and Maintenance Programs in the Dallas/Fort Worth and Houston-Galveston-Brazoria Nonattainment Areas", Final Report, Eastern Research Group June 30, 2016.

Appendix A

OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

Table A-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

	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	
Vehicle Make	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
ACURA								
3.2CL Premium	1	0.12%	1	0.12%	836	99.76%	838	0.00%
3.2TL	2	0.04%	3	0.06%	5,003	99.90%	5,008	0.03%
Integra	2	0.09%	10	0.44%	2,247	99.47%	2,259	0.01%
MDX	2	0.01%	12	0.04%	27,958	99.95%	27,972	0.16%
RSX Type-S	1	0.06%	3	0.19%	1,597	99.75%	1,601	0.01%
TL	6	0.02%	16	0.05%	30,095	99.93%	30,117	0.17%
BLANK	26	0.02%	88	0.07%	129,788	99.91%	129,902	0.75%
ASTON MARTIN								
BLANK	1	0.07%	13	0.85%	1,513	99.08%	1,527	0.01%
AUDI								
A4/S4	1	0.02%	15	0.24%	6,270	99.75%	6,286	0.04%
A4/S4 Cabriolet	3	0.25%	11	0.92%	1,182	98.83%	1,196	0.01%
A6	1	0.07%	4	0.30%	1,339	99.63%	1,344	0.01%
BLANK	10	0.02%	64	0.12%	55,398	99.87%	55,472	0.32%
BMW								
325Ci	1	0.03%	2	0.06%	3,170	99.91%	3,173	0.02%
325i	2	0.02%	11	0.13%	8,226	99.84%	8,239	0.05%
328i	6	0.02%	28	0.12%	24,177	99.86%	24,211	0.14%
328i SA	2	0.03%	7	0.10%	6,794	99.87%	6,803	0.04%
328i xDrive	1	0.06%	3	0.17%	1,785	99.78%	1,789	0.01%
328iC	1	0.29%	1	0.29%	341	99.42%	343	0.00%
330Ci	1	0.03%	3	0.10%	2,984	99.87%	2,988	0.02%
335i	3	0.03%	15	0.17%	8,967	99.80%	8,985	0.05%
525i	2	0.06%	6	0.18%	3,386	99.76%	3,394	0.02%

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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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
528i	1	0.01%	23	0.19%	11,919	99.80%	11,943	0.07%
550i	1	0.04%	5	0.21%	2,403	99.75%	2,409	0.01%
760Li	1	0.09%	1	0.09%	1,147	99.83%	1,149	0.01%
M3	1	0.03%	16	0.46%	3,447	99.51%	3,464	0.02%
M3Ci	1	0.27%	3	0.80%	372	98.94%	376	0.00%
M5	2	0.18%	7	0.63%	1,110	99.20%	1,119	0.01%
Mini Cooper S Countryman	1	0.05%	1	0.05%	1,953	99.90%	1,955	0.01%
X3 3.0i	1	0.05%	5	0.23%	2,153	99.72%	2,159	0.01%
X5	1	0.01%	11	0.09%	11,722	99.90%	11,734	0.07%
X5 4.8i	1	0.11%	3	0.34%	888	99.55%	892	0.01%
Z3	2	0.07%	10	0.34%	2,973	99.60%	2,985	0.02%
428i	1	0.08%	1	0.08%	1,191	99.83%	1,193	0.01%
BLANK	48	0.02%	318	0.16%	196,279	99.81%	196,645	1.14%
BUICK								
Century Custom	1	0.01%	8	0.08%	10,251	99.91%	10,260	0.06%
Century Limited	1	0.07%	1	0.07%	1,431	99.86%	1,433	0.01%
LaCrosse CX	1	0.02%	7	0.12%	5,792	99.86%	5,800	0.03%
LaCrosse CXL	1	0.03%	9	0.29%	3,070	99.68%	3,080	0.02%
LeSabre Custom	3	0.02%	24	0.18%	13,029	99.79%	13,056	0.08%
LeSabre Limited	2	0.04%	13	0.24%	5,492	99.73%	5,507	0.03%
Park Avenue	1	0.03%	6	0.15%	3,952	99.82%	3,959	0.02%
Rainier 2WD	1	0.34%	2	0.68%	289	98.97%	292	0.00%
Rendezvous 2WD	10	0.17%	50	0.85%	5,817	98.98%	5,877	0.03%
Rendezvous 4WD	1	0.07%	4	0.27%	1,450	99.66%	1,455	0.01%
Terraza	1	0.22%	1	0.22%	452	99.56%	454	0.00%

Table A-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
BLANK	16	0.02%	149	0.15%	98,560	99.83%	98,725	0.57%
CADILLAC								
CTS	1	0.01%	8	0.08%	10,376	99.91%	10,385	0.06%
CTS Premium Twin Turbo	1	0.35%	1	0.35%	286	99.31%	288	0.00%
CTS V6	3	0.04%	3	0.04%	6,876	99.91%	6,882	0.04%
CTS-V	1	0.04%	6	0.25%	2,422	99.71%	2,429	0.01%
DeVille Concours	2	0.21%	2	0.21%	966	99.59%	970	0.01%
DeVille	3	0.03%	24	0.21%	11,656	99.77%	11,683	0.07%
DTS	1	0.01%	3	0.04%	6,897	99.94%	6,901	0.04%
Escalade	1	0.02%	19	0.29%	6,488	99.69%	6,508	0.04%
Escalade 1500 2WD	10	0.24%	28	0.68%	4,064	99.07%	4,102	0.02%
Escalade 1500 2WD Luxury	6	0.16%	31	0.81%	3,812	99.04%	3,849	0.02%
Escalade 1500 4WD	5	0.07%	42	0.57%	7,337	99.36%	7,384	0.04%
Escalade 1500 4WD Luxury	7	0.11%	54	0.88%	6,102	99.01%	6,163	0.04%
Escalade ESV	1	0.03%	12	0.36%	3,319	99.61%	3,332	0.02%
SLS	1	0.09%	2	0.18%	1,108	99.73%	1,111	0.01%
SRX	1	0.00%	12	0.04%	28,540	99.95%	28,553	0.16%
BLANK	44	0.03%	245	0.18%	135,161	99.79%	135,450	0.78%
CHEVROLET								
1500 2WD	36	0.03%	206	0.16%	128,027	99.81%	128,269	0.74%
1500 4WD	6	0.03%	37	0.16%	23,254	99.82%	23,297	0.13%
2500 2WD	2	0.01%	17	0.12%	14,142	99.87%	14,161	0.08%
3500 2WD	1	0.03%	4	0.14%	2,860	99.83%	2,865	0.02%
Astro 2WD	12	0.12%	34	0.33%	10,132	99.55%	10,178	0.06%
Aveo	2	0.02%	17	0.19%	8,759	99.78%	8,778	0.05%

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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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Aveo 1LS/1LT	1	0.05%	6	0.28%	2,156	99.68%	2,163	0.01%
Aveo LT	1	0.05%	2	0.10%	2,031	99.85%	2,034	0.01%
Blazer / Trailblazer 2WD	5	0.03%	46	0.23%	19,856	99.74%	19,907	0.11%
Blazer / Trailblazer 4WD	2	0.04%	8	0.17%	4,634	99.78%	4,644	0.03%
Blazer 2WD	7	0.06%	29	0.26%	11,245	99.68%	11,281	0.07%
Blazer 4WD	1	0.03%	6	0.20%	3,056	99.77%	3,063	0.02%
C1500 Pickup 2WD	38	0.04%	162	0.18%	89,101	99.78%	89,301	0.52%
C1500 Silverado 2WD	31	0.07%	152	0.33%	45,250	99.60%	45,433	0.26%
C1500 Suburban 2WD	23	0.05%	112	0.24%	47,013	99.71%	47,148	0.27%
C2500 Pickup 2WD	1	0.02%	22	0.50%	4,351	99.47%	4,374	0.03%
Camaro LT	1	0.01%	8	0.07%	11,980	99.92%	11,989	0.07%
Caprice Classic	1	0.07%	3	0.21%	1,439	99.72%	1,443	0.01%
Cavalier	11	0.06%	51	0.27%	18,572	99.67%	18,634	0.11%
Cobalt	13	0.05%	79	0.27%	28,767	99.68%	28,859	0.17%
Colorado / SSR 2WD	2	0.06%	4	0.11%	3,531	99.83%	3,537	0.02%
Colorado / Trailblazer 2WD	1	0.02%	7	0.11%	6,504	99.88%	6,512	0.04%
Corvette	1	0.01%	23	0.12%	19,296	99.88%	19,320	0.11%
Corvette Grand Sport	1	0.10%	1	0.10%	971	99.79%	973	0.01%
Corvette Stingray 2LT w/Z51	1	0.11%	1	0.11%	896	99.78%	898	0.01%
Corvette Stingray 3LT w/Z51	1	0.07%	1	0.07%	1,426	99.86%	1,428	0.01%
Cruze	1	0.01%	3	0.02%	13,476	99.97%	13,480	0.08%
Cruze 1LT	1	0.01%	3	0.02%	15,361	99.97%	15,365	0.09%
Cruze 2LT	1	0.01%	4	0.05%	7,592	99.93%	7,597	0.04%
Equinox 2WD	2	0.02%	5	0.06%	8,409	99.92%	8,416	0.05%
Equinox FWD	1	0.08%	1	0.08%	1,321	99.85%	1,323	0.01%

