Eastern Research Group, Inc.

FINAL

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

Prepared for:

Texas Commission on Environmental Quality

Prepared by:

Eastern Research Group, Inc.

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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

Prepared for:

Edgar Gilmore
Texas Commission on Environmental Quality
12100 Park 35 Circle
Austin, TX 78753

Prepared by:

Cindy Palacios
Jim Lindner
Sandeep Kishan

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

Rob Klausmeier
dKC de la Torre Klausmeier Consulting
1401 Foxtail Cove
Austin, TX 78704

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Executive Summary

This report documents the evaluation of the Texas Vehicle Emissions Inspection and Maintenance (I/M) program for the 2018 and 2019 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 and Remote Sensing (RS) data from January 1, 2018 through December 31, 2019.

This evaluation generally follows the United States Environmental Protection Agency (EPA) draft guidance on using in-program data for the evaluation of the Texas I/M program performance [EPA, 2001][1] and the EPA guidance on the use of RS for the evaluation of I/M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 were roughly 0.5% 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, ERG found that improvements could be made in a few areas, and a concise list of specific recommendations for improvements in the program is provided in the last section of this Executive Summary. Some of the suggestions will be helpful for future biennial evaluations and will make the results more reflective of overall program performance.

A. COVERAGE

The results of the coverage analysis using out-of-program RS 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 92.1% in 2018 and 93.4% in 2019. In the Houston-Galveston-Brazoria (HGB) program area, the 2018 and 2019 participation rates were 93.0% and 94.2%, respectively. The overall program participation rates were 92.4% in 2018 and 93.7% in 2019.

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 demonstrate the accuracy and completeness of the data in the TIMS. ERG produced frequency

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

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] (NOx) and Two-Speed Idle (TSI). The distributions for HC and CO were typical for vehicle emissions data as they 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 emissions values were found.

Inspection Statistics (Section III.B) – Analysis of the TIMS data indicated that during the evaluation period, over 18.2 million ASM, TSI, and On-board Diagnostics (OBD) tests were performed on approximately 10.3 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. Less than 4% of the OBD tests were fails, over 12% of the ASM tests were fails, and about 11% of the TSI tests were fails.

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.

- In 99.3% of the test sequences a verified initial test or an initial test that could reasonably be assumed to be a true initial test was confirmed, and a final test certified.

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 results to check for proper lock-out of emissions equipment. The following provides a summary of the results:

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

- The drift of the emissions analyzers was measured by comparing the pre-calibration measurements of calibration gas with the post-calibration values. Except for the zero gas for HC, the analysis showed that more than 83% 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 83% 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% of the ASM and 83% 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 indicated that roughly 94% 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 1,373 analyzer audits performed, 1,206 analyzers received three or more audits, and 1,150 of these received three or more passing 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, 6.5% of all ASM inspections were performed when the dynamometer systems had not successfully passed their calibration check within the 72-hour window. Analyzers made by Worldwide Environmental Products, Inc. (WW) and Sun Electric analyzers (SE) made by Snap-On were the most prevalent in this category. Similarly, 0.7% of ASM and TSI inspections were performed when the analyzer should have been locked out. Worldwide and SE analyzers had the most instances in this category.

OBD Inspection Analyzer Communication Performance (Section III.E) – Overall, OBD communication rates between vehicle computers and program analyzers were greater than 99%.

TIMS Handling of OBD Codes (Section III.F) – It appears that the OBD inspection logic used in Texas for light-duty gasoline-powered vehicles agrees 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 143,126 repairs were made to vehicles in order to bring them into compliance with the Texas I/M program. The program requires reporting repair types according to five categories: fuel system, ignition electrical system, emissions system, engine mechanical, and miscellaneous. The fractions of total repairs in these five categories were approximately 25%, 8%, 26%, 1%, and 39%, 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 provided financial assistance to low-income vehicle owners to repair or retire vehicles that failed an emissions test or retire vehicles ten years old or older. The DACM program ended in the summer of 2019. For the period covering January 1, 2018 through December 30, 2019, 286 vehicle repairs were done at Recognized Emissions Repair Facility (RERF) stations under the DACM program. In the last program evaluation report, this figure was 5,262. Given the small number of RERF repairs during the current reporting period, no analysis was performed on these data.

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. For ASM HC, CO, and NOx, post-repair concentrations decreased 51%, 64%, and 55%, respectively. Note that almost all these vehicles were fast-pass ASM tests,[3] and 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 indicated approximately 80% of OBD tests that initially fail for an illuminated malfunction indicator light (MIL) with stored diagnostic trouble codes (DTCs) eventually receive a passing inspection. And within that cohort, 73% of the MIL-On failures passed with confirmed repairs and their monitors reset, and 27% passed after being repaired but without failure mode monitors reset. As has been seen in the earlier studies, when evaluating repairs by 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 5% to 37% of "repaired" vehicles. This large range is consistent with the findings in previous

[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.

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 $11.9 million during this evaluation period performing 51,000 repairs so that they would be in compliance with the Texas I/M program. It should be noted that repair costs are hand-entered by the vehicle emissions inspectors, which can lead to transcription errors.

As in the previous studies, a large percentage (62.2%) 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 $45-$250 and $95-$329.

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 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 95% of the ASM I/M sequences were produced by vehicles that initially passed inspection, with about 4% of the ASM I/M sequences produced by vehicles that initially failed, were repaired, and 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 10% to 12%, ASM CO decreased 18-20%, and ASM NOx decreased 15-18%. For those failing vehicles that received a TSI test, HC emissions decreased 17-19% and CO emissions decreased 12-14%.

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 30-90 days before I/M inspections were compared to the average RS emissions from 1-90 days after the I/M inspections. About 96% of the vehicles measured by RS had I/M sequences produced by passing their initial inspections, while approximately 4% had a Fail-Pass I/M test sequence. Initial pass vehicles had RS emissions decreases of roughly 13% for HC, a 5% increase for CO, and a 7% increase for NOx, while the Fail-Pass vehicles had RS emissions decreases of 24% for HC, 1% for CO, and a 14% increase for NOx.

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 vs. errors of omission were also identified whenever possible, with the former viewed as more likely attempts at committing a fraudulent test, while the latter could be viewed somewhat more leniently. An example of an error of commission would be a Vehicle Identification Number (VIN) mismatch, where the electronic VIN (eVIN) 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 eVIN 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 eight error-of-commission metrics and nine error-of-omission metrics developed, and each station was ranked according to its respective overall score in these two categories.

E. RECOMMENDATIONS

As a result of performing this biennial evaluation of the Texas I/M program, ERG 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 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.

Because the AirCheckTexas program statutorily ended tailpipe testing on January 1, 2020, the recommendations below are focused solely on OBD and RS testing.

OBD Recommendations

OBD Recommendation 1 (***): Investigate requiring a "set" status for certain monitors to prevent hiding malfunctions. Our analysis found that in 2% to 39% of instances when a vehicle received an initial fail for a certain monitored component, the retest OBD result, which follows a repair, could be hidden by an "unset" readiness status for that monitor. This opens 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 retest that follows certain types of initial failures.

OBD Recommendation 2 (***): Review the OBD exemption list. Review the current list of vehicles on the OBD readiness exemption list to ensure it is up to date. This may have been done recently, but the document does not indicate when the last update was performed.

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.

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 to evaluate the RS component of the I/M program, as discussed in Section V. This method has been used in previous program evaluation reports ERG has done for the TCEQ. The number of RS records collected each year increased through calendar year 2013 but has declined each year since then. In the 2018 report, there were 650,000 and 660,000 RS records for DFW and HGB, respectively. For this report, those numbers are 409,000 and 344,000. 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. The Reference Method for evaluating I/M programs compares RS readings from a non-I/M area like San Antonio to the RS readings from an I/M area to identify trends, benefits, and calculate effectiveness of implementing an I/M program. If possible, efforts should continue to obtain RS data from San Antonio for future evaluations.

Repair Tracking Recommendations

Regardless of how malfunctioning vehicle emission control systems are detected, improvements can be made to 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. Because all vehicles are now getting OBD tests, the repair groupings can be based on the DTC, and this would be a good opportunity to revamp the repair categories. Currently, 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. ERG recommends the repair tracking system be redesigned so that it provides inspectors a list of the five to ten most effective repairs for each vehicle technology. ERG performed a study in 2015 for the Maryland Department of the Environment that identified a list of legitimate repairs for a given OBD DTC [ERG 2015]. This approach would provide a convenient, short list of repairs for inspectors that would make the inspectors' task simpler while recording valuable repair information that is most important for the I/M program.

Providing more standardized menu options would also help improve the accuracy of these data by standardizing the entries as well as making it more onerous for the technician to enter incorrect data than to enter real data. If it becomes more difficult to input false data than the real data, then technicians would be motivated to be more accurate when completing these electronic entry forms.

Repair Tracking Recommendation 2 (***). Recording Repair Costs. A large number of repairs cost either $0 or greater than $2,000. 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. For example, repair costs of $0 would not be accepted, and any repairs above a certain threshold (e.g., $1,000), would have to be validated by re-entering the data.

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 confirm with DPS if this change is permanent.

I/M Program Evaluation 2022 Recommendations

For the next I/M program evaluation in 2022, the only I/M program data will be OBD. Therefore, there will be major changes to many 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 will receive a major overhaul. Sections A through C will 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 will be removed. Sections E and F will be expanded for a more detailed evaluation of OBD analyzer performance.

Section IV, Repair. This section will 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 developed an OBD-to-IM240 correlation and has used it for 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 will be removed. Only the OBD factors will be used, with an emphasis on VIN/ eVIN mismatch and/or missing, electronic profile mismatch, and communication protocol mismatch (some of which are new for this 2020 report). It would be useful for this section to include performance results for inspectors as well as stations. Since the OBD analysis has been expanded, ERG recommends excluding some of the metrics that have not proven to be very informative in this and in past evaluations, including the switch from light-duty to heavy-duty inspections, the ranking of stations with particularly high OBD failure rates, and all of the "Errors of Omission" metrics. 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 begins to ensure that a targeted, new analysis is developed to reflect the recent major change to OBD-only testing.

I. INTRODUCTION

The purpose of this report is to fulfill a federal requirement to evaluate the effectiveness of the state's I/M program operating in the DFW and HGB areas. Title 40 Code of Federal Regulations §51.353 (c), Network Type and Program Evaluation, requires all states subject to an enhanced I/M program to evaluate the effectiveness of their program and submit a program evaluation report to the United States EPA every two years. The last program evaluation report was issued on June 29, 2018. The DFW and HGB areas are evaluated because only the enhanced programs are required to be evaluated every two years. The Austin-Round Rock and El Paso programs are not enhanced programs; therefore, those programs are not part of this study.

The DFW and HGB enhanced I/M programs were implemented on May 1, 2002, by the TCEQ and the DPS. These programs incorporated vehicle emissions inspections using OBD computer testing and Acceleration Simulation Mode (ASM) dynamometer testing in Collin, Dallas, Denton, and Tarrant Counties of the DFW area and Harris County of the HGB area. In May 2003, the enhanced I/M program was expanded to include Ellis, Johnson, Kaufman, Parker, and Rockwall Counties of the DFW area, and Brazoria, Fort Bend, Galveston, and Montgomery Counties of the HGB area. The TCEQ contracted with ERG in 2004 to research options for evaluating the DFW and HGB I/M programs, and ERG developed the Texas I/M Program Evaluation Plan [ERG, 2004]. This report detailed numerous potential methods and measures for evaluating the I/M program. Working closely with ERG, the TCEQ selected a set of measures that provide qualitative and quantitative assessments of the four major evaluation elements as described in the EPA's Guidance on Use of In-Program Data for Evaluation of I/M Program Performance, along with several measures that assess actual emissions benefits, as described in the Texas I/M Program Evaluation Plan and the EPA's Guidance on Use of Remote Sensing for Evaluation of I/M Program Performance. This evaluation is required to be conducted in accordance with the TCEQ-selected measures.

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 performed evaluations in 2009 [ERG, 2009], 2012 [ERG 2012], 2014 [ERG 2014], 2016 [ERG 2016], and 2018 [ERG 2018] using the same approach as the 2006 Report.

This 2020 report follows the same general methodology, 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 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, and 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. To create this dataset, RS data (by license plate) were merged with 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 two years and older than 24 years, at the time of the RS measurement, were 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, 2018 and December 31, 2019.

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

Registered at Time of RS	Unique RS-Captured Vehicles by Calendar Year		
	2018	**2019**	**Total**
DFW	75,506	160,663	261,777
HGB	44,104	140,503	221,095
Total	**119,610**	**301,166**	**482,872**

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	5,479,406
HGB	4,840,359
Total	10,319,765

The I/M tests were then matched to the RS/registration dataset by VIN. If an I/M test occurred any time between January 1, 2018, and December 31, 2019, 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 2018 the DFW program area participation rate was calculated as ((69,731/75,506) x 100). Table II-3 shows that the participation rate did increase slightly overall from 2018 to 2019.

Table II-3. Count of Unique I/M Eligible RS 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	
	2018	**2019**	**2018**	**2019**
DFW	69,731	151,120	92.4%	94.0%
HGB	41,103	133,426	93.2%	95.0%
Total	**110,554**	**282,283**	**92.7%**	**94.5%**

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 provides 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 monitored adequately. An iterative series of steps was used to evaluate the accuracy and completeness of the data in the database. Within the database, each record or row was a test entry that contained columns of variables or data fields. The first set of basic filters applied was 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 (excluding variables with unique information for each record, such as those for VIN, license plate, or test date, and excluding variables not relevant to this analysis such as TX96_STIK_COND, TX96_INSUR_CONFIRM, or TX96_SOFTWARE_VERSION). 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 following criteria was use to delete records from the full database containing 26 million inspection records to get a set of successful inspections. 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 1994 or newer than 2019;
- 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 7.8 million records from the dataset (mostly for safety-only inspections and out-of-area inspections), leaving 18.2 million potentially valid emissions inspections in the dataset.

Almost every database variable that stores a categorical result was checked for completeness and appropriateness of information. Variables such as TX96_STIK_COND, TX96_INSUR_CONFIRM, or TX96_SOFTWARE_VERSION that have little relevance to emissions inspection impacts are examples of those that were ignored. Most of the variables in the dataset contained the expected information, but after the record deletions described above, a few variables that still contained anomalous information included:

- There were 12,600 records with an overall inspection cost greater than $100 (TX96_OVERALL_COST>100);
- There were 200 records with a repair cost greater than $2,000 (TX96_REP_OVERALL_COST>2000);
- There were 47 TSI inspections with curb idle revolutions per minute (RPM) greater than 3,000 RPM (TX96_PRI_CURB_IDLE_RPM>3000);
- There were 31% of TSI and 34% of ASM inspections that included an RPM Bypass (TX96_RPM_BYPASS= “B”); and
- Various other variables that had a small number of missing value results or otherwise odd results that did not appear to be significant.

The anomalous records described in the list above were counted and listed but were not deleted from the dataset. Most of the anomalies were investigated, and the results of those investigations are discussed in further detail in other areas of the report. Some of the anomalies could not be investigated further using the contents of the data (for example, the question “Why did so many ASM inspections include an RPM Bypass?” cannot be answered using the contents of the TIMS dataset).

Emissions distributions were also investigated, with the goal of discovering any anomalies. Figure III-1 through Figure III-4 show the distributions of the emissions measurements for HC, CO, NOx, 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 indicated that no gross errors are being made in measuring and recording tailpipe emissions. Also, all observations should have CO_2 concentrations between about 6% and 16%, indicating a combustion process is occurring in the vehicle’s engine, and exhaust dilution is in an acceptable range.

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

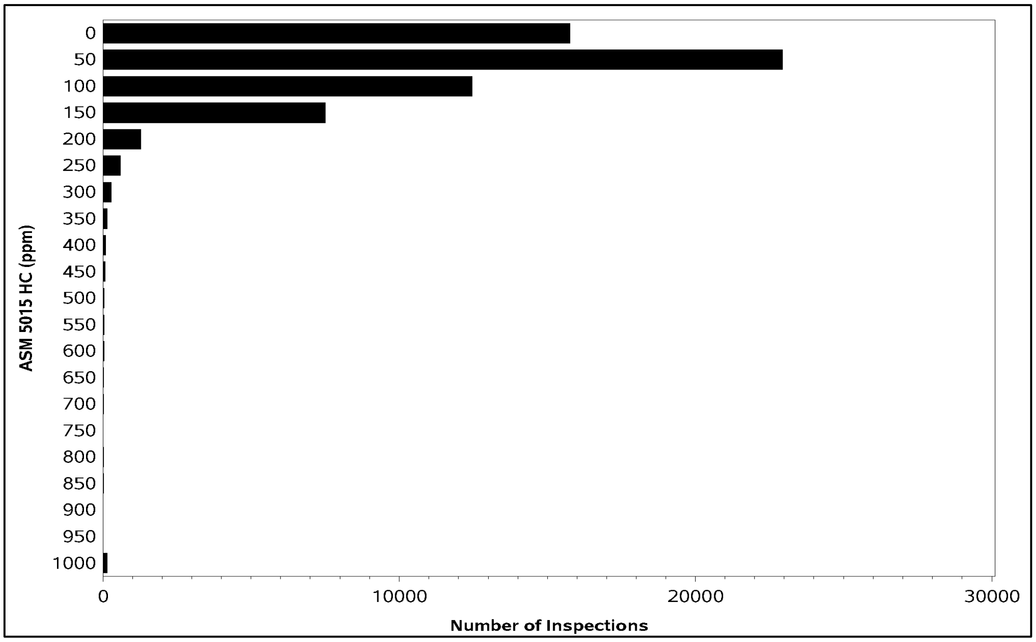


Figure III-2. Distribution of CO (%) Emissions for ASM5015 Inspection

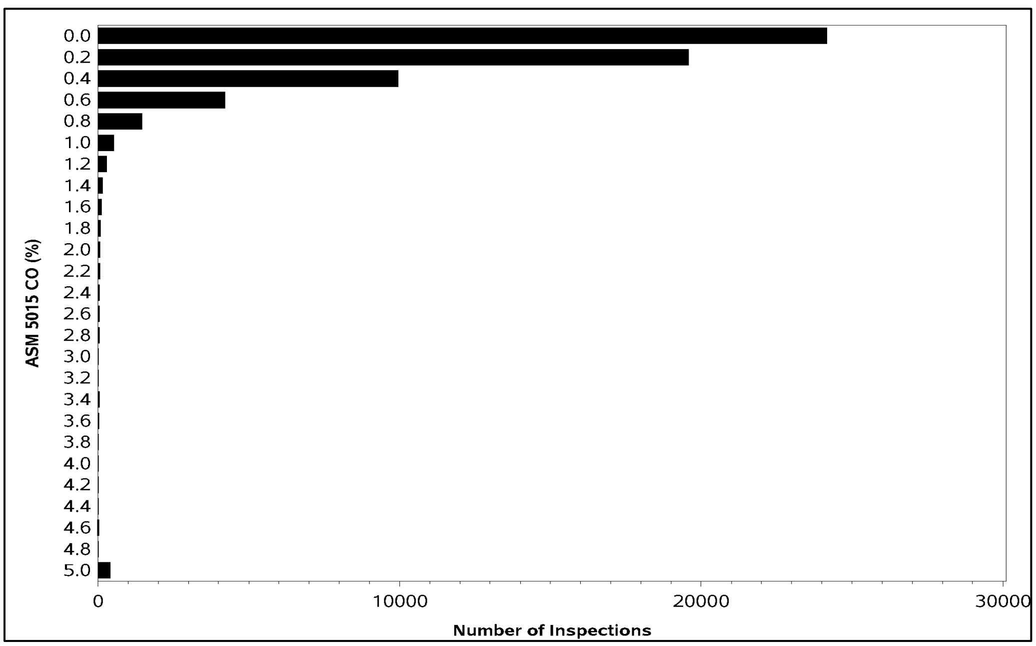


Figure III-3. Distribution of NOx (ppm) Emissions for ASM5015 Inspection

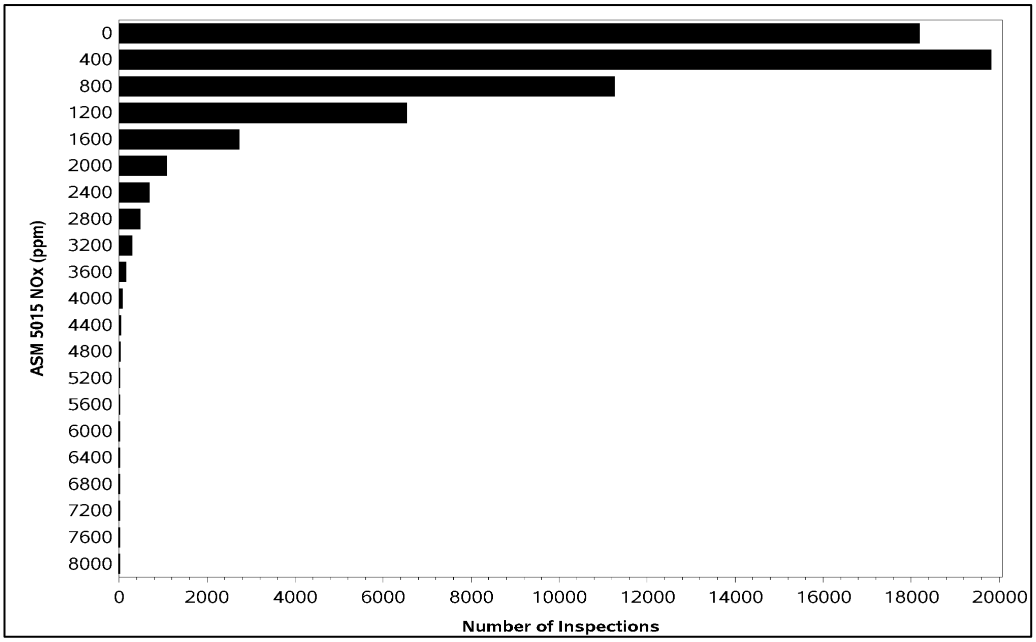


Figure III-4. Distribution of CO_2 (%) Emissions for ASM5015 Inspection

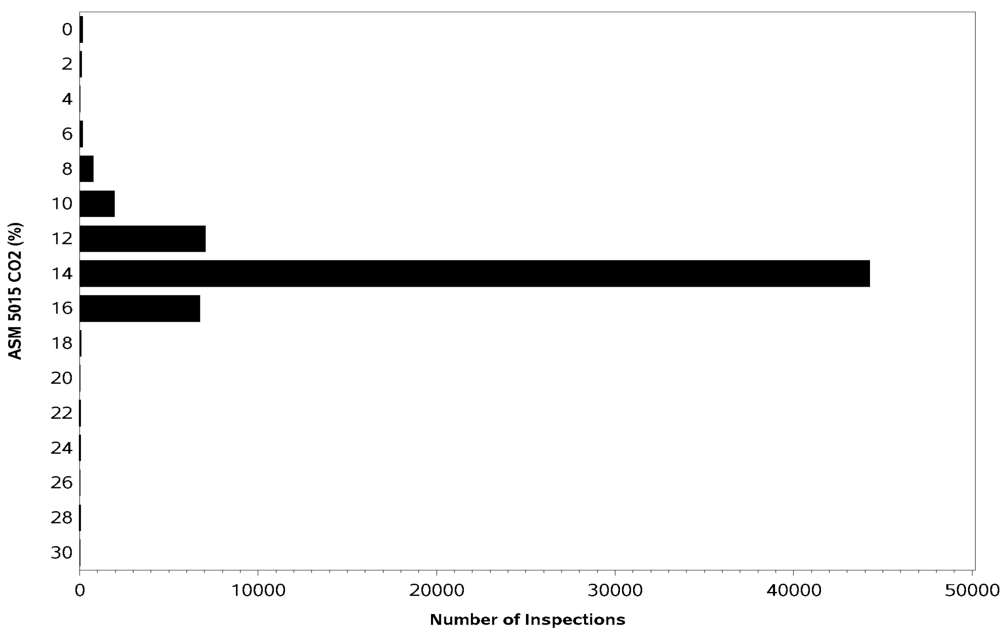


Figure III-5. Distribution of Curb Idle HC (ppm) Emissions for TSI Inspection

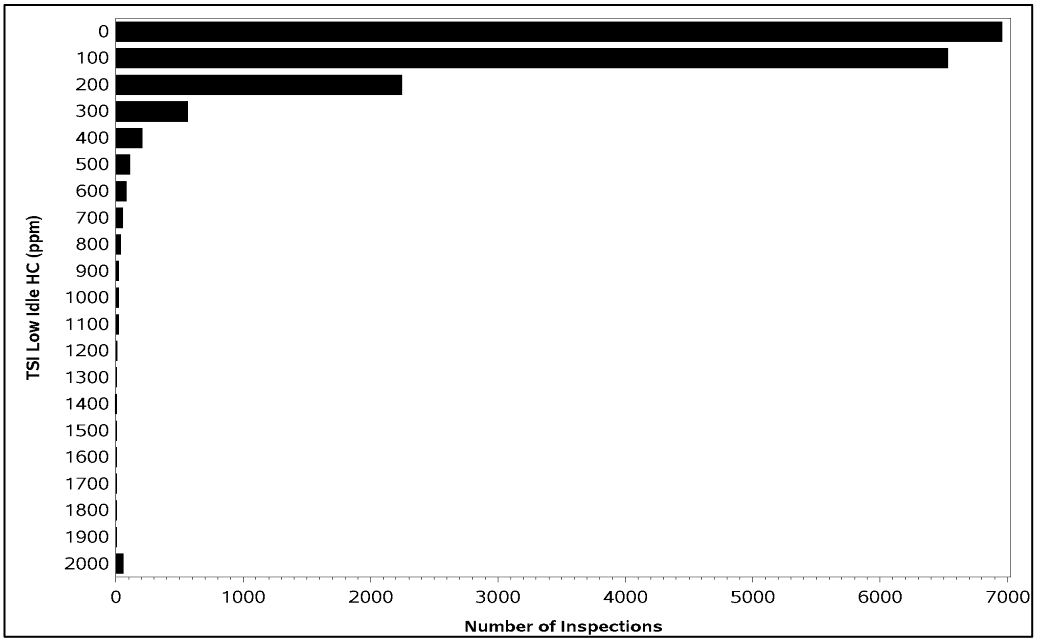


Figure III-6. Distribution of Curb Idle CO (%) Emissions for TSI Inspection

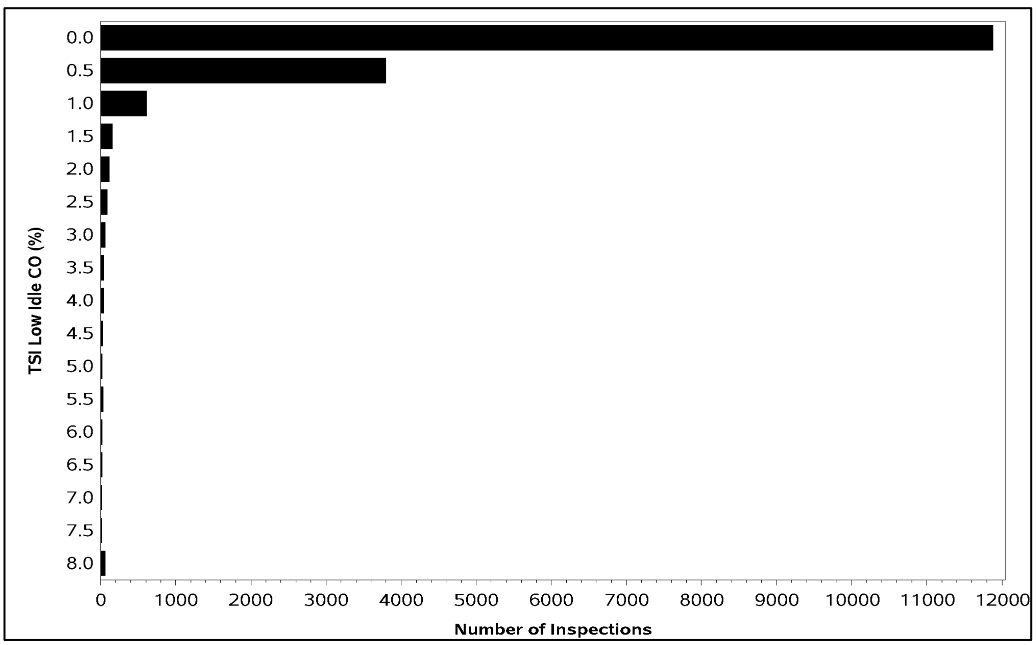
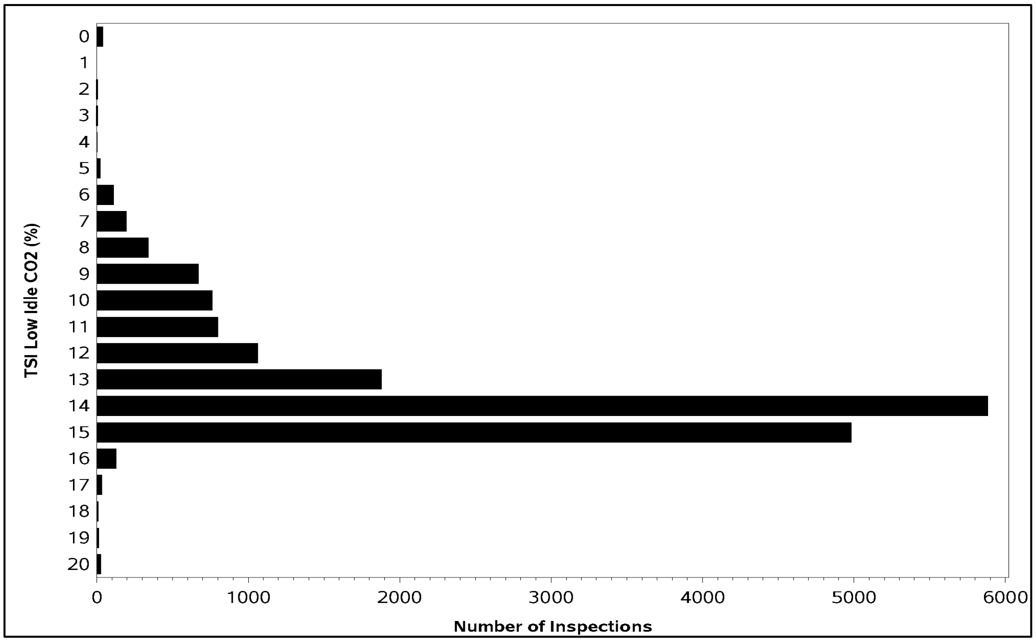


Figure III-7. Distribution of Curb Idle CO_2 (%) Emissions for TSI Inspection



This procedure of checking the contents of the variables in the database is simply an initial Quality Assurance/Quality Control (QA/QC) procedure. Variables related to vehicle emissions are discussed 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 inspections for each type of emissions inspection that was performed in the 2018 – 2019 calendar years in the HGB and DFW areas, how many of those were initial inspections (the first inspection in a test cycle), and how many of the initial inspections were unique vehicles. 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 2018 and another one in 2019; 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 retest inspections that were passed and failed by program area and inspection type.