Table A-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Equinox LS 2WD	1	0.04%	4	0.17%	2,300	99.78%	2,305	0.01%
Express 1500 2WD	2	0.02%	22	0.23%	9,467	99.75%	9,491	0.05%
Express 2500 2WD	2	0.09%	7	0.33%	2,113	99.58%	2,122	0.01%
Express 3500 2WD	2	0.16%	5	0.40%	1,243	99.44%	1,250	0.01%
Express Cargo	1	0.03%	10	0.35%	2,861	99.62%	2,872	0.02%
G1500 Van 2WD	1	0.04%	4	0.18%	2,249	99.78%	2,254	0.01%
HHR	11	0.07%	39	0.23%	16,827	99.70%	16,877	0.10%
HHR LS	2	0.13%	4	0.25%	1,579	99.62%	1,585	0.01%
Impala	4	0.02%	22	0.11%	19,458	99.87%	19,484	0.11%
Impala LS	4	0.04%	17	0.15%	11,093	99.81%	11,114	0.06%
Impala LS Sedan	1	0.01%	6	0.04%	14,680	99.95%	14,687	0.08%
Impala LT Fleet	1	0.01%	5	0.05%	10,639	99.94%	10,645	0.06%
Impala LT Sedan	3	0.02%	12	0.08%	15,393	99.90%	15,408	0.09%
Impala SS Sedan	1	0.03%	6	0.16%	3,820	99.82%	3,827	0.02%
K1500 Pickup 4WD	7	0.04%	45	0.24%	18,600	99.72%	18,652	0.11%
K1500 Silverado 4WD	3	0.05%	22	0.35%	6,220	99.60%	6,245	0.04%
K1500 Suburban 4WD	5	0.04%	32	0.27%	11,945	99.69%	11,982	0.07%
Lumina	1	0.05%	1	0.05%	1,826	99.89%	1,828	0.01%
Lumina LS	1	0.05%	2	0.10%	1,950	99.85%	1,953	0.01%
Malibu	5	0.04%	22	0.17%	12,724	99.79%	12,751	0.07%
Malibu 1LT	4	0.02%	14	0.06%	22,217	99.92%	22,235	0.13%
Malibu 2LT	4	0.04%	4	0.04%	9,690	99.92%	9,698	0.06%
Malibu Classic	1	0.04%	6	0.26%	2,316	99.70%	2,323	0.01%
Malibu LS	3	0.01%	38	0.14%	26,946	99.85%	26,987	0.16%
Malibu LT	1	0.03%	4	0.10%	3,937	99.87%	3,942	0.02%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Malibu LTZ	1	0.02%	2	0.04%	5,525	99.95%	5,528	0.03%
Malibu LX	1	0.04%	3	0.13%	2,284	99.83%	2,288	0.01%
S Series Pickup 2WD	3	0.03%	25	0.24%	10,523	99.73%	10,551	0.06%
S10 Blazer 2WD	4	0.09%	7	0.16%	4,467	99.75%	4,478	0.03%
S10 Pickup 2WD	10	0.11%	22	0.24%	8,959	99.64%	8,991	0.05%
Sierra 1500 2WD	1	0.05%	10	0.47%	2,115	99.48%	2,126	0.01%
Silverado LS	1	0.01%	2	0.03%	7,833	99.96%	7,836	0.05%
Silverado LT	3	0.00%	44	0.06%	74,673	99.94%	74,720	0.43%
Silverado LTZ	1	0.01%	9	0.06%	15,091	99.93%	15,101	0.09%
Silverado Work Truck	1	0.01%	26	0.16%	16,027	99.83%	16,054	0.09%
Sonic LT	3	0.03%	3	0.03%	10,168	99.94%	10,174	0.06%
SSR / Colorado / Trailblazer	5	0.03%	39	0.22%	17,813	99.75%	17,857	0.10%
Suburban LT	1	0.01%	2	0.02%	10,239	99.97%	10,242	0.06%
Tahoe 2WD	55	0.07%	225	0.28%	81,385	99.66%	81,665	0.47%
Tahoe 4WD	12	0.05%	67	0.27%	24,985	99.68%	25,064	0.14%
Tahoe LT	2	0.01%	16	0.09%	18,634	99.90%	18,652	0.11%
Tahoe Police	1	0.03%	4	0.10%	3,971	99.87%	3,976	0.02%
Tahoe Police 2WD	1	0.16%	2	0.32%	615	99.51%	618	0.00%
Trailblazer 2WD	7	0.10%	12	0.17%	6,954	99.73%	6,973	0.04%
Traverse 2LT	1	0.02%	3	0.05%	5,641	99.93%	5,645	0.03%
Traverse FWD	2	0.07%	1	0.03%	3,014	99.90%	3,017	0.02%
Traverse LTZ	1	0.03%	1	0.03%	3,214	99.94%	3,216	0.02%
Uplander2WD	1	0.23%	2	0.45%	441	99.32%	444	0.00%
Venture / Uplander	1	0.02%	4	0.08%	4,705	99.89%	4,710	0.03%
Venture 2WD	3	0.06%	9	0.17%	5,274	99.77%	5,286	0.03%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
BLANK	369	0.03%	1,919	0.15%	1,261,020	99.82%	1,263,308	7.30%
CHRYSLER								
200 LX	2	0.04%	5	0.11%	4,488	99.84%	4,495	0.03%
300 Base	1	0.02%	4	0.06%	6,246	99.92%	6,251	0.04%
300 Touring	1	0.01%	5	0.03%	14,687	99.96%	14,693	0.08%
300C	1	0.01%	4	0.04%	9,746	99.95%	9,751	0.06%
PT Cruiser Classic LHD	2	0.02%	14	0.12%	11,300	99.86%	11,316	0.07%
PT Cruiser Limited LHD	2	0.05%	5	0.13%	3,776	99.81%	3,783	0.02%
PT Cruiser Touring LHD	3	0.04%	13	0.16%	8,265	99.81%	8,281	0.05%
Sebring	1	0.02%	3	0.06%	4,930	99.92%	4,934	0.03%
Sebring LXi	1	0.05%	12	0.60%	1,982	99.35%	1,995	0.01%
Sebring Touring	4	0.06%	8	0.12%	6,628	99.82%	6,640	0.04%
Town & Country	1	0.01%	3	0.02%	12,037	99.97%	12,041	0.07%
Town & Country FWD LHD	1	0.02%	3	0.05%	5,752	99.93%	5,756	0.03%
Town & Country LX FWD	1	0.04%	4	0.15%	2,595	99.81%	2,600	0.02%
Town & Country LXi FWD	1	0.06%	4	0.26%	1,560	99.68%	1,565	0.01%
BLANK	34	0.02%	190	0.11%	167,800	99.87%	168,024	0.97%
DODGE								
1500	5	0.01%	25	0.06%	40,724	99.93%	40,754	0.24%
Avenger SE	4	0.02%	8	0.04%	20,167	99.94%	20,179	0.12%
Avenger SXT	1	0.01%	6	0.08%	7,724	99.91%	7,731	0.04%
Caliber Mainstreet	1	0.06%	2	0.13%	1,573	99.81%	1,576	0.01%
Caliber SE	1	0.02%	2	0.05%	4,267	99.93%	4,270	0.02%
Caliber SXT	1	0.01%	5	0.06%	9,078	99.93%	9,084	0.05%
Caravan	1	0.04%	2	0.08%	2,403	99.88%	2,406	0.01%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Caravan / Grand Caravan SXT FW	1	0.01%	16	0.16%	10,211	99.83%	10,228	0.06%
Caravan C/V FWD	1	0.01%	19	0.17%	10,839	99.82%	10,859	0.06%
Caravan FWD	1	0.04%	5	0.18%	2,745	99.78%	2,751	0.02%
Caravan SE FWD	1	0.03%	2	0.06%	3,475	99.91%	3,478	0.02%
Caravan Sport FWD	2	0.06%	5	0.16%	3,121	99.78%	3,128	0.02%
Challenger Base	1	0.01%	6	0.07%	8,243	99.92%	8,250	0.05%
Charger (RWD)	2	0.01%	3	0.02%	17,604	99.97%	17,609	0.10%
Charger R/T	2	0.02%	5	0.05%	10,038	99.93%	10,045	0.06%
Charger SE	2	0.02%	11	0.09%	12,517	99.90%	12,530	0.07%
Charger SXT	1	0.01%	5	0.05%	10,761	99.94%	10,767	0.06%
Dakota 2WD	4	0.04%	25	0.26%	9,419	99.69%	9,448	0.05%
Dart SXT	4	0.06%	3	0.05%	6,605	99.89%	6,612	0.04%
Durango	1	0.01%	7	0.06%	12,165	99.93%	12,173	0.07%
Durango 2WD	7	0.14%	9	0.17%	5,137	99.69%	5,153	0.03%
Durango 4WD	1	0.03%	5	0.14%	3,444	99.83%	3,450	0.02%
Grand Caravan	2	0.01%	11	0.07%	16,085	99.92%	16,098	0.09%
Intrepid SE	2	0.13%	3	0.20%	1,509	99.67%	1,514	0.01%
Journey	3	0.02%	9	0.05%	16,463	99.93%	16,475	0.10%
Magnum / Magnum SXT	1	0.02%	2	0.04%	4,575	99.93%	4,578	0.03%
Neon	1	0.06%	1	0.06%	1,725	99.88%	1,727	0.01%
Neon SXT	1	0.02%	10	0.21%	4,689	99.77%	4,700	0.03%
Nitro Heat	1	0.04%	1	0.04%	2,330	99.91%	2,332	0.01%
RAM 1500	1	0.01%	12	0.08%	14,339	99.91%	14,352	0.08%
Ram Pickup	1	0.02%	4	0.10%	4,056	99.88%	4,061	0.02%
Ram Pickup 1500 2WD	25	0.03%	101	0.10%	98,872	99.87%	98,998	0.57%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Ram Pickup 1500 4WD	1	0.01%	9	0.07%	12,289	99.92%	12,299	0.07%
Ram Pickup 2500 2WD	2	0.52%	1	0.26%	378	99.21%	381	0.00%
Ram Pickup 2WD	19	0.06%	99	0.33%	30,140	99.61%	30,258	0.17%
Ram Pickup 4WD	6	0.13%	15	0.34%	4,428	99.53%	4,449	0.03%
Stratus SE	2	0.08%	8	0.32%	2,480	99.60%	2,490	0.01%
Stratus SE Plus	1	0.13%	2	0.26%	754	99.60%	757	0.00%
Stratus SXT	5	0.10%	10	0.20%	5,062	99.70%	5,077	0.03%
Viper SRT-10	1	0.22%	2	0.43%	462	99.35%	465	0.00%
BLANK	94	0.02%	535	0.11%	491,673	99.87%	492,302	2.84%
FERRARI								
BLANK	1	0.07%	2	0.14%	1,452	99.79%	1,455	0.01%
FORD								
500 Limited FWD	1	0.05%	3	0.14%	2,065	99.81%	2,069	0.01%
Crown Victoria	1	0.07%	3	0.20%	1,502	99.73%	1,506	0.01%
Crown Victoria (Police)	2	0.03%	21	0.29%	7,315	99.69%	7,338	0.04%
Crown Victoria Police Intercep	2	0.07%	12	0.43%	2,803	99.50%	2,817	0.02%
E150 2WD	16	0.21%	31	0.41%	7,431	99.37%	7,478	0.04%
E150 Cargo Van	2	0.09%	4	0.18%	2,252	99.73%	2,258	0.01%
E150 Cargo/Regular Van	1	0.07%	5	0.35%	1,414	99.58%	1,420	0.01%
E250 2WD	1	0.06%	7	0.44%	1,578	99.50%	1,586	0.01%
E250 Cargo Van	1	0.20%	1	0.20%	493	99.60%	495	0.00%
E350 2WD	1	0.10%	6	0.60%	1,001	99.31%	1,008	0.01%
E350 Super Wagon	3	1.19%	5	1.98%	245	96.84%	253	0.00%
Edge	1	0.00%	10	0.03%	34,320	99.97%	34,331	0.20%
Escape	3	0.01%	23	0.04%	54,971	99.95%	54,997	0.32%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Escape Limited 2WD	1	0.03%	1	0.03%	3,949	99.95%	3,951	0.02%
Escape XLS 2WD	2	0.02%	9	0.08%	11,774	99.91%	11,785	0.07%
Escape XLT 2WD	5	0.02%	18	0.08%	23,173	99.90%	23,196	0.13%
Expedition	3	0.01%	15	0.05%	33,106	99.95%	33,124	0.19%
Expedition Eddie Bauer 2WD	10	0.03%	57	0.16%	35,568	99.81%	35,635	0.21%
Expedition Eddie Bauer 4WD	3	0.07%	6	0.14%	4,413	99.80%	4,422	0.03%
Expedition XLS	1	0.11%	6	0.66%	899	99.23%	906	0.01%
Expedition XLT 2WD	9	0.03%	62	0.21%	30,140	99.76%	30,211	0.17%
Explorer	2	0.00%	20	0.04%	44,927	99.95%	44,949	0.26%
Explorer Eddie Bauer 2WD	1	0.01%	10	0.11%	8,696	99.87%	8,707	0.05%
Explorer LTD 2WD	2	0.07%	5	0.17%	2,869	99.76%	2,876	0.02%
Explorer Sport 2WD	5	0.08%	22	0.36%	6,043	99.56%	6,070	0.04%
Explorer Sport Trac 2WD	10	0.07%	55	0.39%	14,096	99.54%	14,161	0.08%
Explorer Sport Trac 4WD	2	0.15%	3	0.23%	1,320	99.62%	1,325	0.01%
Explorer XL	2	0.01%	15	0.11%	14,088	99.88%	14,105	0.08%
Explorer XL 4WD	2	0.06%	1	0.03%	3,244	99.91%	3,247	0.02%
Explorer XLS 2WD	4	0.03%	19	0.14%	13,839	99.83%	13,862	0.08%
Explorer XLT 2WD	6	0.02%	23	0.09%	25,436	99.89%	25,465	0.15%
Explorer XLT 4WD	2	0.03%	9	0.12%	7,546	99.85%	7,557	0.04%
F150	25	0.01%	192	0.09%	216,577	99.90%	216,794	1.25%
F150 2WD	38	0.04%	263	0.27%	97,744	99.69%	98,045	0.57%
F150 2WD Super Crew	49	0.06%	186	0.24%	75,947	99.69%	76,182	0.44%
F150 4WD	7	0.05%	40	0.30%	13,095	99.64%	13,142	0.08%
F150 4WD Super Crew	16	0.06%	48	0.18%	26,856	99.76%	26,920	0.16%
F150 Heritage	1	0.03%	9	0.31%	2,890	99.66%	2,900	0.02%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
F150 Regular Cab	2	0.08%	10	0.39%	2,542	99.53%	2,554	0.01%
F150 Regular Cab Styleside	3	0.03%	5	0.05%	9,282	99.91%	9,290	0.05%
F150 Super Cab	1	0.09%	3	0.28%	1,052	99.62%	1,056	0.01%
F150 Super Cab Flareside	1	0.01%	6	0.09%	6,991	99.90%	6,998	0.04%
F150 Super Cab Styleside	9	0.04%	24	0.10%	23,950	99.86%	23,983	0.14%
F150 Super Cab Styleside 4WD	1	0.03%	1	0.03%	2,968	99.93%	2,970	0.02%
F150 Super Crew 2WD	17	0.05%	90	0.26%	35,076	99.70%	35,183	0.20%
F150 Super Crew 4WD	3	0.03%	16	0.18%	8,650	99.78%	8,669	0.05%
F250 Super Cab	5	0.56%	3	0.34%	881	99.10%	889	0.01%
F250 Super Duty 2WD	2	0.30%	3	0.45%	661	99.25%	666	0.00%
F250 Super Duty 4WD	1	0.36%	2	0.72%	274	98.92%	277	0.00%
Focus LX	2	0.06%	3	0.09%	3,260	99.85%	3,265	0.02%
Focus SE	2	0.00%	18	0.04%	45,410	99.96%	45,430	0.26%
Focus SEL	1	0.02%	4	0.07%	5,378	99.91%	5,383	0.03%
Focus SES	3	0.02%	3	0.02%	12,961	99.95%	12,967	0.07%
Focus ZTS	1	0.04%	3	0.11%	2,605	99.85%	2,609	0.02%
Focus ZX4	1	0.01%	6	0.06%	10,608	99.93%	10,615	0.06%
Freestyle SEL	1	0.04%	3	0.13%	2,324	99.83%	2,328	0.01%
Fusion Hybrid	4	0.19%	8	0.38%	2,107	99.43%	2,119	0.01%
Fusion S	1	0.01%	17	0.17%	10,169	99.82%	10,187	0.06%
Fusion SE	17	0.03%	99	0.19%	51,499	99.78%	51,615	0.30%
Fusion SE Hybrid	1	0.05%	2	0.09%	2,211	99.86%	2,214	0.01%
Fusion SEL	2	0.01%	42	0.29%	14,246	99.69%	14,290	0.08%
Fusion Titanium	1	0.02%	2	0.05%	4,129	99.93%	4,132	0.02%
LTD Crown Victoria	1	0.04%	4	0.17%	2,348	99.79%	2,353	0.01%