Table III-1. Number of Inspections

Test Type	DFW			HGB		
	Total Inspections	Initial Inspections	Unique Initial Inspections	Total Inspections	Initial Inspections	Unique Initial Inspections
OBD	9,606,891	9,160,086	5,450,994	8,489,219	8,066,684	4,813,330
TSI	8,393	7,595	5,990	8,574	7,886	6,115
ASM	32,355	27,906	22,422	29,090	25,811	20,914
Total	**9,647,639**	**9,195,587**	**5,479,406**	**8,526,883**	**8,100,381**	**4,840,359**

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

Test Type	DFW			HGB		
	Pass	Fail	Failure Percent	Pass	Fail	Failure Percent
OBD	8,841,000	319,080	3.5%	7,773,919	292,758	3.6%
TSI	7,093	502	6.6%	7,475	411	5.2%
ASM	24,314	3,592	12.9%	23,389	2,422	9.4%
Total	**8,872,407**	**323,174**	**3.5%**	**7,804,783**	**295,591**	**3.6%**

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

Test Type	DFW			HGB		
	Pass	Fail	Failure Percent	Pass	Fail	Failure Percent
OBD	401,528	45,275	10.1%	382,110	40,424	9.6%
TSI	587	211	26.4%	551	137	19.9%
ASM	2,944	1,505	33.8%	2,559	720	22.0%
Total	**405,059**	**46,991**	**10.4%**	**385,220**	**41,281**	**9.7%**

Inspection counts by model year are presented in the figures below. Figure III-8 and Figure III-9 show the number of inspections of each type 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. 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 retests). 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

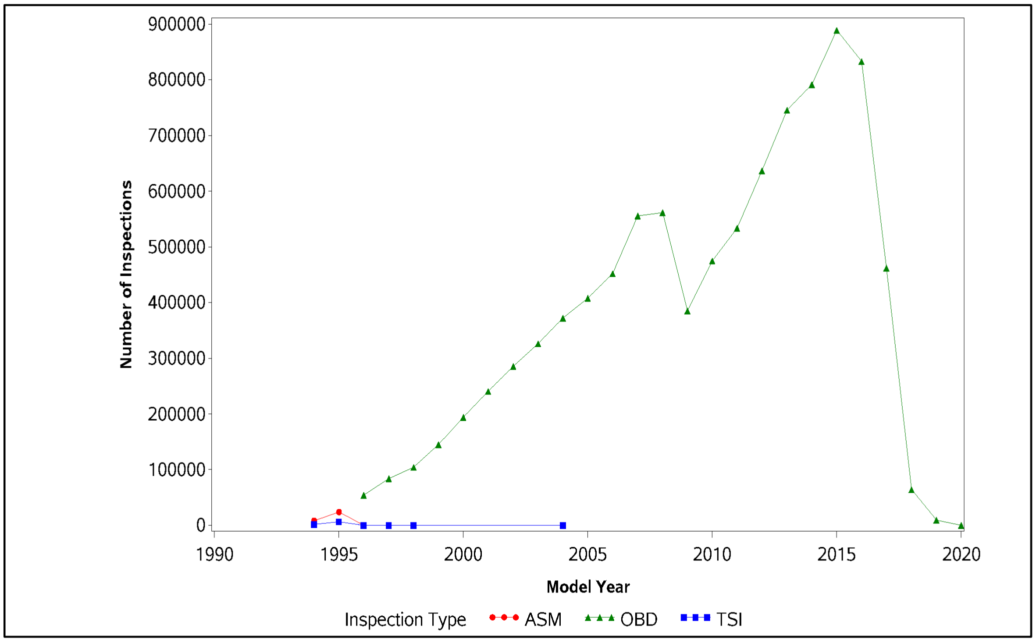


Figure III-9. Number of Inspections by Model Year per Inspection Type, HGB Program Area

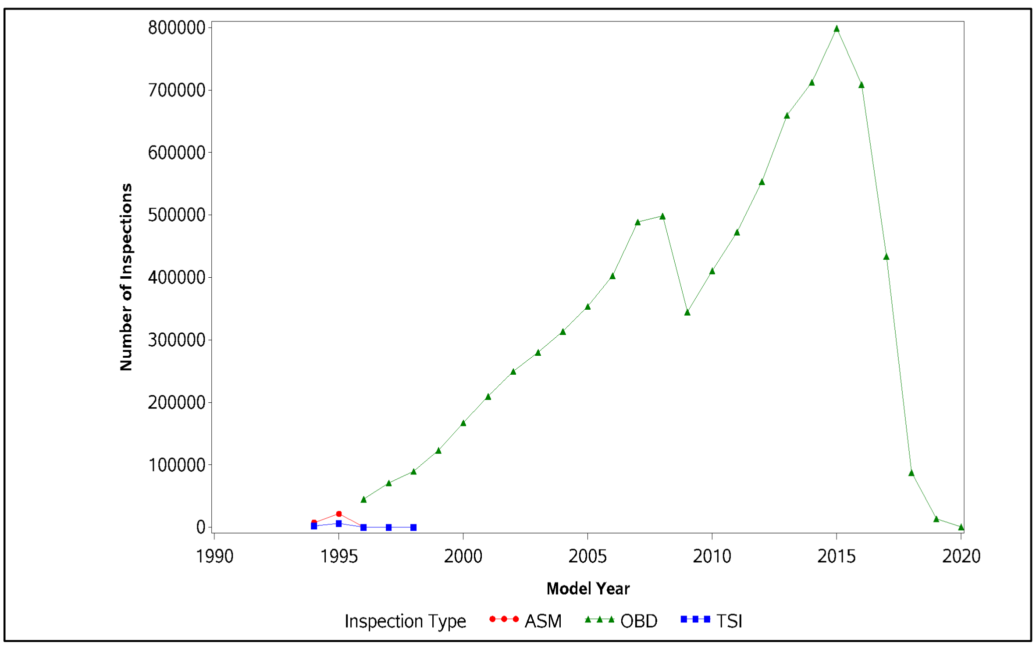


Figure III-10. Number of Inspections by Year and Month of Inspection

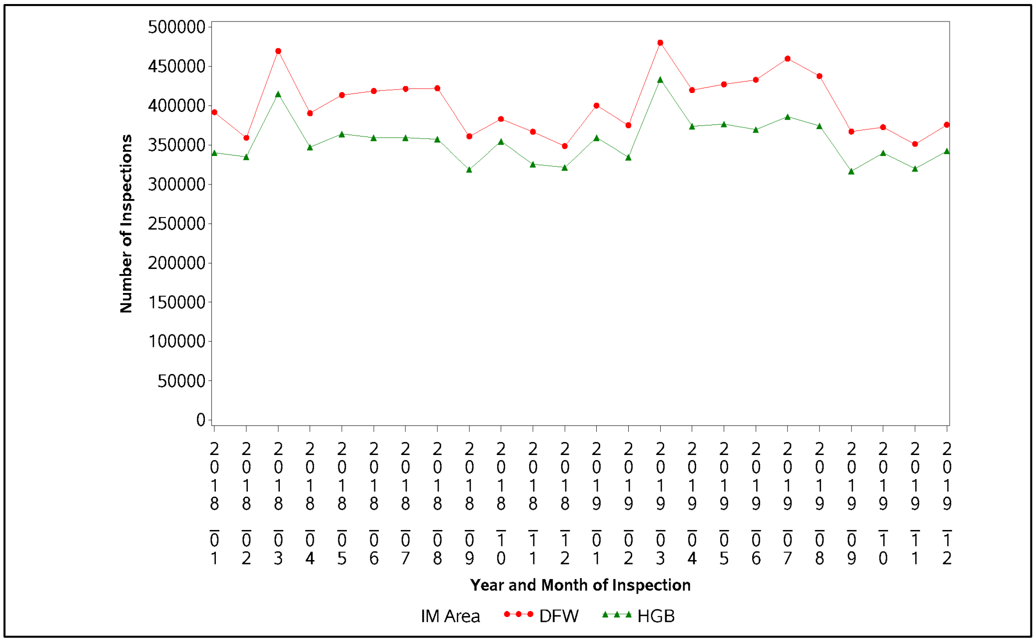


Figure III-11. Initial Inspection Failure Rate by Model Year per Inspection Type, DFW Program Area

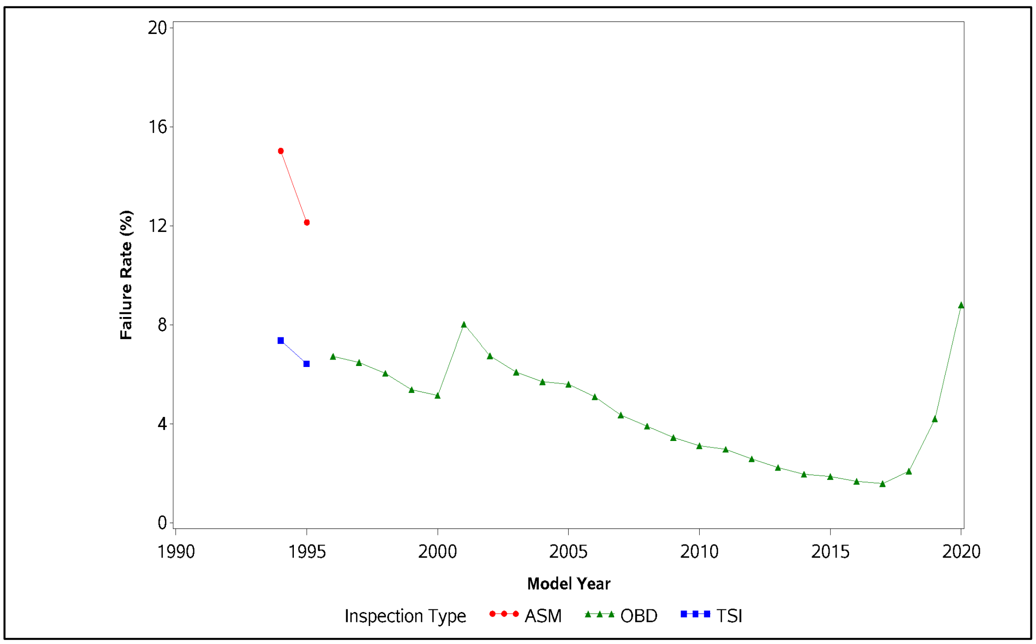
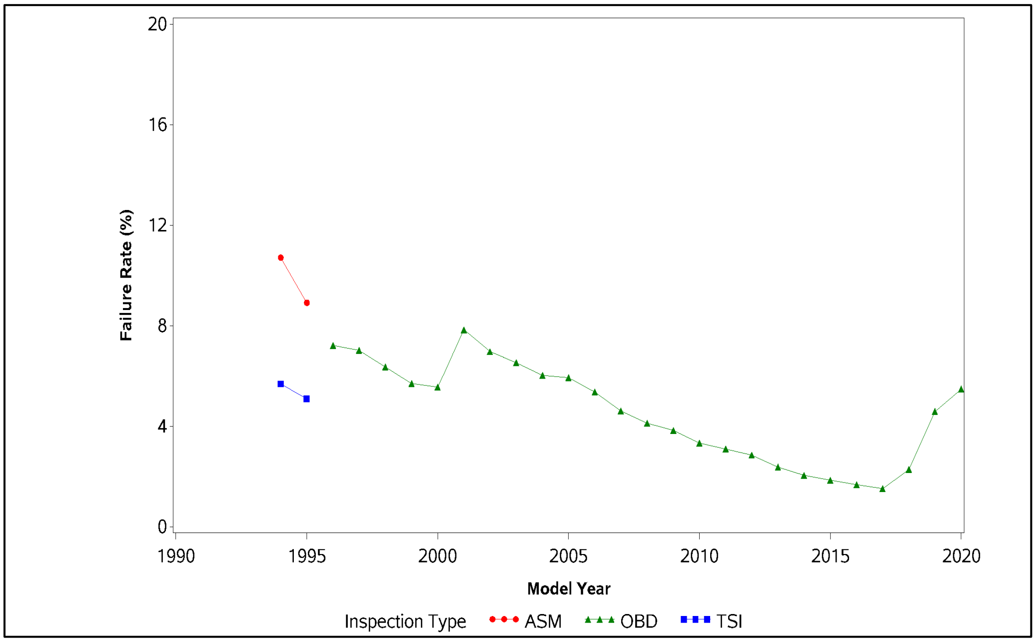


Figure III-12. Initial Inspection Failure Rate by Model Year per Inspection Type, HGB Program Area



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 evaluation period, including all of 2018 and 2019. Initial and retest 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 indicate whether an inspection is an initial or a retest inspection. However, many factors can affect the information stored in these variables (such as the time span between an initial and a retest inspection, whether the motorist chose a different inspection station for the retest, or whether a safety-only inspection was performed at some point). For the purposes of this section and this report, ERG made new initial/retest assignments. The first inspection for a VIN was labeled an initial inspection. Additional inspections to that VIN were labeled as retests 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 2018 were excluded from the counts as they could have been preceded by additional inspections in 2017. Also, for the purpose of identifying final inspections, any inspection cycles that appeared to end in the last three months of 2019 were excluded as there could be additional inspections in early 2020.

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 retest. Additional sequences might include additional failed inspections before the ultimately passed inspection. Sequences should not be found where additional retest 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 inspection 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 retest, 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 infrequent 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	7,645,685	95.2%	P	6,696,625	94.9%
FP	323,726	4.0%	FP	309,832	4.4%
F	24,785	0.3%	F	22,065	0.3%
FFP	24,049	0.3%	FFP	22,611	0.3%
FFFP	4,146	0.1%	FFFP	3,706	0.1%
FF	2,884	0.0%	FF	2,327	0.0%
FFFFP	997	0.0%	FFFFP	844	0.0%
FFF	599	0.0%	FFF	481	0.0%
Other	966	0.0%	Other	765	0.0%

In Table III-4, the top two rows, which represent the two "ideal" inspection sequences, comprise about 99% 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 retest? 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 retests. It was found that the sequences that end with a failed inspection are distributed fairly uniformly over all months of 2018 and 2019, 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 RS after their incomplete inspection cycle. These non-compliant vehicles were observed at approximately half the frequency as compliant vehicles. There were 28,268 NFP vehicles in the DFW area, accounting for 7.4% of all failing vehicles, and there were 24,873 NFP vehicles in the HGB area, accounting for 6.9% of all failing vehicles.

Several hundred less common sequences accounted for the remaining 0.01-0.02% 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, NOx, 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 NOx for zero, low-span, and mid-span bottle gases, and for O_2 with ambient air. The analyzer is then calibrated on the mid-span gases to within 1% of the bottle gas values. Next, the analyzer is tested on the low-span gases and must fall within 2% of the bottle gas value. If the analyzer cannot be brought within specifications during the calibration, the instrument is automatically prohibited from performing any portion of 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% blend tolerance, which is also shown in the table. Finally, the table shows the specified accuracy of the analyzer for I/M inspections for each pollutant and gas level. These tolerances for I/M inspections are less stringent than the 1% mid-span and 2% low-span tolerances that are used for calibrations. The I/M inspection tolerances are applicable to this analysis of pre-calibration readings since the concern here is with whether analyzer drift affected I/M inspection results just prior to calibration. As an example, 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% 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 0% 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.

Results

Span test calibration records (175,327 records) from the TIMS between January 1, 2018, and December 31, 2019 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 165,433 records in the dataset. Records for the Austin and El Paso program areas were deleted from the dataset, leaving 100,314 HGB/DFW program area records in the dataset. Finally, an additional ten records with pre-calibration readings of zero for each gas concentration were deleted, leaving 100,304 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 for O_2 should be 20.7%, corresponding to the O_2 content of ambient air. Analyzers with manufacturer codes of SE, JB (John Bean manufactured by Snap-On), and WW measured near 20.7% O_2 in almost all calibrations, while analyzers with the manufacturer code ESP (Environmental System Products) measured less than 3% 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% O_2 than at 20.7% O_2, the two sets of readings are plotted separately.

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

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

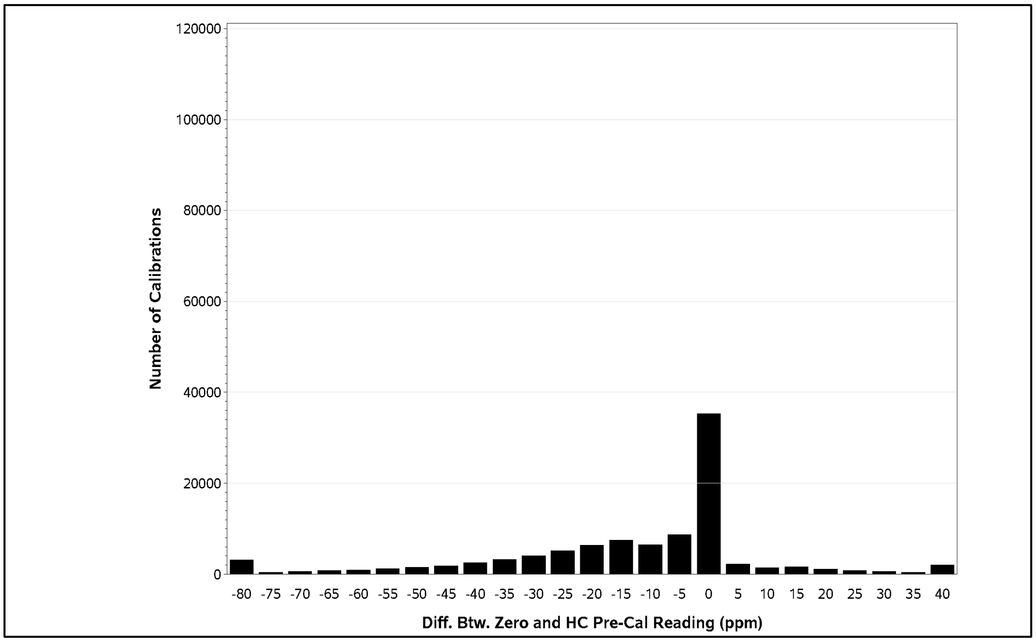


Figure III-14. Distribution of Difference Between Zero and CO Pre-Calibration Reading

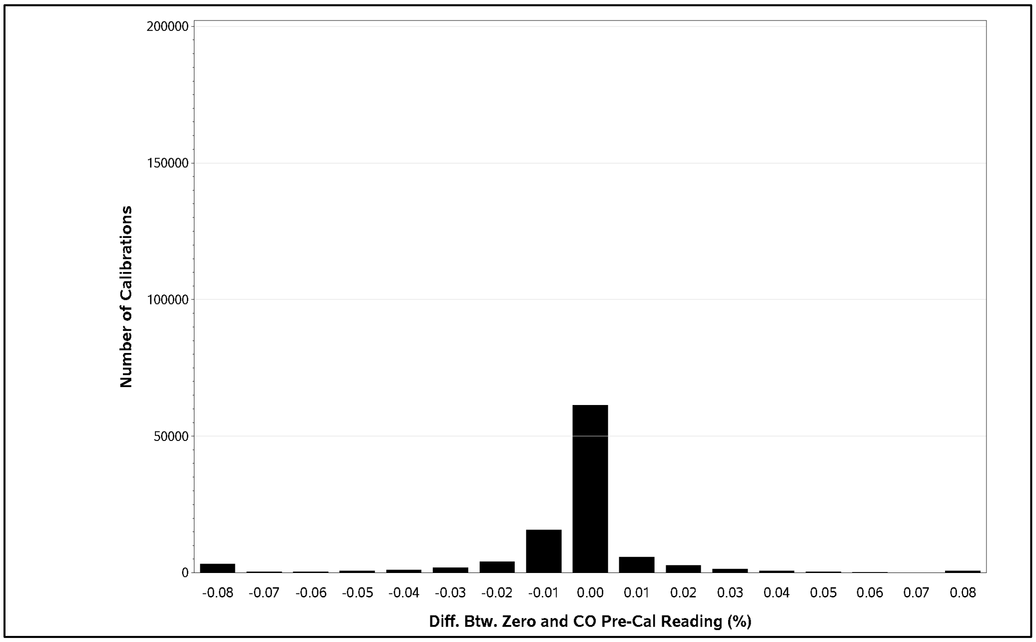


Figure III-15. Distribution of Difference Between Zero and NO Pre-Calibration Reading

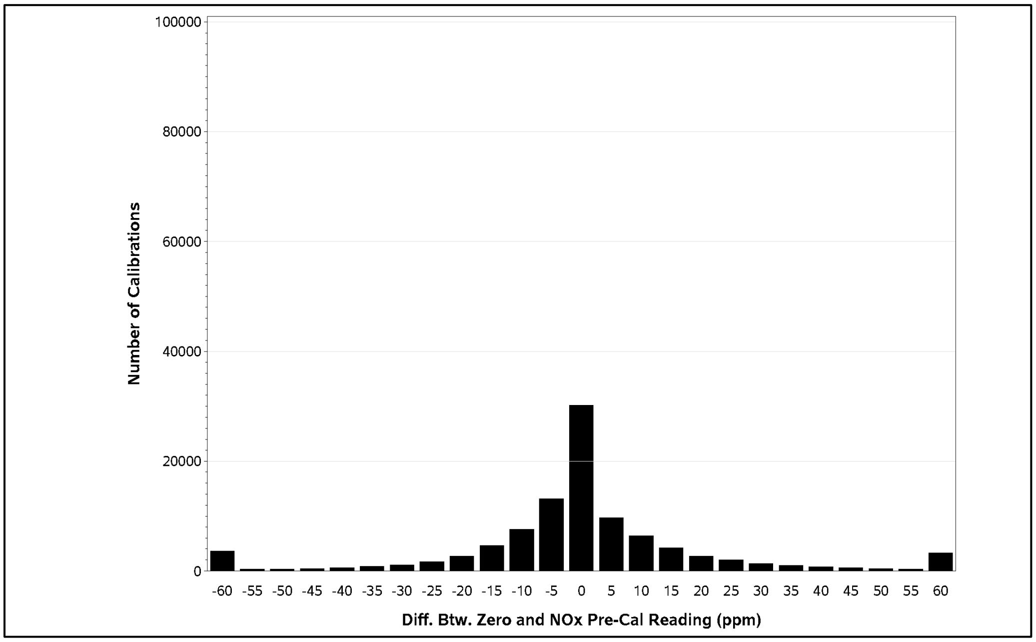


Figure III-16. Distribution of Difference Between Zero and CO_2 Pre-Calibration Reading

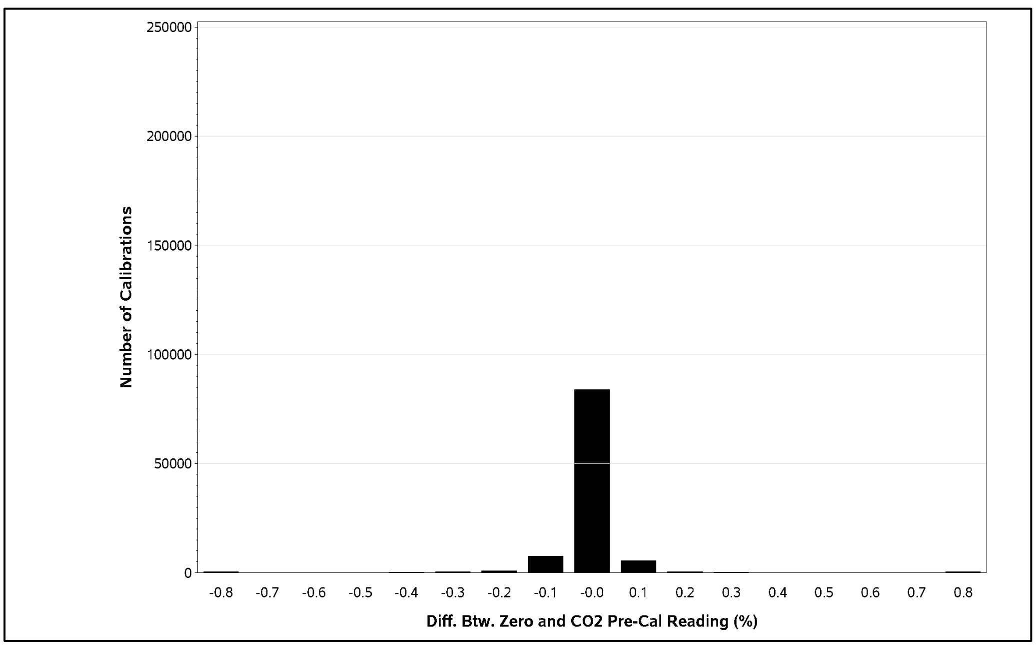


Figure III-17. Distribution of Difference Between Zero and O_2 Pre-Calibration Reading

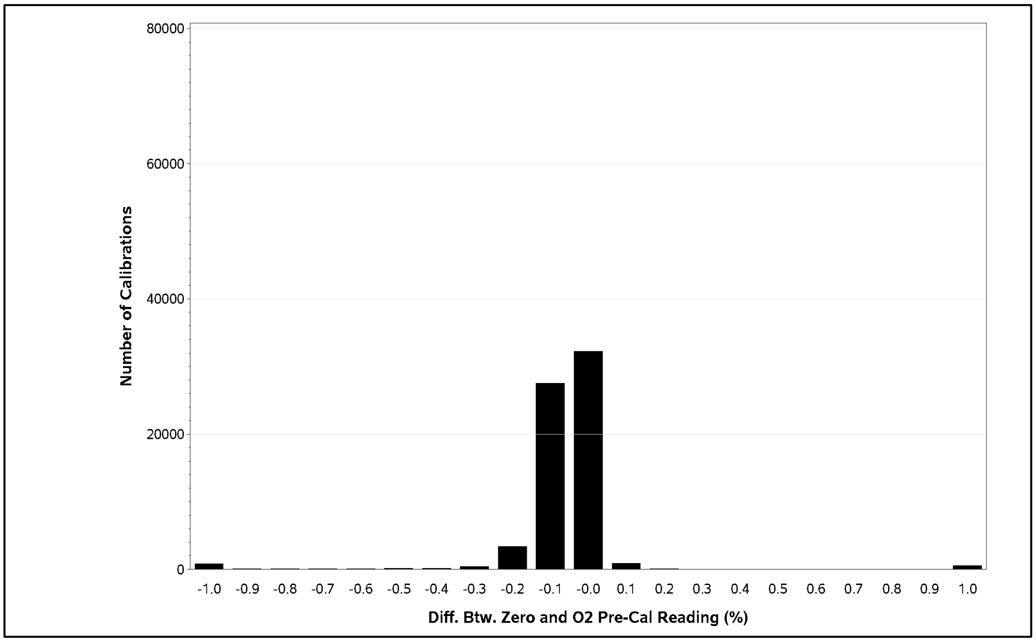


Figure III-18. Distribution of Difference Between 20.7% and O_2 Pre-Calibration Reading