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LTD Crown Victoria LX	1	0.05%	4	0.19%	2,059	99.76%	2,064	0.01%
Mustang	9	0.02%	58	0.12%	48,927	99.86%	48,994	0.28%
Mustang GT	2	0.01%	31	0.09%	33,339	99.90%	33,372	0.19%
Ranger	1	0.02%	28	0.48%	5,755	99.50%	5,784	0.03%
Ranger 2WD	20	0.04%	113	0.25%	44,369	99.70%	44,502	0.26%
Ranger 4WD	1	0.03%	11	0.38%	2,853	99.58%	2,865	0.02%
Ranger Regular Cab 2WD	3	0.03%	15	0.17%	8,843	99.80%	8,861	0.05%
Ranger Super Cab 2WD	3	0.03%	17	0.19%	9,062	99.78%	9,082	0.05%
Ranger Super Cab 4WD	1	0.10%	2	0.20%	995	99.70%	998	0.01%
Taurus LIMITED	3	0.07%	2	0.05%	4,136	99.88%	4,141	0.02%
Taurus Police	1	0.11%	1	0.11%	931	99.79%	933	0.01%
Taurus SE	4	0.02%	16	0.07%	22,384	99.91%	22,404	0.13%
Taurus SE SVG	2	0.13%	2	0.13%	1,531	99.74%	1,535	0.01%
Thunderbird	1	0.04%	3	0.13%	2,367	99.83%	2,371	0.01%
Thunderbird LX	1	0.12%	4	0.49%	809	99.39%	814	0.00%
Windstar GL Wagon	1	0.06%	1	0.06%	1,549	99.87%	1,551	0.01%
Windstar LX	1	0.03%	3	0.09%	3,515	99.89%	3,519	0.02%
Windstar SE	2	0.14%	1	0.07%	1,470	99.80%	1,473	0.01%
BLANK	339	0.03%	1,929	0.15%	1,305,703	99.83%	1,307,971	7.55%
GEO								
Geo Prizm Lsi	1	0.12%	1	0.12%	832	99.76%	834	0.00%
BLANK	1	0.10%	2	0.19%	1,043	99.71%	1,046	0.01%
GMC								
1500 2WD	8	0.03%	45	0.14%	31,135	99.83%	31,188	0.18%
1500 Suburban 2WD	3	0.03%	23	0.21%	11,029	99.76%	11,055	0.06%

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1500 Suburban 4WD	1	0.04%	3	0.12%	2,447	99.84%	2,451	0.01%
1500 Suburban 4WD Luxury	2	0.08%	16	0.61%	2,620	99.32%	2,638	0.02%
2500 2WD	2	0.06%	4	0.12%	3,451	99.83%	3,457	0.02%
Acadia SLE FWD	1	0.05%	2	0.10%	1,982	99.85%	1,985	0.01%
Canyon / Envoy 2WD	2	0.04%	12	0.23%	5,308	99.74%	5,322	0.03%
Envoy/Envoy XL SLE 2WD	7	0.07%	19	0.19%	10,109	99.74%	10,135	0.06%
Envoy/Envoy XL SLE 4WD	1	0.05%	7	0.33%	2,132	99.63%	2,140	0.01%
Full Size Truck 1500 4WD	1	0.09%	10	0.87%	1,143	99.05%	1,154	0.01%
Safari 2WD	3	0.13%	13	0.55%	2,360	99.33%	2,376	0.01%
Sierra / Yukon / 1500 4WD	1	0.02%	3	0.07%	4,185	99.90%	4,189	0.02%
Sierra 1500 2WD	9	0.04%	58	0.23%	25,345	99.74%	25,412	0.15%
Sierra 1500 Pickup 2WD	3	0.03%	27	0.30%	9,076	99.67%	9,106	0.05%
Sierra 1500 Pickup 4WD	1	0.02%	7	0.12%	5,813	99.86%	5,821	0.03%
Sierra Denali / Yukon 1500 4WD	1	0.02%	3	0.06%	4,717	99.92%	4,721	0.03%
Sierra SL	1	0.06%	2	0.11%	1,788	99.83%	1,791	0.01%
Sierra SLE	2	0.01%	15	0.06%	24,535	99.93%	24,552	0.14%
Sierra SLT	1	0.01%	3	0.03%	10,579	99.96%	10,583	0.06%
Sonoma Pickup 2WD	2	0.05%	10	0.27%	3,670	99.67%	3,682	0.02%
Yukon 2WD	13	0.07%	68	0.34%	19,755	99.59%	19,836	0.11%
Yukon 4WD Luxury	5	0.16%	31	0.98%	3,122	98.86%	3,158	0.02%
BLANK	77	0.03%	410	0.16%	262,443	99.81%	262,930	1.52%
HONDA								
Accord	16	0.04%	44	0.10%	43,320	99.86%	43,380	0.25%
Accord EX	15	0.02%	45	0.05%	83,321	99.93%	83,381	0.48%
Accord EX L	1	0.01%	3	0.03%	10,125	99.96%	10,129	0.06%