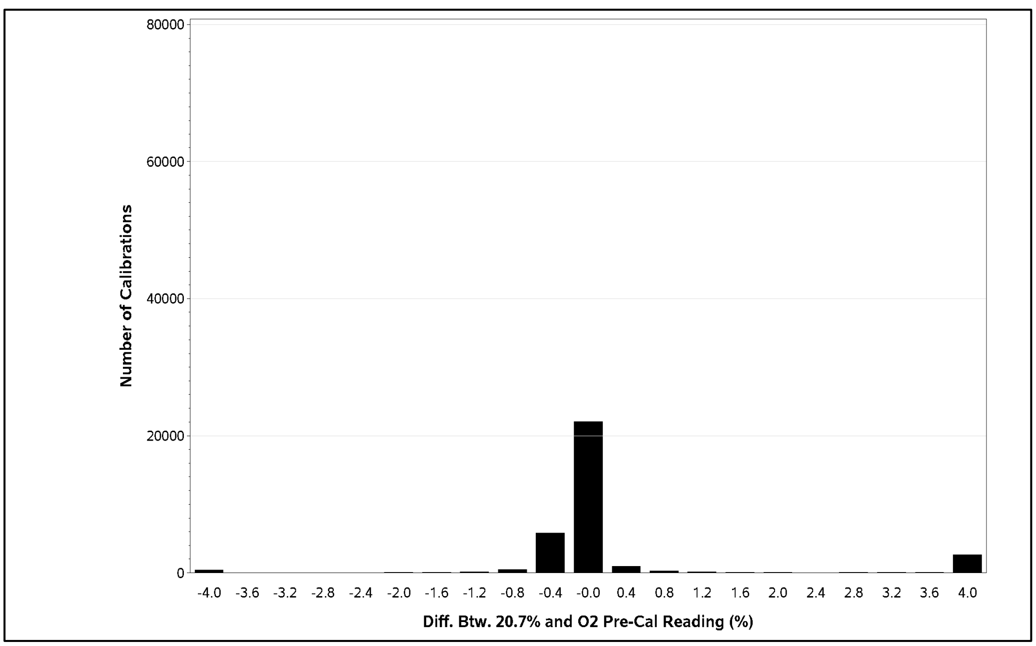


Figure III-19. Distribution of Difference Between Low-Span Bottle and HC Pre-Calibration Reading

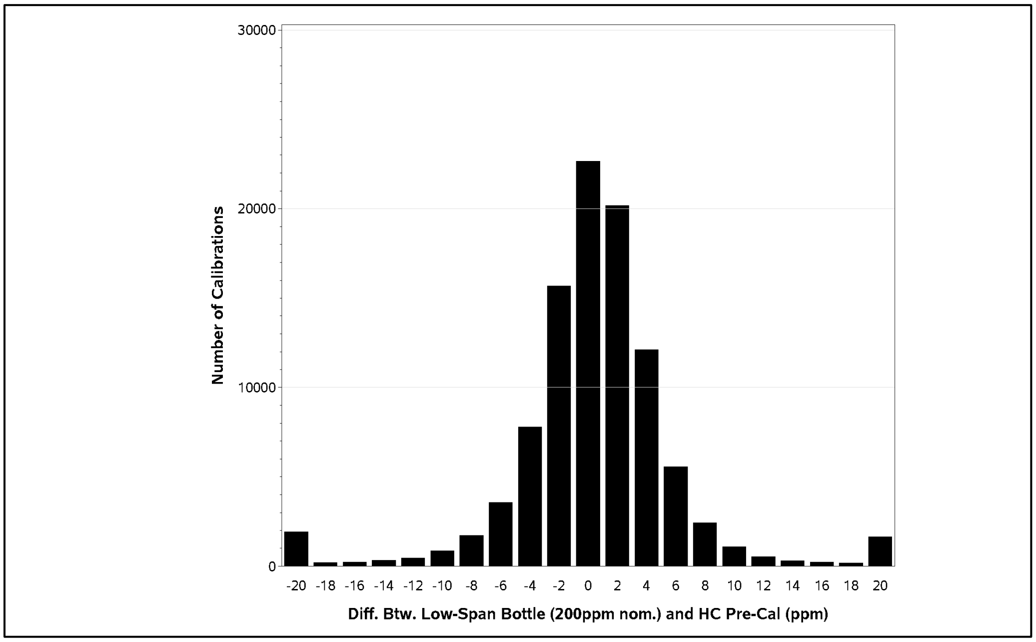


Figure III-20. Distribution of Difference Between Low-Span Bottle and CO Pre-Calibration Reading

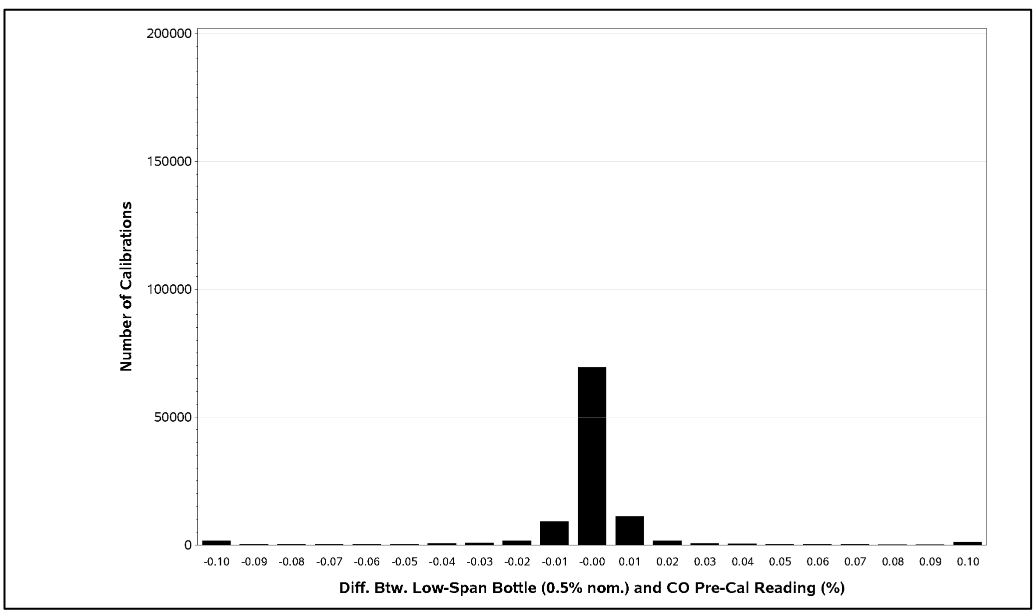


Figure III-21. Distribution of Difference Between Low-Span Bottle and NOx Pre-Calibration Reading

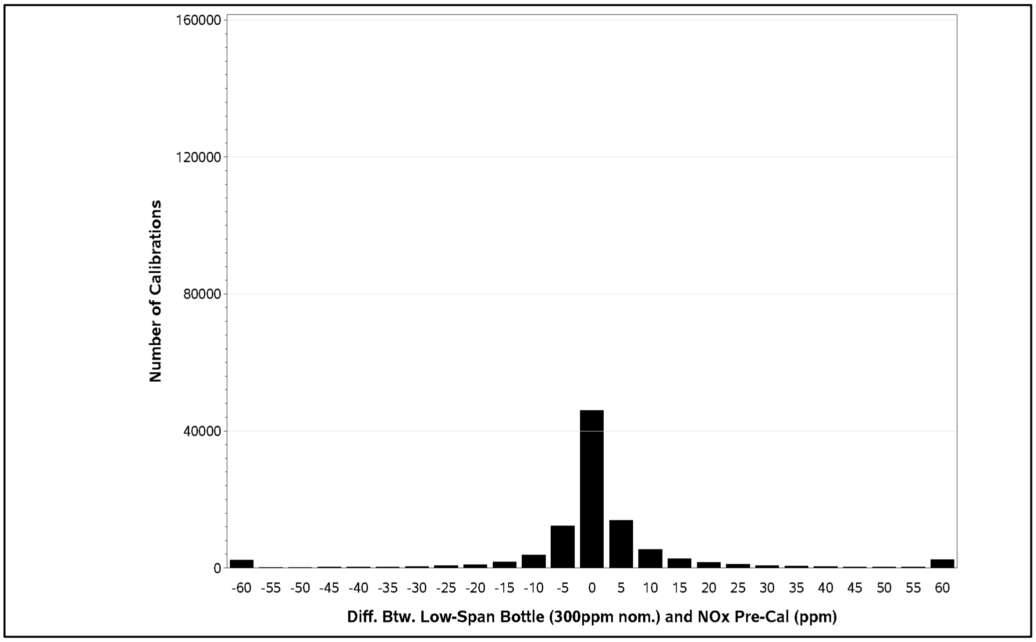


Figure III-22. Distribution of Difference Between Low-Span Bottle and CO_2 Pre-Calibration Reading

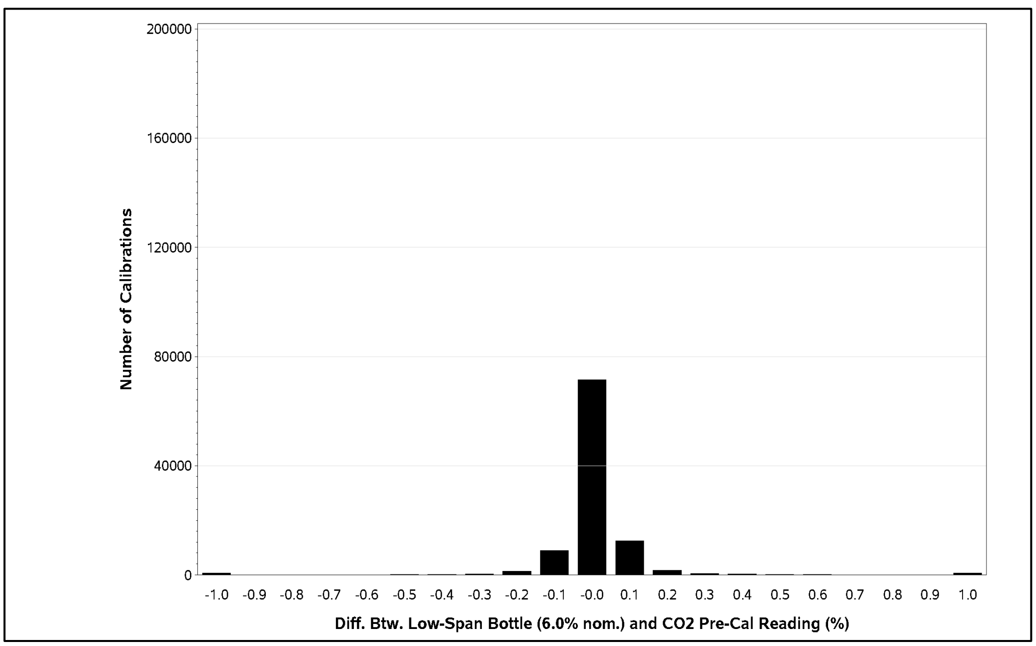


Figure III-23. Distribution of Difference Between Mid-Span Bottle and HC Pre-Calibration Reading

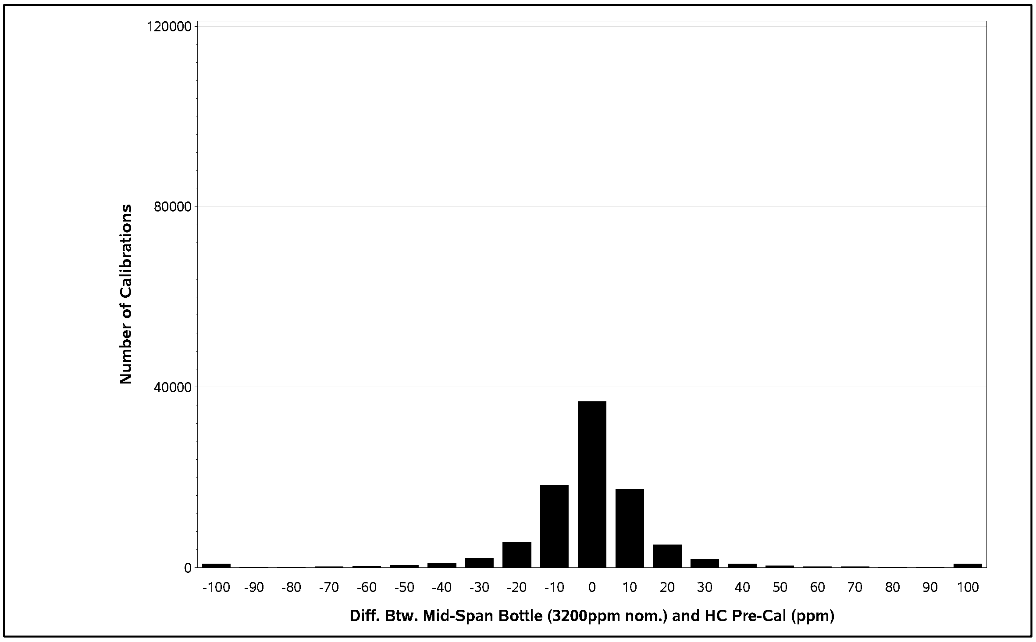


Figure III-24. Distribution of Difference Between Mid-Span Bottle and CO Pre-Calibration Reading

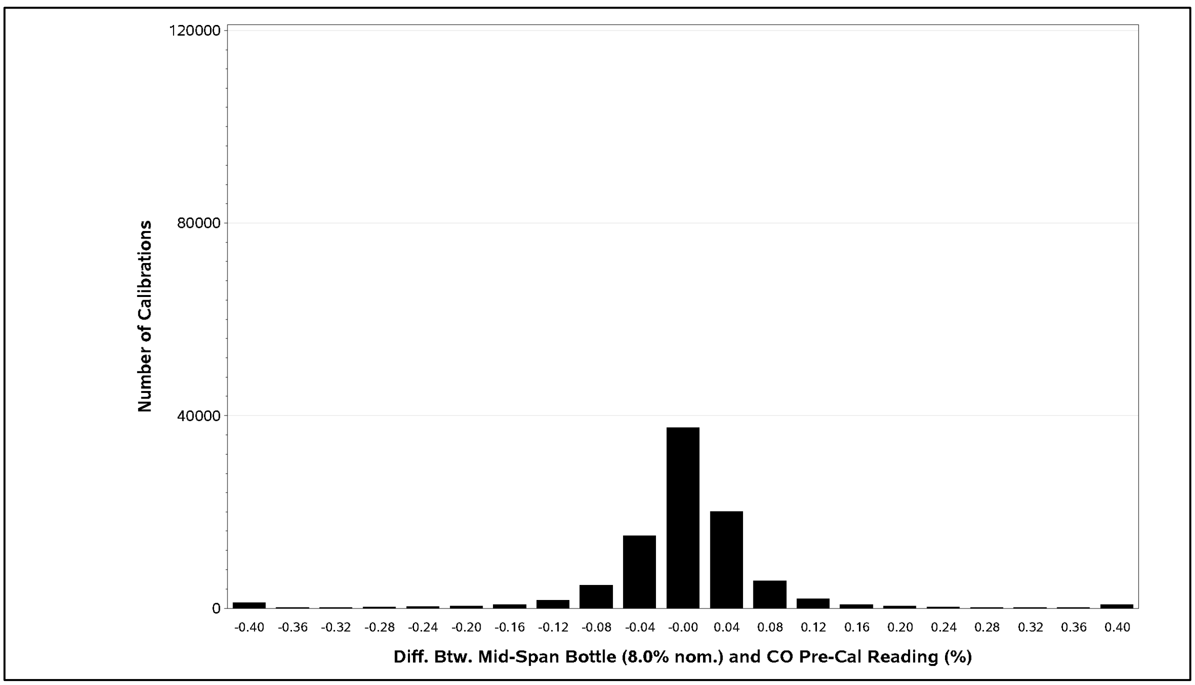


Figure III-25. Distribution of Difference Between Mid-Span Bottle and NOx Pre-Calibration Reading