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Accord EX-L	2	0.02%	4	0.03%	11,862	99.95%	11,868	0.07%
Accord LX	5	0.01%	36	0.05%	67,671	99.94%	67,712	0.39%
Accord LX P	1	0.02%	4	0.07%	6,141	99.92%	6,146	0.04%
Accord LX-SE	2	0.05%	2	0.05%	3,699	99.89%	3,703	0.02%
Accord SE	3	0.02%	16	0.10%	15,392	99.88%	15,411	0.09%
Accord VP	1	0.04%	6	0.23%	2,616	99.73%	2,623	0.02%
Civic	8	0.03%	42	0.15%	27,245	99.82%	27,295	0.16%
Civic EX	4	0.01%	29	0.05%	56,086	99.94%	56,119	0.32%
Civic LX	23	0.02%	54	0.05%	103,482	99.93%	103,559	0.60%
CR-V	5	0.01%	26	0.03%	78,712	99.96%	78,743	0.45%
CR-V EX 2WD	1	0.03%	3	0.08%	3,970	99.90%	3,974	0.02%
CR-V EX-L 2WD	1	0.02%	1	0.02%	6,238	99.97%	6,240	0.04%
FIT HB Sport	1	0.02%	4	0.06%	6,475	99.92%	6,480	0.04%
Odyssey	6	0.01%	47	0.05%	95,067	99.94%	95,120	0.55%
Passport 2WD	2	0.11%	2	0.11%	1,797	99.78%	1,801	0.01%
Pilot	3	0.00%	25	0.04%	67,146	99.96%	67,174	0.39%
Prelude	1	0.05%	15	0.69%	2,172	99.27%	2,188	0.01%
BLANK	118	0.01%	552	0.07%	805,947	99.92%	806,617	4.66%
HUMMER								
H3 - Base 4WD	2	0.13%	1	0.06%	1,596	99.81%	1,599	0.01%
H3 - SUV 4WD	2	0.06%	14	0.45%	3,068	99.48%	3,084	0.02%
BLANK	6	0.05%	36	0.29%	12,536	99.67%	12,578	0.07%
HYUNDAI								
Accent	1	0.00%	12	0.04%	28,731	99.95%	28,744	0.17%
Azera	1	0.02%	8	0.19%	4,262	99.79%	4,271	0.02%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Elantra	5	0.01%	39	0.08%	51,895	99.92%	51,939	0.30%
Elantra (XD)	2	0.01%	26	0.13%	19,722	99.86%	19,750	0.11%
Genesis	1	0.10%	1	0.10%	969	99.79%	971	0.01%
Genesis / Equus	1	0.01%	3	0.04%	8,215	99.95%	8,219	0.05%
Genesis Coupe	1	0.02%	1	0.02%	4,735	99.96%	4,737	0.03%
Santa Fe	6	0.01%	71	0.16%	44,800	99.83%	44,877	0.26%
Sonata	11	0.01%	119	0.15%	81,667	99.84%	81,797	0.47%
Tiburon	4	0.08%	7	0.14%	4,824	99.77%	4,835	0.03%
Tucson	2	0.02%	8	0.06%	12,763	99.92%	12,773	0.07%
Tuscon	1	0.02%	8	0.13%	5,952	99.85%	5,961	0.03%
BLANK	38	0.02%	266	0.11%	247,910	99.88%	248,214	1.43%
INFINITY								
Cube	1	0.01%	7	0.07%	9,724	99.92%	9,732	0.06%
EX35	1	0.04%	1	0.04%	2,585	99.92%	2,587	0.01%
G25/G37 Coupe	1	0.01%	9	0.09%	9,923	99.90%	9,933	0.06%
G35	5	0.03%	16	0.08%	19,914	99.89%	19,935	0.12%
I30	1	0.02%	8	0.18%	4,377	99.79%	4,386	0.03%
M35/M45	2	0.02%	5	0.06%	8,011	99.91%	8,018	0.05%
Q50	1	0.01%	2	0.02%	8,040	99.96%	8,043	0.05%
QX4 (SUV)	1	0.05%	3	0.16%	1,929	99.79%	1,933	0.01%
BLANK	8	0.01%	86	0.07%	115,204	99.92%	115,298	0.67%
ISUZU								
Amigo/Rodeo 2WD	4	0.14%	11	0.39%	2,781	99.46%	2,796	0.02%
Axiom 2WD	1	0.14%	3	0.42%	702	99.43%	706	0.00%
Rodeo 2WD	3	0.05%	11	0.19%	5,670	99.75%	5,684	0.03%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Trooper 4WD	1	0.07%	1	0.07%	1,352	99.85%	1,354	0.01%
BLANK	2	0.02%	27	0.21%	13,065	99.78%	13,094	0.08%
JAGUAR								
S-Type	1	0.03%	7	0.18%	3,959	99.80%	3,967	0.02%
Vandenplas	1	0.29%	2	0.58%	339	99.12%	342	0.00%
XK8	1	0.19%	1	0.19%	523	99.62%	525	0.00%
X-Type	1	0.04%	1	0.04%	2,437	99.92%	2,439	0.01%
BLANK	5	0.03%	37	0.20%	18,736	99.78%	18,778	0.11%
JEEP								
Cherokee 2WD	5	0.09%	16	0.28%	5,652	99.63%	5,673	0.03%
Compass Rallye LHD FWD	2	0.07%	2	0.07%	2,789	99.86%	2,793	0.02%
Grand Cherokee	1	0.00%	18	0.06%	30,404	99.94%	30,423	0.18%
Grand Cherokee 2WD	3	0.03%	21	0.23%	9,249	99.74%	9,273	0.05%
Grand Cherokee 4WD	1	0.02%	12	0.18%	6,568	99.80%	6,581	0.04%
Grand Cherokee Laredo 2WD	2	0.01%	13	0.08%	15,392	99.90%	15,407	0.09%
Grand Cherokee Laredo 4WD	1	0.01%	8	0.11%	7,341	99.88%	7,350	0.04%
Grand Cherokee Limited 4WD	1	0.02%	1	0.02%	4,127	99.95%	4,129	0.02%
Liberty Sport 2WD	2	0.02%	10	0.10%	10,303	99.88%	10,315	0.06%
Liberty Sport 4WD	2	0.04%	8	0.17%	4,710	99.79%	4,720	0.03%
Wrangler	4	0.01%	22	0.06%	35,487	99.93%	35,513	0.21%
Wrangler 4WD	3	0.03%	30	0.26%	11,716	99.72%	11,749	0.07%
Wrangler Unlimited Sport	1	0.03%	1	0.03%	3,316	99.94%	3,318	0.02%
Wrangler X / Wrangler Willys	1	0.03%	7	0.23%	3,038	99.74%	3,046	0.02%
Wrangler X LHD 4WD	1	0.10%	1	0.10%	1,030	99.81%	1,032	0.01%
BLANK	26	0.01%	222	0.09%	235,933	99.89%	236,181	1.36%

Table A-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
KIA								
Optima	1	0.01%	11	0.11%	9,959	99.88%	9,971	0.06%
Optima / Optima Hybrid	4	0.01%	14	0.05%	29,964	99.94%	29,982	0.17%
Rio	2	0.01%	6	0.04%	17,115	99.95%	17,123	0.10%
Rondo	1	0.04%	1	0.04%	2,715	99.93%	2,717	0.02%
Sedona	1	0.02%	4	0.08%	4,745	99.89%	4,750	0.03%
Soul	2	0.01%	12	0.03%	35,999	99.96%	36,013	0.21%
Spectra	3	0.01%	24	0.11%	21,803	99.88%	21,830	0.13%
BLANK	12	0.01%	106	0.06%	184,804	99.94%	184,922	1.07%
LEXUS								
ES300	4	0.02%	19	0.11%	17,271	99.87%	17,294	0.10%
ES330	2	0.02%	14	0.12%	11,235	99.86%	11,251	0.06%
ES350	1	0.01%	15	0.08%	17,962	99.91%	17,978	0.10%
GS 350	1	0.01%	9	0.11%	7,899	99.87%	7,909	0.05%
IS250	2	0.02%	15	0.13%	11,877	99.86%	11,894	0.07%
IS300	1	0.03%	6	0.16%	3,835	99.82%	3,842	0.02%
LS 460	1	0.02%	3	0.05%	5,498	99.93%	5,502	0.03%
LS400	1	0.02%	5	0.09%	5,444	99.89%	5,450	0.03%
LS430	1	0.02%	3	0.05%	5,610	99.93%	5,614	0.03%
LX470	2	0.06%	5	0.15%	3,414	99.80%	3,421	0.02%
RX300	1	0.01%	16	0.12%	13,328	99.87%	13,345	0.08%
RX330	2	0.01%	24	0.16%	15,237	99.83%	15,263	0.09%
RX350	2	0.01%	19	0.12%	15,707	99.87%	15,728	0.09%
RX400h	2	0.06%	9	0.26%	3,445	99.68%	3,456	0.02%
SC400	1	0.32%	2	0.64%	311	99.04%	314	0.00%

Table A-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
SC430	1	0.02%	5	0.10%	4,954	99.88%	4,960	0.03%
BLANK	21	0.01%	245	0.07%	333,871	99.92%	334,137	1.93%
LINCOLN								
Aviator	10	0.30%	23	0.68%	3,354	99.03%	3,387	0.02%
LS	3	0.06%	7	0.14%	5,135	99.81%	5,145	0.03%
Navigator	2	0.03%	4	0.06%	6,266	99.90%	6,272	0.04%
Navigator 2WD	9	0.07%	58	0.42%	13,597	99.51%	13,664	0.08%
Navigator 4WD	1	0.03%	11	0.31%	3,535	99.66%	3,547	0.02%
Town Car	1	0.07%	3	0.20%	1,515	99.74%	1,519	0.01%
Town Car Cartier	4	0.15%	7	0.27%	2,611	99.58%	2,622	0.02%
Town Car Executive	3	0.06%	25	0.48%	5,230	99.47%	5,258	0.03%
Town Car Signature	8	0.09%	39	0.42%	9,269	99.50%	9,316	0.05%
Town Car Signature Limited	2	0.05%	10	0.25%	4,042	99.70%	4,054	0.02%
Town Car Ultimate	1	0.12%	3	0.37%	807	99.51%	811	0.00%
BLANK	37	0.05%	222	0.29%	77,283	99.67%	77,542	0.45%
LAND ROVER								
Range Rover	7	0.02%	37	0.12%	29,833	99.85%	29,877	0.17%
BLANK	4	0.02%	42	0.17%	24,161	99.81%	24,207	0.14%
MASERATI								
BLANK	1	0.04%	6	0.26%	2,295	99.70%	2,302	0.01%
MAZDA								
3	3	0.01%	30	0.12%	24,438	99.87%	24,471	0.14%
5	1	0.03%	9	0.26%	3,464	99.71%	3,474	0.02%
6	8	0.05%	75	0.49%	15,291	99.46%	15,374	0.09%
626	6	0.15%	18	0.44%	4,084	99.42%	4,108	0.02%

Table A-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
B-Series Regular Cab 2WD	2	0.07%	12	0.43%	2,763	99.50%	2,777	0.02%
CX-7	6	0.05%	33	0.30%	10,927	99.64%	10,966	0.06%
Mazda 3	1	0.00%	18	0.05%	33,740	99.94%	33,759	0.19%
Mazda 5	2	0.05%	7	0.17%	4,152	99.78%	4,161	0.02%
Mazda 6	2	0.01%	34	0.23%	14,439	99.75%	14,475	0.08%
MPV	9	0.17%	37	0.71%	5,161	99.12%	5,207	0.03%
MX5 Miata	2	0.08%	18	0.73%	2,441	99.19%	2,461	0.01%
MX-5 Miata	1	0.02%	15	0.23%	6,554	99.76%	6,570	0.04%
Protege	8	0.09%	49	0.53%	9,257	99.39%	9,314	0.05%
RX-8	3	0.11%	10	0.35%	2,838	99.54%	2,851	0.02%
Tribute LX 2WD	1	0.02%	5	0.10%	5,049	99.88%	5,055	0.03%
BLANK	50	0.03%	385	0.22%	174,861	99.75%	175,296	1.01%
MERCURY								
Cougar XR7	1	0.16%	2	0.31%	638	99.53%	641	0.00%
Grand Marquis GS	4	0.04%	13	0.12%	10,442	99.84%	10,459	0.06%
Grand Marquis LS	9	0.06%	30	0.19%	16,161	99.76%	16,200	0.09%
Mariner Premier 2WD	1	0.09%	1	0.09%	1,116	99.82%	1,118	0.01%
Milan Premier	2	0.09%	3	0.13%	2,226	99.78%	2,231	0.01%
Villager sport	2	0.92%	1	0.46%	215	98.62%	218	0.00%
Villager Wagon	2	0.14%	2	0.14%	1,467	99.73%	1,471	0.01%
BLANK	15	0.03%	74	0.14%	51,642	99.83%	51,731	0.30%
MERCEDES								
C230	1	0.01%	27	0.31%	8,683	99.68%	8,711	0.05%
C240	1	0.03%	5	0.15%	3,327	99.82%	3,333	0.02%
C250	1	0.01%	6	0.05%	12,705	99.94%	12,712	0.07%

Table A-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
C280	2	0.10%	6	0.31%	1,916	99.58%	1,924	0.01%
C300	5	0.04%	11	0.08%	13,804	99.88%	13,820	0.08%
C350	1	0.03%	4	0.14%	2,886	99.83%	2,891	0.02%
CLK350	1	0.04%	2	0.08%	2,555	99.88%	2,558	0.01%
CLK430	1	0.10%	2	0.20%	991	99.70%	994	0.01%
CLS550	1	0.04%	3	0.12%	2,444	99.84%	2,448	0.01%
E350	1	0.00%	21	0.08%	25,726	99.91%	25,748	0.15%
E500W	1	0.06%	2	0.12%	1,679	99.82%	1,682	0.01%
ML320	1	0.03%	2	0.06%	3,382	99.91%	3,385	0.02%
ML430	1	0.14%	2	0.28%	704	99.58%	707	0.00%
R350	1	0.06%	1	0.06%	1,577	99.87%	1,579	0.01%
S430V	1	0.04%	2	0.07%	2,665	99.89%	2,668	0.02%
S550	1	0.01%	5	0.06%	8,857	99.93%	8,863	0.05%
SLK320	1	0.13%	1	0.13%	763	99.74%	765	0.00%
BLANK	32	0.02%	170	0.09%	192,301	99.90%	192,503	1.11%
MITSUBISHI								
Diamante LS	1	0.14%	2	0.29%	694	99.57%	697	0.00%
Eclipse	3	0.30%	8	0.80%	991	98.90%	1,002	0.01%
Eclipse GS	3	0.08%	13	0.33%	3,904	99.59%	3,920	0.02%
Eclipse GS Spyder	1	0.10%	7	0.70%	992	99.20%	1,000	0.01%
Eclipse GS/GS Sport/SE	1	0.21%	1	0.21%	469	99.58%	471	0.00%
Eclipse RS	1	0.14%	7	0.97%	715	98.89%	723	0.00%
Endeavor LS FWD	2	0.08%	3	0.12%	2,446	99.80%	2,451	0.01%
Endeavor XLS FWD	1	0.15%	5	0.73%	676	99.12%	682	0.00%
Galant ES	1	0.10%	2	0.19%	1,036	99.71%	1,039	0.01%

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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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Galant ES / GTZ / LS	3	0.05%	19	0.32%	5,926	99.63%	5,948	0.03%
Galant ES / SE/ GTS	1	0.03%	5	0.17%	2,970	99.80%	2,976	0.02%
Galant ES/SE	1	0.06%	22	1.26%	1,728	98.69%	1,751	0.01%
Galant FE	3	0.15%	18	0.91%	1,963	98.94%	1,984	0.01%
Lancer ES	1	0.01%	7	0.07%	9,798	99.92%	9,806	0.06%
Montero Sport 2WD	2	0.04%	5	0.09%	5,571	99.87%	5,578	0.03%
Outlander XLS F4WD	1	0.25%	1	0.25%	399	99.50%	401	0.00%
Outlander XLS FWD	1	0.07%	3	0.20%	1,464	99.73%	1,468	0.01%
Raider LS 2WD	1	0.14%	1	0.14%	733	99.73%	735	0.00%
BLANK	38	0.06%	155	0.23%	65,886	99.71%	66,079	0.38%
NISSAN								
Altima	26	0.01%	181	0.08%	217,482	99.90%	217,689	1.26%
Juke	2	0.02%	10	0.08%	11,825	99.90%	11,837	0.07%
Maxima	5	0.01%	48	0.09%	55,647	99.90%	55,700	0.32%
Murano	2	0.00%	20	0.05%	40,379	99.95%	40,401	0.23%
Pathfinder	2	0.00%	22	0.05%	45,675	99.95%	45,699	0.26%
Pickup Crew Cab	1	0.01%	9	0.13%	7,164	99.86%	7,174	0.04%
Pickup King Cab	4	0.04%	15	0.14%	10,821	99.82%	10,840	0.06%
Quest	3	0.02%	19	0.13%	14,457	99.85%	14,479	0.08%
Rogue	2	0.00%	19	0.04%	46,600	99.95%	46,621	0.27%
Rogue Select	1	0.01%	1	0.01%	6,752	99.97%	6,754	0.04%
Sentra	15	0.02%	47	0.05%	95,791	99.94%	95,853	0.55%
Sentra / 200SX	5	0.12%	5	0.12%	4,305	99.77%	4,315	0.02%
Titan	7	0.02%	16	0.05%	32,020	99.93%	32,043	0.19%
Truck Regular Bed	1	0.02%	5	0.11%	4,509	99.87%	4,515	0.03%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Versa	6	0.01%	18	0.03%	53,837	99.96%	53,861	0.31%
Xterra	5	0.02%	37	0.11%	32,447	99.87%	32,489	0.19%
BLANK	96	0.01%	526	0.08%	665,468	99.91%	666,090	3.85%
OLSMOBILE								
Alero Level II	1	0.04%	12	0.44%	2,718	99.52%	2,731	0.02%
Aurora	1	0.12%	1	0.12%	843	99.76%	845	0.00%
Bravada 4WD	2	0.22%	1	0.11%	923	99.68%	926	0.01%
Intrigue	1	0.33%	1	0.33%	300	99.34%	302	0.00%
BLANK	6	0.06%	8	0.08%	9,591	99.85%	9,605	0.06%
OTHER								
1500	1	0.01%	16	0.12%	13,760	99.88%	13,777	0.08%
2500 2WD	1	0.04%	5	0.19%	2,688	99.78%	2,694	0.02%
328i	3	0.09%	4	0.11%	3,517	99.80%	3,524	0.02%
528i	1	0.05%	1	0.05%	2,067	99.90%	2,069	0.01%
Accord EX	1	0.03%	2	0.06%	3,267	99.91%	3,270	0.02%
Altima	4	0.01%	28	0.09%	32,076	99.90%	32,108	0.19%
Avenger SE	2	0.04%	4	0.08%	4,954	99.88%	4,960	0.03%
Avenger SXT	1	0.06%	1	0.06%	1,626	99.88%	1,628	0.01%
Camaro LT	1	0.04%	3	0.13%	2,310	99.83%	2,314	0.01%
Camry	3	0.01%	9	0.03%	31,328	99.96%	31,340	0.18%
Challenger Base	1	0.03%	4	0.13%	3,014	99.83%	3,019	0.02%
Charger (RWD)	1	0.09%	1	0.09%	1,167	99.83%	1,169	0.01%
Charger SE	1	0.03%	4	0.12%	3,463	99.86%	3,468	0.02%
Civic LX	4	0.03%	5	0.04%	12,783	99.93%	12,792	0.07%
Cooper	1	0.04%	5	0.18%	2,809	99.79%	2,815	0.02%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Corolla	3	0.01%	7	0.03%	25,783	99.96%	25,793	0.15%
Crown Victoria (Police)	2	0.64%	1	0.32%	308	99.04%	311	0.00%
CR-V	1	0.01%	3	0.02%	17,309	99.98%	17,313	0.10%
Cube	1	0.03%	3	0.09%	3,375	99.88%	3,379	0.02%
Elantra	1	0.01%	6	0.04%	14,129	99.95%	14,136	0.08%
Equinox 1LT	1	0.02%	3	0.07%	4,471	99.91%	4,475	0.03%
ES 300h	1	0.08%	1	0.08%	1,192	99.83%	1,194	0.01%
ES350	1	0.07%	2	0.13%	1,487	99.80%	1,490	0.01%
Escalade	1	0.06%	3	0.19%	1,554	99.74%	1,558	0.01%
Escalade 1500 2WD	1	0.38%	1	0.38%	262	99.24%	264	0.00%
Escape	1	0.01%	6	0.04%	14,834	99.95%	14,841	0.09%
Explorer	2	0.01%	10	0.07%	13,622	99.91%	13,634	0.08%
F150	4	0.01%	23	0.05%	48,715	99.94%	48,742	0.28%
F150 2WD Super Crew	3	0.09%	14	0.41%	3,394	99.50%	3,411	0.02%
Focus SE	1	0.01%	2	0.02%	9,629	99.97%	9,632	0.06%
Fusion S	1	0.05%	2	0.10%	2,056	99.85%	2,059	0.01%
Fusion SE	2	0.02%	20	0.19%	10,420	99.79%	10,442	0.06%
G35 Coupe	1	0.06%	3	0.17%	1,795	99.78%	1,799	0.01%
Grand Caravan	1	0.02%	3	0.07%	4,390	99.91%	4,394	0.03%
GS 350	1	0.03%	2	0.06%	3,136	99.90%	3,139	0.02%
HHR	1	0.07%	3	0.22%	1,371	99.71%	1,375	0.01%
Highlander Ltd	1	0.19%	1	0.19%	515	99.61%	517	0.00%
Impala LTZ	1	0.07%	1	0.07%	1,440	99.86%	1,442	0.01%
Jetta/Rabbit/GTI	1	0.06%	4	0.25%	1,583	99.69%	1,588	0.01%
Journey	2	0.05%	4	0.10%	4,001	99.85%	4,007	0.02%