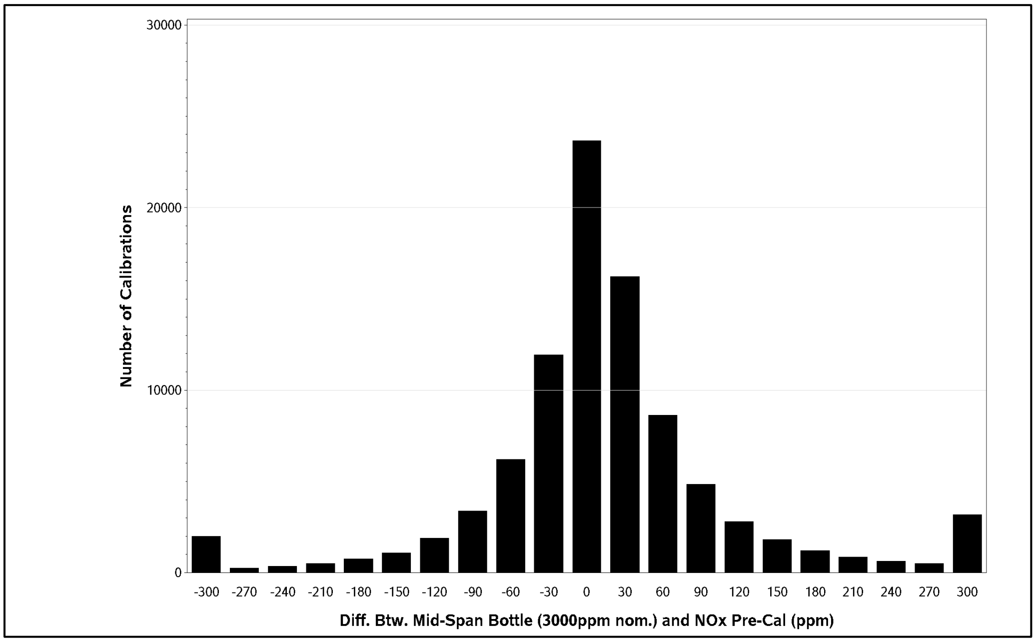


Figure III-26. Distribution of Difference Between Mid-Span Bottle and CO_2 Pre-Calibration Reading

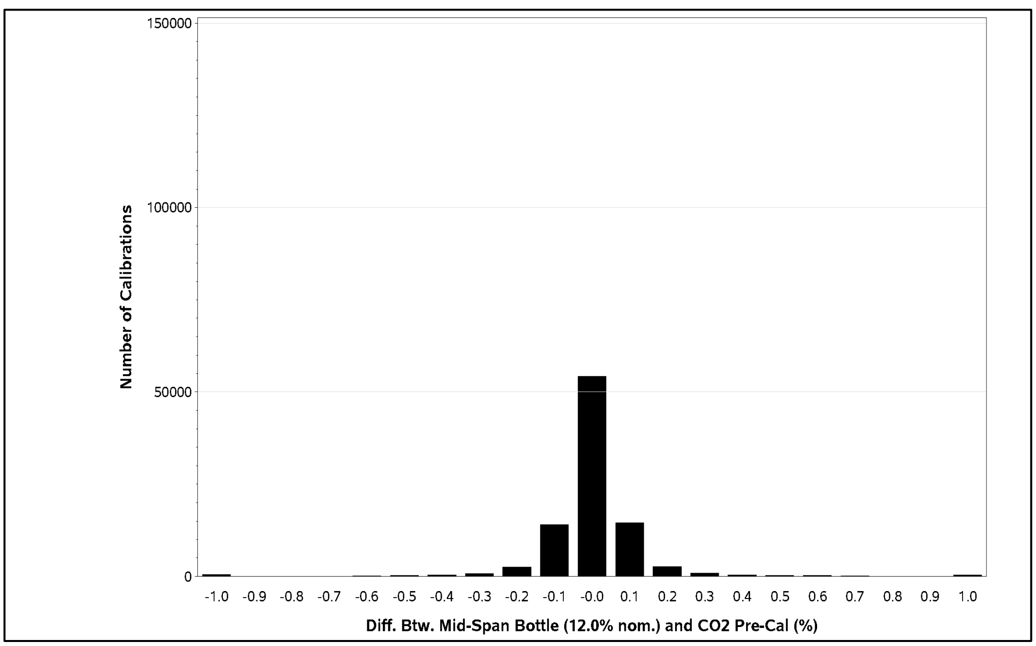


Table III-6 shows the specified value and tolerance for each gas type/concentration level, the total number of pre-calibration records available at that level, the percent of records for which values fell within the tolerance bounds, and finally, the difference from the specified value that would include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

Note that the number of total record counts varies somewhat by concentration level in Table III-6. About 100,300 records were available at the zero level, 99,700 records at the low-span level, and 92,800 at the mid-span level. The analyzer conducts the zero calibration, low-span, then high-span. Analyzers must pass the zero calibration to be eligible to try span calibrations and must pass zero and low span to be eligible to try high span calibrations. This results in more zero calibration records than low span calibration records, and more low span calibration records than high span calibration records.

For almost all gas type/concentration level combinations, more than 85% of pre-calibration records fell within the tolerance of the analyzer. The exception is the zero level HC, where only 41% 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% 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
			Number	Percent	
Zero Gas					
HC (ppm)	0 ± 4	100,302	41,606	41.5%	48
CO (%)	0.00 ± 0.02	100,302	89,487	89.2%	0.03
NOx (ppm)	0 ± 25	100,302	83,907	83.7%	40
CO_2 (%)	0.0 ± 0.3	100,302	98,774	98.5%	0.1
O_2 (%)	0.0 ± 0.1	66,679	60,615	90.9%	0.1
O_2 (%)	20.7 ± 1.04	33,623	29,695	88.3%	2.3
Low-Span Gas					
HC (ppm)	200 ± 6	99,687	86,088	86.4%	8
CO (%)	0.50 ± 0.02	99,694	89,603	89.9%	0.02
NOx (ppm)	300 ± 25	99,215	89,633	90.3%	25
CO_2 (%)	6.0 ± 0.3	99,689	96,747	97.0%	0.1
Mid-Span Gas					
HC (ppm)	3200 ± 160	92,849	91,923	99.0%	26
CO (%)	8.00 ± 0.24	92,853	89,515	96.4%	0.1
NOx (ppm)	3000 ± 150	92,703	77,607	83.7%	178
CO_2 (%)	12.00 ± 0.36	92,852	89,808	96.7%	0.2

Analyzer Dilution Correction Factors

For every ASM or TSI emissions test, a 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 NOx 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 agree with a relatively small tolerance.

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, DCF CO/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 are considered in this analysis.

In addition, many emissions analyzers also measure exhaust gas oxygen concentration with an electrochemical cell. Assuming an ambient air oxygen concentration of 20.9%, the exhaust oxygen measurement can also be used to estimate dilution in the exhaust. A 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% O_2. Typically, new vehicles with no exhaust system leaks and operating at stoichiometric air/fuel ratio have 0.0% tailpipe oxygen concentrations.

If CO, CO_2, and O_2 are measured correctly, the independent DCFs (CO/CO_2 and O_2) for each vehicle inspection should agree with each other. Previous studies have indicated that the difference between the two DCFs should be no larger than about ±0.14 [ERG, 2000].

Results

For this analysis, vehicle inspection records from the TIMS for vehicles tested in the DFW and HGB program areas were used. Results for 77,261 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 60,600 records for the ASM2525 test condition, 60,607 records for the ASM5015 test condition, 16,616 records for the low-idle TSI inspection, and 16,637 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 vs. 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 DCF O_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 are discussed in further detail in the O_2 Emissions Concentration Anomalies and CO_2 Emission Concentration Anomalies sub sections.