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	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	
Vehicle Make	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
Malibu 1LS	1	0.16%	1	0.16%	605	99.67%	607	0.00%
Malibu 2LT	1	0.05%	1	0.05%	2,076	99.90%	2,078	0.01%
Malibu Fleet	1	0.19%	1	0.19%	531	99.62%	533	0.00%
Mazda 3	2	0.03%	3	0.04%	6,966	99.93%	6,971	0.04%
Mini Cooper Countryman	1	0.09%	1	0.09%	1,173	99.83%	1,175	0.01%
Mirage DE	2	0.63%	1	0.32%	312	99.05%	315	0.00%
MKZ	1	0.05%	3	0.15%	1,954	99.80%	1,958	0.01%
Murano	1	0.02%	4	0.08%	5,148	99.90%	5,153	0.03%
Range Rover	1	0.02%	9	0.20%	4,563	99.78%	4,573	0.03%
RAV4	2	0.02%	3	0.03%	11,364	99.96%	11,369	0.07%
RX350	1	0.06%	2	0.12%	1,657	99.82%	1,660	0.01%
Santa Fe	1	0.01%	11	0.14%	7,712	99.84%	7,724	0.04%
Sentra	1	0.01%	3	0.03%	11,809	99.97%	11,813	0.07%
Sienna	1	0.01%	4	0.05%	7,373	99.93%	7,378	0.04%
SMART fortwo	1	0.04%	1	0.04%	2,386	99.92%	2,388	0.01%
Sonata	8	0.05%	36	0.24%	14,823	99.70%	14,867	0.09%
Soul	1	0.01%	1	0.01%	10,428	99.98%	10,430	0.06%
Transit Connect	1	0.03%	8	0.23%	3,465	99.74%	3,474	0.02%
Tundra	1	0.01%	3	0.02%	12,274	99.97%	12,278	0.07%
Wrangler	2	0.02%	3	0.03%	10,023	99.95%	10,028	0.06%
BLANK	81	0.02%	344	0.08%	450,325	99.91%	450,750	2.60%
PLYMOUTH								
Neon LX	1	0.16%	1	0.16%	626	99.68%	628	0.00%
Voyager	1	0.07%	3	0.20%	1,473	99.73%	1,477	0.01%

Table A-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
PONTIAC								
G5 LS	2	0.08%	6	0.23%	2,591	99.69%	2,599	0.02%
G6 GT	1	0.02%	8	0.13%	6,289	99.86%	6,298	0.04%
G6 GTP	1	0.12%	2	0.25%	799	99.63%	802	0.00%
Grand Am SE	1	0.02%	8	0.19%	4,117	99.78%	4,126	0.02%
Grand Am SE1	1	0.02%	7	0.14%	4,979	99.84%	4,987	0.03%
Grand Prix GT	2	0.04%	6	0.11%	5,634	99.86%	5,642	0.03%
Grand Prix GTP	2	0.15%	3	0.22%	1,356	99.63%	1,361	0.01%
Grand Prix SE	1	0.14%	2	0.28%	711	99.58%	714	0.00%
Grand Prix Sedan	3	0.09%	6	0.19%	3,227	99.72%	3,236	0.02%
Sunfire	4	0.09%	12	0.28%	4,331	99.63%	4,347	0.03%
Sunfire SE	1	0.10%	2	0.21%	967	99.69%	970	0.01%
Transport	1	0.17%	1	0.17%	594	99.66%	596	0.00%
Vibe	3	0.04%	7	0.09%	7,397	99.86%	7,407	0.04%
BLANK	21	0.03%	129	0.18%	70,558	99.79%	70,708	0.41%
PORSCHE								
911	2	0.02%	19	0.21%	8,949	99.77%	8,970	0.05%
Cayenne	4	0.06%	45	0.73%	6,127	99.21%	6,176	0.04%
Cayman / Boxster	3	0.15%	14	0.68%	2,033	99.17%	2,050	0.01%
Panamera	2	0.07%	8	0.27%	2,930	99.66%	2,940	0.02%
BLANK	11	0.04%	149	0.58%	25,511	99.38%	25,671	0.15%
ROLLS ROYCE								
BLANK	1	0.25%	1	0.25%	394	99.49%	396	0.00%
SAAB								
9/3/2018	2	0.04%	9	0.19%	4,634	99.76%	4,645	0.03%

Table A-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
9/5/2018	1	0.11%	2	0.23%	880	99.66%	883	0.01%
BLANK	1	0.02%	11	0.20%	5,544	99.78%	5,556	0.03%
Scion								
Scion tC	1	0.01%	12	0.08%	15,630	99.92%	15,643	0.09%
BLANK	4	0.01%	61	0.10%	59,449	99.89%	59,514	0.34%
SATURN								
Aura XE	3	0.08%	5	0.13%	3,744	99.79%	3,752	0.02%
ION Level 1	1	0.08%	2	0.17%	1,193	99.75%	1,196	0.01%
ION Level 2	8	0.10%	26	0.33%	7,875	99.57%	7,909	0.05%
ION Level 3	2	0.08%	11	0.42%	2,606	99.50%	2,619	0.02%
SC1	1	0.50%	2	0.99%	199	98.51%	202	0.00%
SC1 / SL	2	0.35%	16	2.80%	553	96.85%	571	0.00%
SC2 / SL1 / SW1	3	0.16%	48	2.55%	1,835	97.30%	1,886	0.01%
SL2 / SW2	7	0.32%	44	1.99%	2,157	97.69%	2,208	0.01%
Vue FWD	14	0.13%	57	0.53%	10,639	99.34%	10,710	0.06%
BLANK	27	0.06%	228	0.48%	47,231	99.46%	47,486	0.27%
SUBARU								
BRZ	1	0.07%	11	0.77%	1,414	99.16%	1,426	0.01%
Forester	2	0.01%	23	0.11%	20,307	99.88%	20,332	0.12%
Impreza	1	0.01%	17	0.16%	10,605	99.83%	10,623	0.06%
Legacy/Outback	1	0.01%	14	0.21%	6,760	99.78%	6,775	0.04%
BLANK	5	0.01%	62	0.11%	54,232	99.88%	54,299	0.31%
SUZUKI								
Esteem	1	0.26%	1	0.26%	387	99.49%	389	0.00%
Grand Vitara 2WD	1	0.05%	12	0.57%	2,104	99.39%	2,117	0.01%

Table A-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
SX4	1	0.04%	1	0.04%	2,689	99.93%	2,691	0.02%
BLANK	10	0.06%	35	0.22%	15,996	99.72%	16,041	0.09%
TOYOTA								
4dr Wagon 2WD	1	0.03%	3	0.08%	3,676	99.89%	3,680	0.02%
4Runner	1	0.00%	7	0.03%	22,444	99.96%	22,452	0.13%
4Runner 2WD	1	0.01%	23	0.18%	12,556	99.81%	12,580	0.07%
4Runner 4WD	1	0.03%	8	0.21%	3,754	99.76%	3,763	0.02%
4Runner Limited	2	0.02%	13	0.14%	9,577	99.84%	9,592	0.06%
4Runner SR5	3	0.01%	31	0.08%	39,090	99.91%	39,124	0.23%
Avalon	2	0.00%	30	0.06%	48,197	99.93%	48,229	0.28%
Camry	28	0.01%	197	0.07%	294,679	99.92%	294,904	1.70%
Camry Hybrid	3	0.03%	6	0.05%	11,188	99.92%	11,197	0.06%
Celica	1	0.02%	4	0.08%	5,289	99.91%	5,294	0.03%
Corolla	23	0.01%	85	0.05%	165,812	99.93%	165,920	0.96%
Corolla/Matrix	10	0.02%	42	0.07%	57,133	99.91%	57,185	0.33%
FJ Cruiser	3	0.02%	9	0.07%	12,230	99.90%	12,242	0.07%
Highlander	6	0.01%	45	0.07%	60,147	99.92%	60,198	0.35%
Highlander Hybrid	1	0.03%	2	0.06%	3,582	99.92%	3,585	0.02%
Matrix	3	0.04%	4	0.05%	7,942	99.91%	7,949	0.05%
Prius	3	0.02%	15	0.08%	19,510	99.91%	19,528	0.11%
RAV4	5	0.01%	30	0.04%	66,784	99.95%	66,819	0.39%
RAV4 4dr 2WD	1	0.04%	4	0.16%	2,468	99.80%	2,473	0.01%
Sequoia / Highlander	1	0.01%	11	0.15%	7,320	99.84%	7,332	0.04%
Sequoia Limited	2	0.02%	11	0.12%	9,448	99.86%	9,461	0.05%
Sequoia SR5	1	0.01%	5	0.06%	8,906	99.93%	8,912	0.05%

Table A-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Sienna	1	0.00%	4	0.01%	29,684	99.98%	29,689	0.17%
Sienna LE	1	0.00%	13	0.05%	27,673	99.95%	27,687	0.16%
Sienna XLE	2	0.02%	9	0.09%	9,677	99.89%	9,688	0.06%
Solara	1	0.01%	10	0.06%	15,890	99.93%	15,901	0.09%
T100 XTRACAB 2WD	1	0.08%	4	0.33%	1,194	99.58%	1,199	0.01%
Tacoma	2	0.01%	17	0.05%	31,358	99.94%	31,377	0.18%
Tacoma Deluxe	3	0.01%	17	0.08%	20,444	99.90%	20,464	0.12%
Tacoma DLX	3	0.01%	28	0.09%	32,656	99.91%	32,687	0.19%
Tacoma XTRACAB 4WD	1	0.04%	8	0.35%	2,307	99.61%	2,316	0.01%
Tundra	4	0.01%	24	0.04%	58,652	99.95%	58,680	0.34%
Tundra DX	1	0.05%	2	0.10%	2,089	99.86%	2,092	0.01%
Tundra Limited	4	0.06%	5	0.07%	7,239	99.88%	7,248	0.04%
Tundra SR5	5	0.01%	39	0.09%	45,110	99.90%	45,154	0.26%
Yaris	2	0.01%	16	0.08%	18,885	99.90%	18,903	0.11%
BLANK	135	0.01%	890	0.08%	1,166,472	99.91%	1,167,497	6.74%
VOLKSWAGEN								
Golf / GTI / Jetta Wagon	1	0.03%	12	0.35%	3,460	99.63%	3,473	0.02%
Golf/Golf R/GTI/Jetta/Jetta Sp	1	0.02%	1	0.02%	6,039	99.97%	6,041	0.03%
Jetta	2	0.02%	21	0.20%	10,657	99.78%	10,680	0.06%
Jetta/Golf/GTI	1	0.07%	25	1.63%	1,510	98.31%	1,536	0.01%
Jetta/Rabbit/GTI	3	0.01%	27	0.12%	22,441	99.87%	22,471	0.13%
New Beetle	7	0.07%	34	0.35%	9,787	99.58%	9,828	0.06%
New Beetle Convertible	2	0.05%	12	0.30%	3,929	99.64%	3,943	0.02%
Passat	4	0.01%	37	0.13%	28,490	99.86%	28,531	0.16%
BLANK	25	0.02%	186	0.15%	126,067	99.83%	126,278	0.73%

Table A-1. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
VOLVO								
S40 / V40	2	0.16%	4	0.32%	1,261	99.53%	1,267	0.01%
S70 / V70	2	0.10%	10	0.52%	1,924	99.38%	1,936	0.01%
XC90	3	0.03%	6	0.06%	10,167	99.91%	10,176	0.06%
BLANK	19	0.04%	33	0.07%	49,176	99.89%	49,228	0.28%
WINNEBAGO								
BLANK	1	0.88%	1	0.88%	112	98.25%	114	0.00%
Grand Total	**3,880**	**0.02%**	**20,928**	**0.12%**	**17,289,456**	**99.86%**	**17,314,264**	**100.00%**

Appendix B

DTC Groups

Table B-1. Evap DTCs

DTC	DTC Description	DTC	DTC Description
P0093	Fuel System Leak Detected - Large Leak	P0496	Evap High Purge Flow
P0094	Fuel System Leak Detected - Small Leak	P0497	Evap Low Purge Flow
P0440	Evap Malfunction	P0498	Evap Vent Valve Control Circuit Low
P0441	Evap Incorrect Purge Flow	P0499	Evap Vent Valve Control Circuit High
P0442	Evap Leak Detected (small leak)	P2024	Evap Fuel Vapor Temperature Sensor Circuit
P0443	Evap Purge Control Valve Circuit	P2025	Evap Fuel Vapor Temperature Sensor Performance
P0444	Evap Purge Control Valve Circuit Open	P2026	Evap Fuel Vapor Temperature Sensor Circuit Low Voltage
P0445	Evap Purge Control Valve Circuit Shorted	P2027	Evap Fuel Vapor Temperature Sensor Circuit High Voltage
P0446	Evap Vent Control Circuit Malfunction	P2028	Evap Fuel Vapor Temperature Sensor Circuit Intermittent
P0447	Evap Vent Control Circuit Open	P2400	Evap Leak Detection Pump Control Circuit/Open
P0448	Evap Vent Control Circuit Shorted	P2401	Evap Leak Detection Pump Control Circuit Low
P0449	Evap Vent Valve/Solenoid Circuit Malfunction	P2402	Evap Leak Detection Pump Control Circuit High
P0450	Evap Pressure Sensor Malfunction	P2403	Evap Leak Detection Pump Sense Circuit/Open
P0451	Evap Pressure Sensor Range/Performance	P2404	Evap Leak Detection Pump Sense Circuit Range/Performance
P0452	Evap Pressure Sensor Low Input	P2405	Evap Leak Detection Pump Sense Circuit Low
P0453	Evap Pressure Sensor High Input	P2406	Evap Leak Detection Pump Sense Circuit High
P0454	Evap Pressure Sensor Intermittent	P2407	Evap Leak Detection Pump Sense Circuit Intermittent/Erratic
P0455	Evap Leak Detected (gross leak)	P2408	Fuel Cap Sensor/Switch Circuit
P0456	Evap Leak Detected (very small leak)	P2409	Fuel Cap Sensor/Switch Circuit Range/Performance
P0457	Evap Leak Detected (fuel cap loose/off)	P2410	Fuel Cap Sensor/Switch Circuit Low
P0458	Evap Purge Control Valve Circuit Low	P2411	Fuel Cap Sensor/Switch Circuit High
P0459	Evap Purge Control Valve Circuit High	P2412	Fuel Cap Sensor/Switch Circuit Intermittent/Erratic
P0465	Purge Flow Sensor Circuit Malfunction	P2418	Evap Switching Valve Control Circuit / Open
P0466	Purge Flow Sensor Circuit Range/Performance	P2419	Evap Switching Valve Control Circuit Low
P0467	Purge Flow Sensor Circuit Low Input	P2420	Evap Switching Valve Control Circuit High
P0468	Purge Flow Sensor Circuit High Input	P2421	Evap Vent Valve Stuck Open
P0469	Purge Flow Sensor Circuit Intermittent	P2422	Evap Vent Valve Stuck Closed

Table B-2. Catalyst DTCs[9]

DTC	DTC Description	DTC	DTC Description
P0420	Catalyst System Efficiency Below Threshold	P0431	Warm Up Catalyst Efficiency Below Threshold
P0421	Warm Up Catalyst Efficiency Below Threshold	P0432	Main Catalyst Efficiency Below Threshold
P0422	Main Catalyst Efficiency Below Threshold	P0433	Heated Catalyst Efficiency Below Threshold
P0423	Heated Catalyst Efficiency Below Threshold	P0434	Heated Catalyst Temperature Below Threshold
P0424	Heated Catalyst Temperature Below Threshold	P0435	Catalyst Temperature Sensor
P0425	Catalyst Temperature Sensor	P0436	Catalyst Temperature Sensor Range/Performance
P0426	Catalyst Temperature Sensor Range/Performance	P0437	Catalyst Temperature Sensor Low
P0427	Catalyst Temperature Sensor Low	P0438	Catalyst Temperature Sensor High
P0428	Catalyst Temperature Sensor High	P0439	Catalyst Heater Control Circuit
P0429	Catalyst Heater Control Circuit	P2423	HC Adsorption Catalyst Efficiency Below Threshold
P0430	Catalyst System Efficiency Below Threshold	P2424	HC Adsorption Catalyst Efficiency Below Threshold

Table B-3. EGR DTCs

DTC	DTC Description	DTC	DTC Description
P0400	EGR Flow	P0489	EGR Control Circuit Low
P0401	EGR Flow Insufficient Detected	P0490	EGR Control Circuit High
P0402	EGR Flow Excessive Detected	P2141	EGR Throttle Control Circuit Low
P0403	EGR Control Circuit	P2142	EGR Throttle Control Circuit High
P0404	EGR Control Circuit Range/Performance	P2143	EGR Vent Control Circuit/Open
P0405	EGR Sensor "A" Circuit Low	P2144	EGR Vent Control Circuit Low
P0406	EGR Sensor "A" Circuit High	P2145	EGR Vent Control Circuit High
P0407	EGR Sensor "B" Circuit Low	P2413	EGR System Performance
P0408	EGR Sensor "B" Circuit High	P2425	EGR Cooling Valve Control Circuit/Open
P0409	EGR Sensor "A" Circuit	P2426	EGR Cooling Valve Control Circuit Low
P0486	EGR Sensor "B" Circuit	P2427	EGR Cooling Valve Control Circuit High
P0487	EGR Throttle Position Control Circuit	P2428	Exhaust Gas Temperature Too High
P0488	EGR Throttle Position Control Range/Perf	P2429	Exhaust Gas Temperature Too High

[9] Includes heated catalyst DTCs, although none were present in the data analyzed for this study.