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

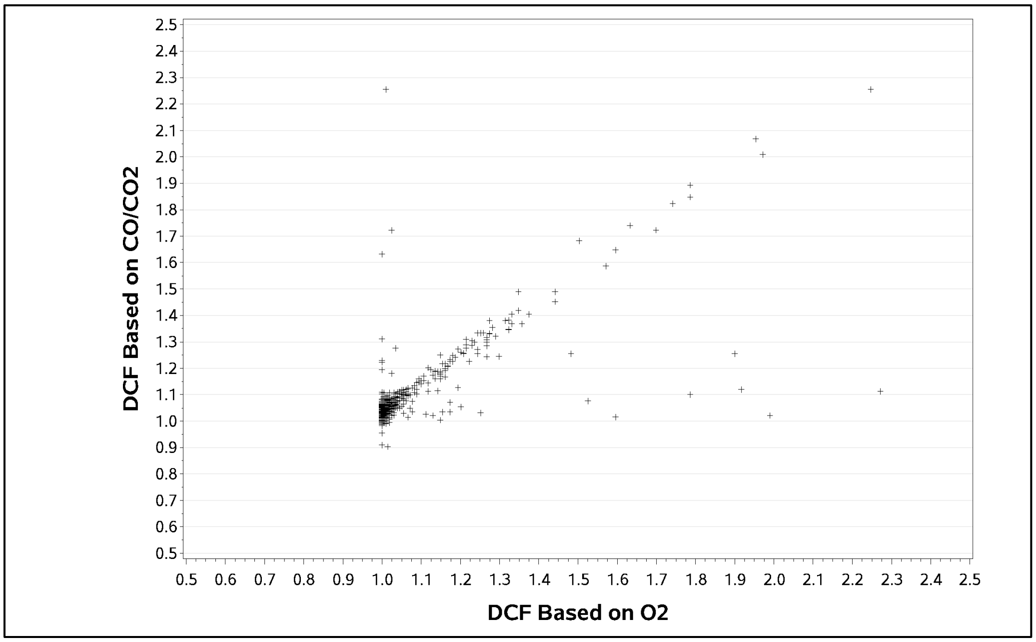


Figure III-28. Comparison of ASM5015 DCF CO/CO_2 and DCF O_2

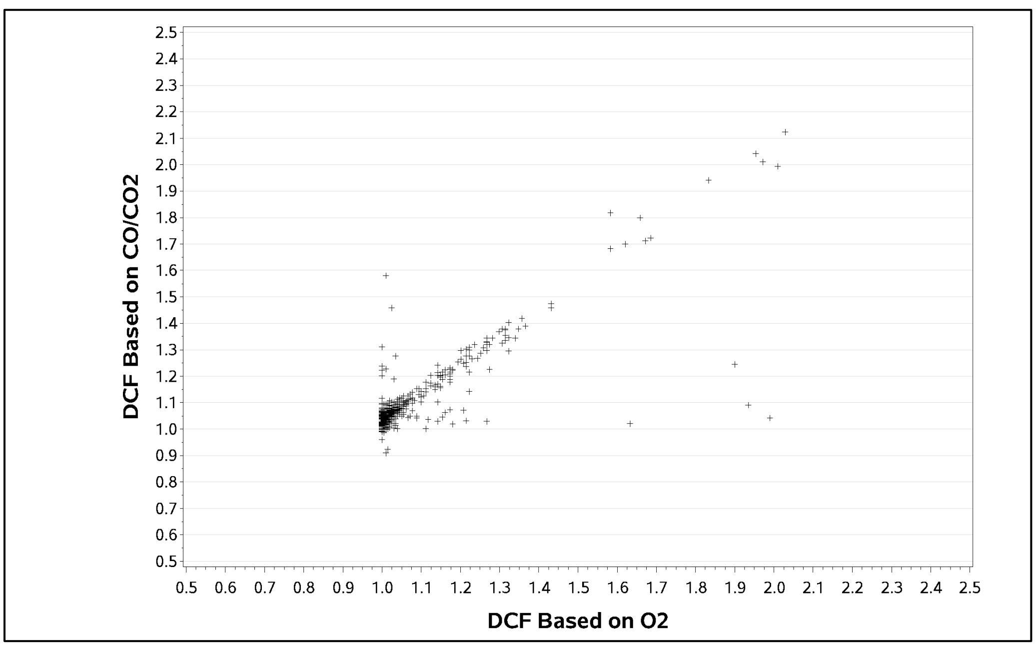


Figure III-29. Comparison of Low-Speed Idle TSI DCF CO/CO_2 and DCF O_2

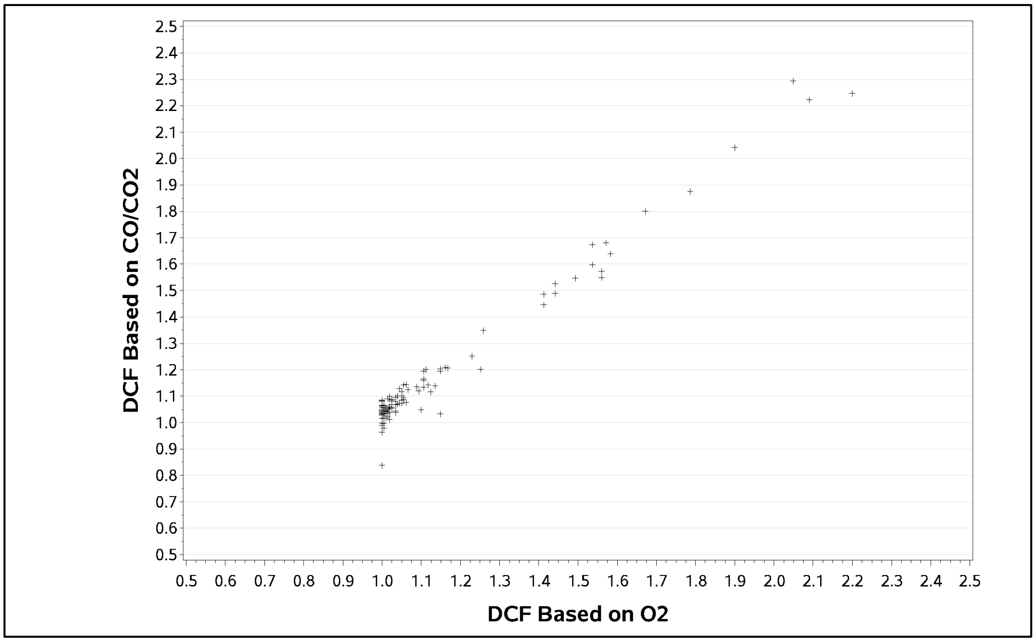
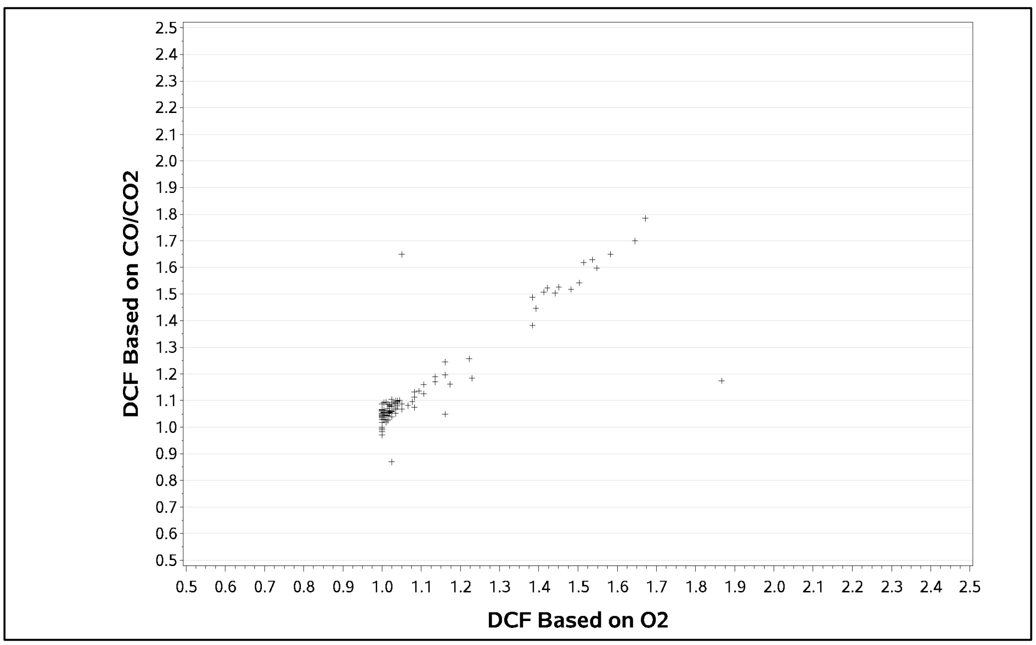


Figure III-30. Comparison of High-Speed Idle TSI DCF CO/CO_2 and DCF O_2



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% of records have a difference of less than 0.14. For the TSI inspection records, another 83% have a difference of less than 0.14.

Table III-7. Distribution of Differences Between DCFCO/CO_2 and DCF O_2

DCF Difference	ASM2525		ASM5015		TSI Low		TSI High	
<0.01	4,367	7.2%	4,849	8.0%	947	5.7%	822	4.9%
0.01-0.14	48,296	79.7%	47,749	78.8%	12,973	78.0%	13,280	79.8%
0.14-0.3	990	1.6%	943	1.6%	461	2.8%	313	1.9%
0.3-1.0	893	1.5%	926	1.5%	341	2.1%	318	1.9%
1-10	1,454	2.4%	1,529	2.5%	468	2.8%	449	2.7%
>10	4,601	7.6%	4,612	7.6%	1,435	8.6%	1,464	8.8%
Total	**60,601**	**100.0%**	**60,608**	**100.0%**	**16,625**	**100.0%**	**16,646**	**100.0%**

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 99% 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	56,362	93.0%	55,481	91.5%
0.01-0.14	3,693	6.1%	4,534	7.5%
0.14-0.3	119	0.2%	136	0.2%
0.3-1.0	138	0.2%	160	0.3%
1-10	118	0.2%	138	0.2%
>10	171	0.3%	159	0.3%
Total	**60,601**	**100.0%**	**60,608**	**100.0%**

The TIMS record for each inspection contains an identification (ID) 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) was compared by analyzer manufacturer, as shown in Table III-9. The ESP, JB, and Worldwide rates of differences of less than 0.14 are 85-98%, while the SE rates of differences of less than 0.14 are much lower (6%). This is probably due to erroneous O_2 concentrations for these SE 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	3,806	9.1%	0	0.0%	4	0.1%	1,039	6.6%
0.01-0.14	33,012	78.9%	93	84.5%	155	5.5%	14,489	91.4%
0.14-0.3	751	1.8%	0	0.0%	50	1.8%	142	0.9%
0.3-1.0	745	1.8%	0	0.0%	91	3.2%	90	0.6%
1-10	1,051	2.5%	0	0.0%	437	15.4%	41	0.3%
>10	2,456	5.9%	17	15.5%	2,095	74.0%	44	0.3%
Total	**41,821**	**100.0%**	**110**	**100.0%**	**2,832**	**100.0%**	**15,845**	**100.0%**

O_2 Emissions Concentration Anomalies

One factor that was found to cause problems with the DCF calculations was inaccuracy in the reported O_2 emissions concentrations. The tailpipe oxygen concentration for stoichiometric combustion and no air-in-leakage would be 0.0% O_2, while the ambient air concentration of O_2 is approximately 20.9%. The percent of otherwise valid inspection records that included O_2 concentrations greater than 20.5% is shown in Table III-10, for each test condition. From the table, 6-7% 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%) 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%	3,721	6.1%	3763	6.2%	1,212	7.3%	1242	7.5%
O_2 <20.5%	56,881	93.9%	56845	93.8%	15,413	92.7%	15,404	92.5%
Total	**60,602**	**100.0%**	**60,608**	**100.0%**	**16,625**	**100.0%**	**16,646**	**100.0%**

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 95% of inspection records, but only approximately 55% of suspicious O_2 concentrations.

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

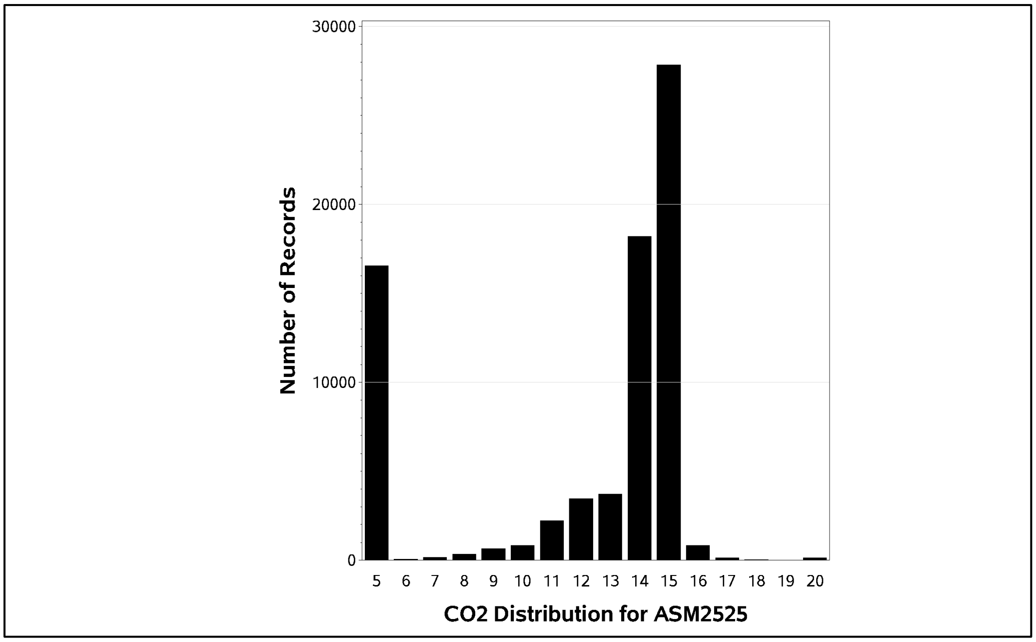
Analyzer Mfg. ID	O_2 >20.5%	O_2 <20.5%	Total
ESP	2,021	39,800	41,821
	4.8%	95.2%	100.0%
JB	17	93	110
	15.5%	84.5%	100.0%
SE	1,684	1,148	2,832
	59.5%	40.5%	100.0%
WW	41	15,804	15,845
	0.3%	99.7%	100.0%
Totals	**3,763**	**56,845**	**60,608**
	6.2%	**93.8%**	**100.0%**

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% CO_2. CO_2 values lower than 15.6% can occur because of air-in-leakage or because some of the carbon is in the form of CO or HC, but any CO_2 values higher than 15.6% 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%, as expected. However, a small fraction of CO_2 values exceeds 16.5%, for 0.5% of ASM2525 inspection records. These records were investigated further.

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



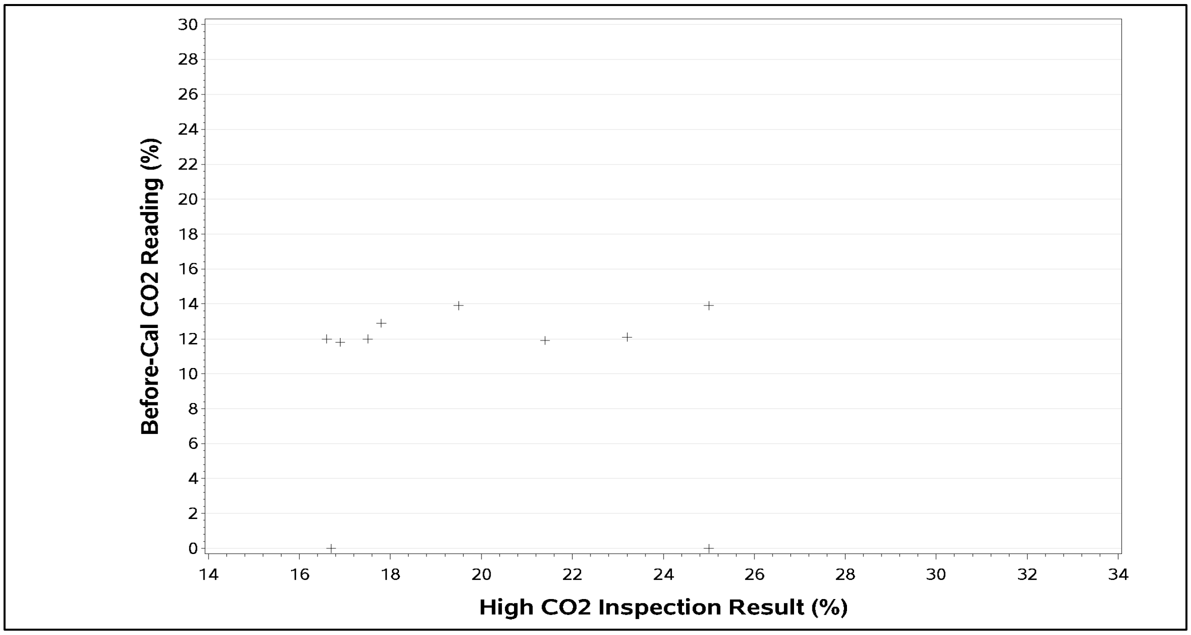
The rate of high CO_2 concentrations was found to vary slightly among the different analyzer manufacturers, as shown in Table III-12, although the differences were not as pronounced as those found for the suspicious O_2 concentrations.

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	215	52,606	52,821
	0.4%	99.6%	100.0%
JB	0	140	140
	0.0%	100.0%	100.0%
SE	56	3,644	3,700
	1.5%	98.5%	100.0%
WW	29	20,552	20,581
	0.1%	99.9%	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% 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% is that the CO/CO_2-based DCF will be less than one, indicating a "concentration" condition, rather than a dilution condition. Records with very high CO concentrations will also have a DCF of less than one. Due to the small number of records now that very few vehicles receive tailpipe test, these few discrepancies should not be a concern to the program.

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, NOx, 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% 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-span and mid-span gas audits are listed in Table III-13 (these are the same as the nominal bottle gas values for low- and mid-span calibrations). Actual labeled bottle gas concentrations may vary up to 5% from the nominal values, so the labeled bottle gas values are recorded in the analyzer and transmitted to the TIMS for each audit.

Table III-13. 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
NOx (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 four audits per analyzer. A frequency distribution of the number of audits per analyzer is shown in Table III-14. As can be seen from the table, 1,101 of the 1,373 analyzers, or approximately 80%, received four or more audits, and 94% received two or more audits. Of these, 1,150 of the analyzers (84%) received two or more passing audits. Some stations may not have been operating the entire period, so it may have been appropriate for them to receive fewer than four audits, But 94% of the analyzers with fewer than four audits were enrolled in the TIMS by January 1, 2018. Many of the analyzers received more than four audits; in fact, about 36% 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-14. Number of Gas Audits per Analyzer Over a Two-Year Period

Number of Audits	Number of Analyzers	Percent of Analyzers
1	89	6.5%
2	78	5.7%
3	105	7.6%
4	120	8.7%
5	144	10.5%
6	162	11.8%
7	181	13.2%
8	195	14.2%
More than 8	299	21.8%
Total	**1,373**	**100.0%**

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

Difference (%) = 100 x [(Reading – Bottle Value) / Bottle Value]

The distributions of percentage differences between readings and bottle gas values for CO, HC, CO_2, and NO_X at the low- and mid-span levels are shown in Figure III-33 through Figure III-40. In almost all the figures, most readings fall between ± 4% 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-33. Percent Difference Between Reading and Bottle Gas, Low-Span CO