Table B-4. O_2 System DTCs[10]

DTC	DTC Description	DTC	DTC Description
P0030	HO2S Heater Control Circuit	P0166	O2 Sensor Circuit No Activity Detected
P0031	HO2S Heater Control Circuit Low	P0167	O2 Sensor Heater Circuit
P0032	HO2S Heater Control Circuit High	P2195	O2 Sensor Signal Stuck Lean
P0036	HO2S Heater Control Circuit	P2196	O2 Sensor Signal Stuck Rich
P0037	HO2S Heater Control Circuit Low	P2197	O2 Sensor Signal Stuck Lean
P0038	HO2S Heater Control Circuit High	P2198	O2 Sensor Signal Stuck Rich
P0040	O2 Sensor Signals Swapped B1 S1/ B2 S1	P2231	O2 Sensor Signal Circuit Shorted to Heater Circuit
P0041	O2 Sensor Signals Swapped B1 S2/ B2 S2	P2232	O2 Sensor Signal Circuit Shorted to Heater Circuit
P0042	HO2S Heater Control Circuit	P2233	O2 Sensor Signal Circuit Shorted to Heater Circuit
P0043	HO2S Heater Control Circuit Low	P2234	O2 Sensor Signal Circuit Shorted to Heater Circuit
P0044	HO2S Heater Control Circuit High	P2235	O2 Sensor Signal Circuit Shorted to Heater Circuit
P0050	HO2S Heater Control Circuit	P2236	O2 Sensor Signal Circuit Shorted to Heater Circuit
P0051	HO2S Heater Control Circuit Low	P2237	O2 Sensor Positive Current Control Circuit/Open
P0052	HO2S Heater Control Circuit High	P2238	O2 Sensor Positive Current Control Circuit Low
P0053	HO2S Heater Resistance	P2239	O2 Sensor Positive Current Control Circuit High
P0054	HO2S Heater Resistance	P2240	O2 Sensor Positive Current Control Circuit/Open
P0055	HO2S Heater Resistance	P2241	O2 Sensor Positive Current Control Circuit Low
P0056	HO2S Heater Control Circuit	P2242	O2 Sensor Positive Current Control Circuit High
P0057	HO2S Heater Control Circuit Low	P2243	O2 Sensor Reference Voltage Circuit/Open
P0058	HO2S Heater Control Circuit High	P2244	O2 Sensor Reference Voltage Performance
P0059	HO2S Heater Resistance	P2245	O2 Sensor Reference Voltage Circuit Low
P0060	HO2S Heater Resistance	P2246	O2 Sensor Reference Voltage Circuit High
P0061	HO2S Heater Resistance	P2247	O2 Sensor Reference Voltage Circuit/Open
P0062	HO2S Heater Control Circuit	P2248	O2 Sensor Reference Voltage Performance
P0063	HO2S Heater Control Circuit Low	P2249	O2 Sensor Reference Voltage Circuit Low
P0064	HO2S Heater Control Circuit High	P2250	O2 Sensor Reference Voltage Circuit High
P0130	O2 Sensor Circuit	P2251	O2 Sensor Negative Current Control Circuit/Open
P0131	O2 Sensor Circuit Low Voltage	P2252	O2 Sensor Negative Current Control Circuit Low`
P0132	O2 Sensor Circuit High Voltage	P2253	O2 Sensor Negative Current Control Circuit High
P0133	O2 Sensor Circuit Slow Response	P2254	O2 Sensor Negative Current Control Circuit/Open

[10] Includes oxygen sensor and oxygen sensor heater.

Table B-4. O_2 System DTCs[10]

DTC	DTC Description	DTC	DTC Description
P0134	O2 Sensor Circuit No Activity Detected	P2255	O2 Sensor Negative Current Control Circuit Low
P0135	O2 Sensor Heater Circuit	P2256	O2 Sensor Negative Current Control Circuit High
P0136	O2 Sensor Circuit	P2270	O2 Sensor Signal Stuck Lean
P0137	O2 Sensor Circuit Low Voltage	P2271	O2 Sensor Signal Stuck Rich
P0138	O2 Sensor Circuit High Voltage	P2272	O2 Sensor Signal Stuck Lean
P0139	O2 Sensor Circuit Slow Response	P2273	O2 Sensor Signal Stuck Rich
P0140	O2 Sensor Circuit No Activity Detected	P2274	O2 Sensor Signal Stuck Lean
P0141	O2 Sensor Heater Circuit	P2275	O2 Sensor Signal Stuck Rich
P0142	O2 Sensor Circuit	P2276	O2 Sensor Signal Stuck Lean
P0143	O2 Sensor Circuit Low Voltage	P2277	O2 Sensor Signal Stuck Rich
P0144	O2 Sensor Circuit High Voltage	P2278	O2 Sensor Signals Swapped B1 S3 / B2 S3
P0145	O2 Sensor Circuit Slow Response	P2297	O2 Sensor Out of Range During Deceleration
P0146	O2 Sensor Circuit No Activity Detected	P2298	O2 Sensor Out of Range During Deceleration
P0147	O2 Sensor Heater Circuit	P2414	O2 Sensor Exhaust Sample Error
P0150	O2 Sensor Circuit	P2415	O2 Sensor Exhaust Sample Error
P0151	O2 Sensor Circuit Low Voltage	P2416	O2 Sensor Signals Swapped B1 S2 / B1 S3
P0152	O2 Sensor Circuit High Voltage	P2417	O2 Sensor Signals Swapped B2 S2 / B2 S3
P0153	O2 Sensor Circuit Slow Response	P2626	O2 Sensor Pumping Current Trim Circuit/Open
P0154	O2 Sensor Circuit No Activity Detected	P2627	O2 Sensor Pumping Current Trim Circuit Low
P0155	O2 Sensor Heater Circuit	P2628	O2 Sensor Pumping Current Trim Circuit High
P0156	O2 Sensor Circuit	P2629	O2 Sensor Pumping Current Trim Circuit/Open
P0157	O2 Sensor Circuit Low Voltage	P2630	O2 Sensor Pumping Current Trim Circuit Low
P0158	O2 Sensor Circuit High Voltage	P2631	O2 Sensor Pumping Current Trim Circuit High
P0159	O2 Sensor Circuit Slow Response	P2A00	O2 Sensor Circuit Range/Performance
P0160	O2 Sensor Circuit No Activity Detected	P2A01	O2 Sensor Circuit Range/Performance
P0161	O2 Sensor Heater Circuit	P2A02	O2 Sensor Circuit Range/Performance
P0162	O2 Sensor Circuit	P2A03	O2 Sensor Circuit Range/Performance
P0163	O2 Sensor Circuit Low Voltage	P2A04	O2 Sensor Circuit Range/Performance
P0164	O2 Sensor Circuit High Voltage	P2A05	O2 Sensor Circuit Range/Performance
P0165	O2 Sensor Circuit Slow Response		

Table B-5. Secondary Air Intake System DTCs

DTC	DTC Description	DTC	DTC Description
P0410	Secondary Air Injection System	P2431	Secondary Air Injection System Air Flow/Pressure Sensor Circuit Range/Performance
P0411	Secondary Air Injection System Incorrect Flow Detected	P2432	Secondary Air Injection System Air Flow/Pressure Sensor Circuit Low
P0412	Secondary Air Injection System Switching Valve "A" Circuit	P2433	Secondary Air Injection System Air Flow/Pressure Sensor Circuit High
P0413	Secondary Air Injection System Switching Valve "A" Circuit Open	P2434	Secondary Air Injection System Air Flow/Pressure Sensor Circuit Intermittent/Erratic
P0414	Secondary Air Injection System Switching Valve "A" Circuit Shorted	P2435	Secondary Air Injection System Air Flow/Pressure Sensor Circuit
P0415	Secondary Air Injection System Switching Valve "B" Circuit	P2436	Secondary Air Injection System Air Flow/Pressure Sensor Circuit Range/Performance
P0416	Secondary Air Injection System Switching Valve "B" Circuit Open	P2437	Secondary Air Injection System Air Flow/Pressure Sensor Circuit Low
P0417	Secondary Air Injection System Switching Valve "B" Circuit Shorted	P2438	Secondary Air Injection System Air Flow/Pressure Sensor Circuit High
P0418	Secondary Air Injection System Control "A" Circuit	P2439	Secondary Air Injection System Air Flow/Pressure Sensor Circuit Intermittent/Erratic
P0419	Secondary Air Injection System Control "B" Circuit	P2440	Secondary Air Injection System Switching Valve Stuck Open
P0491	Secondary Air Injection System Insufficient Flow	P2441	Secondary Air Injection System Switching Valve Stuck Closed
P0492	Secondary Air Injection System Insufficient Flow	P2442	Secondary Air Injection System Switching Valve Stuck Open
P2257	Secondary Air Injection System Control "A" Circuit Low	P2443	Secondary Air Injection System Switching Valve Stuck Closed
P2258	Secondary Air Injection System Control "A" Circuit High	P2444	Secondary Air Injection System Pump Stuck On
P2259	Secondary Air Injection System Control "B" Circuit Low	P2445	Secondary Air Injection System Pump Stuck Off
P2260	Secondary Air Injection System Control "B" Circuit High	P2446	Secondary Air Injection System Pump Stuck On
P2430	Secondary Air Injection System Air Flow/Pressure Sensor Circuit	P2447	Secondary Air Injection System Pump Stuck Off