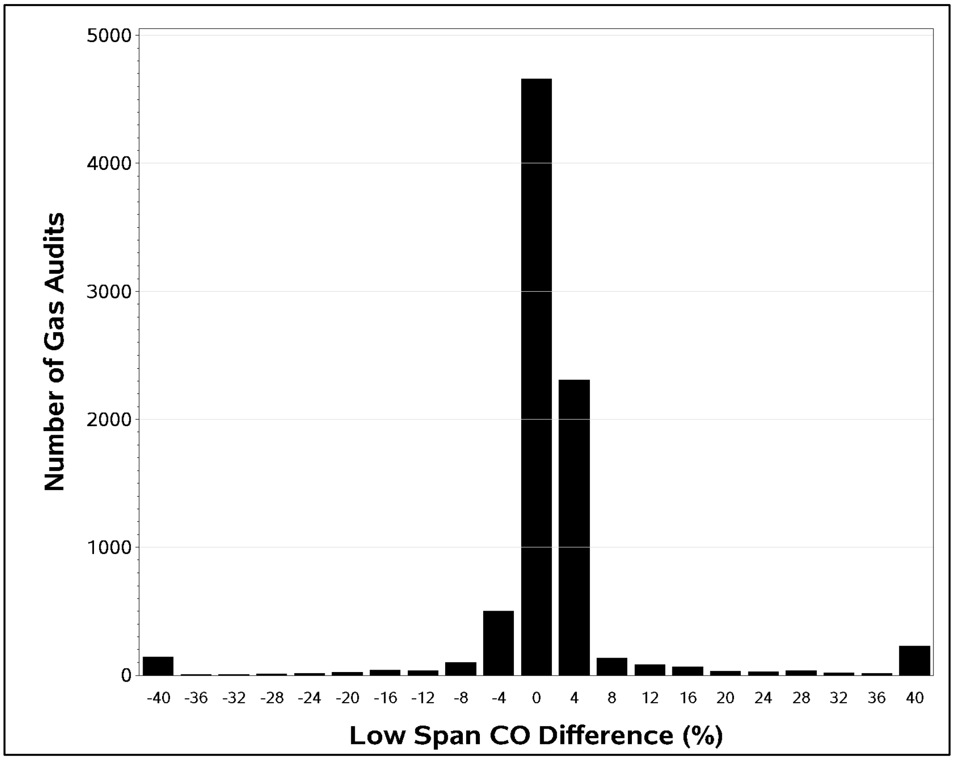


Figure III-34. Percent Difference Between Reading and Bottle Gas, Low-Span HC

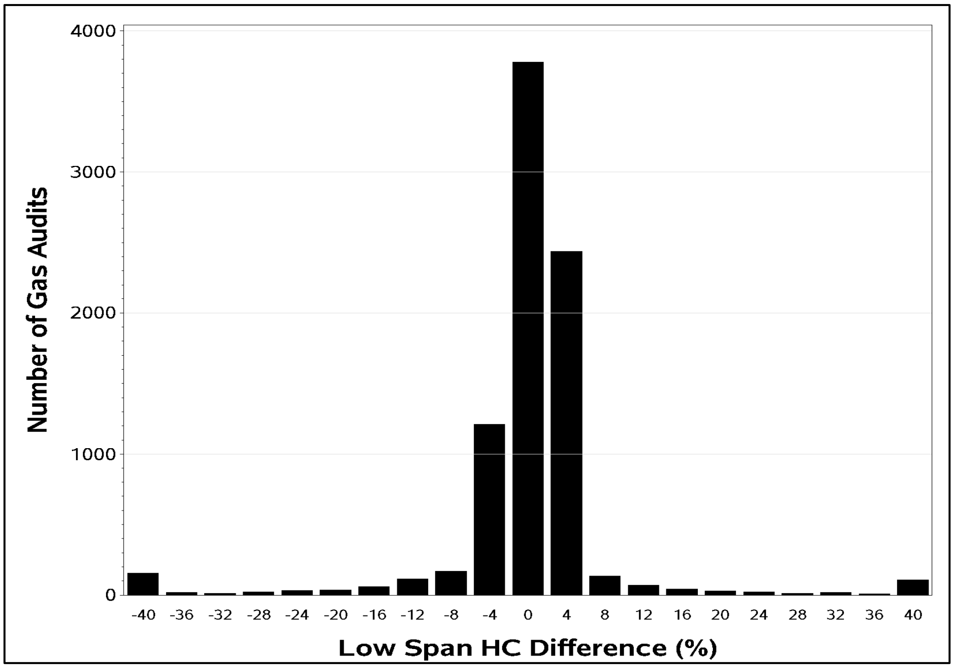


Figure III-35. Percent Difference Between Reading and Bottle Gas, Low-Span CO_2

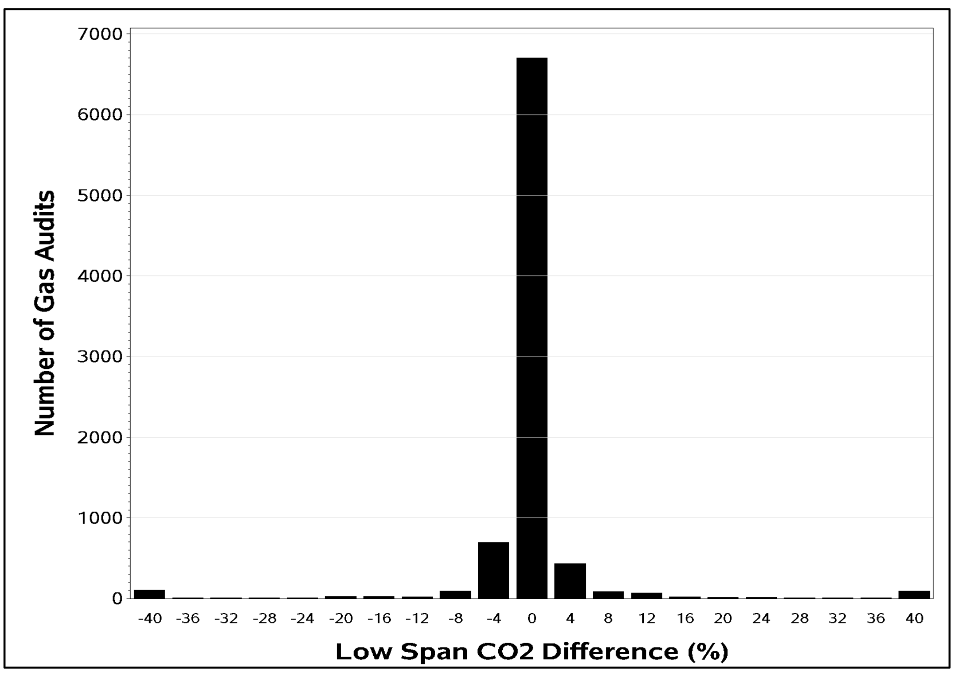


Figure III-36. Percent Difference Between Reading and Bottle Gas, Low-Span NO_X

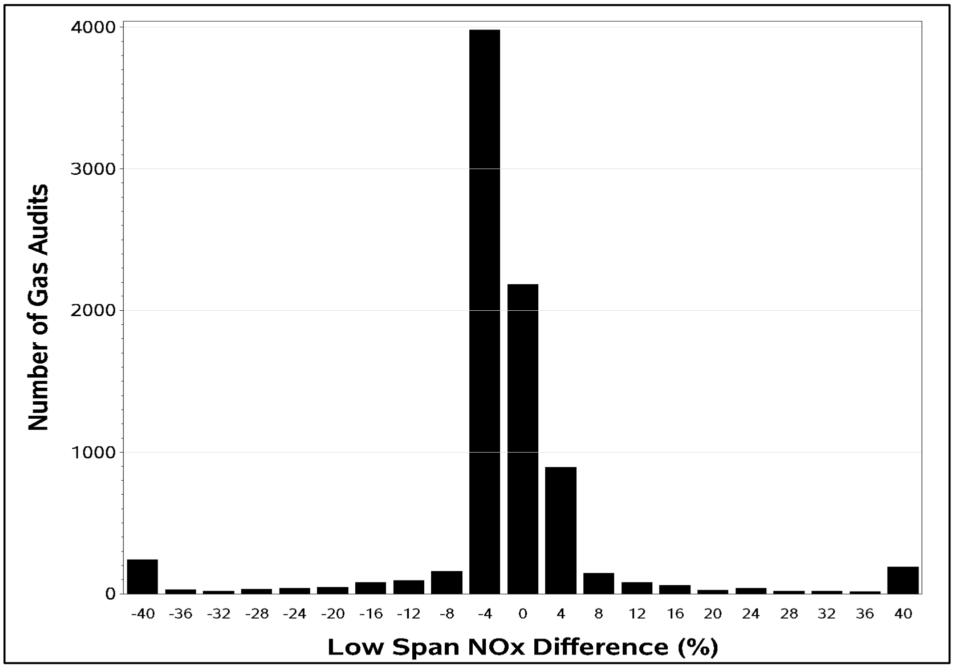


Figure III-37. Percent Difference Between Reading and Bottle Gas, Mid-Span CO

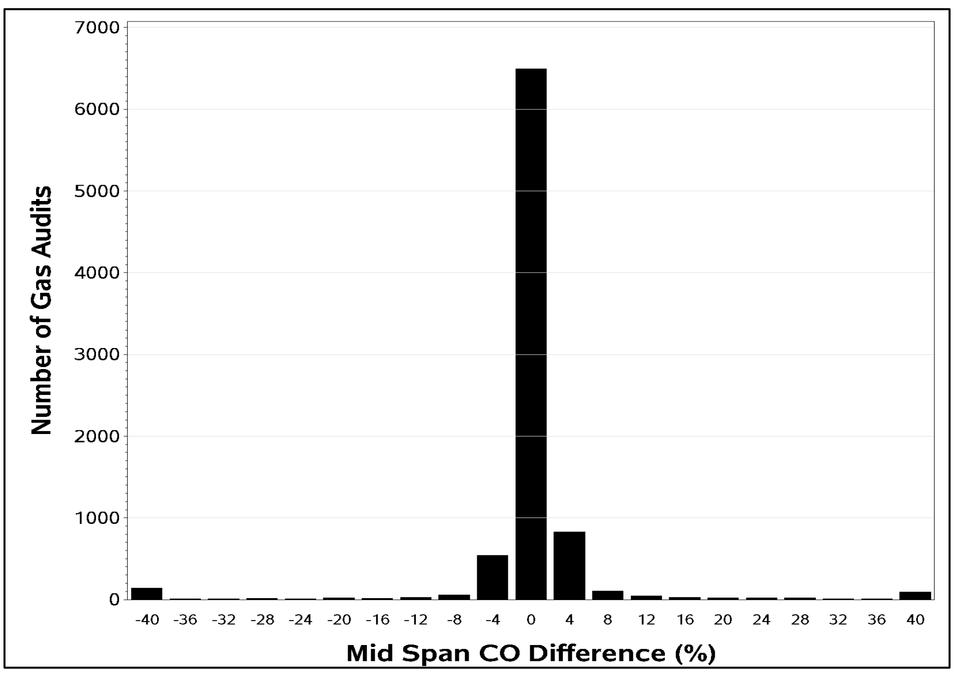


Figure III-38. Percent Difference Between Reading and Bottle Gas, Mid-Span HC

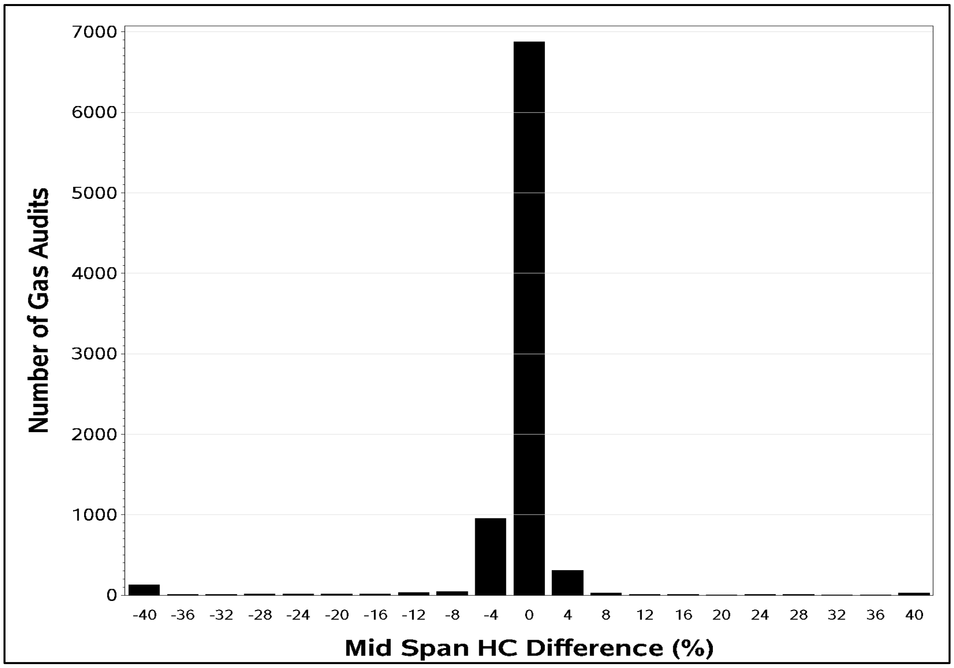


Figure III-39. Percent Difference Between Reading and Bottle Gas, Mid-Span CO_2

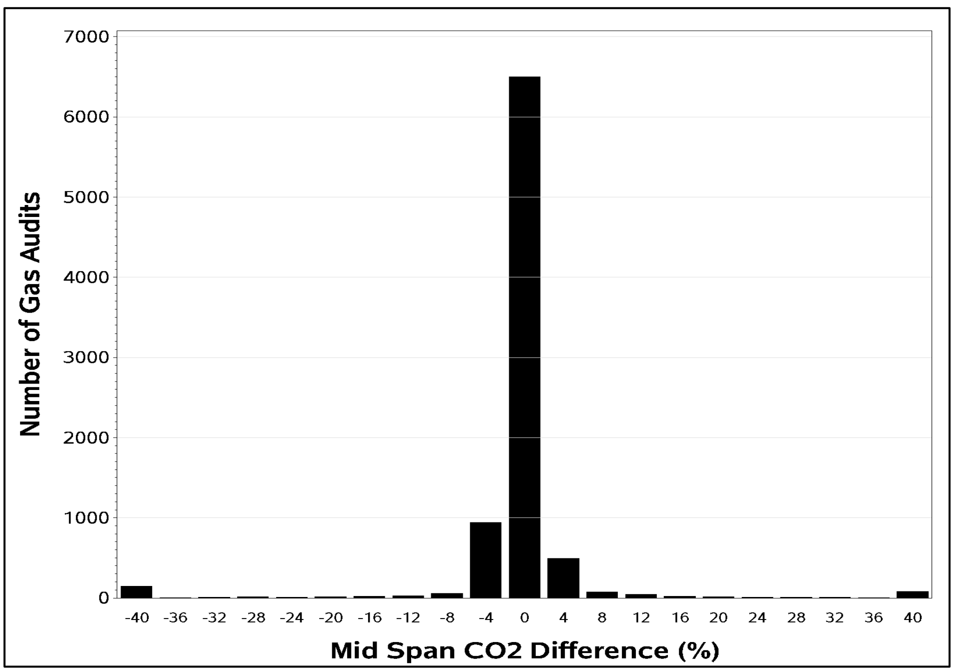


Figure III-40. Percent Difference Between Reading and Bottle Gas, Mid-Span NO_X

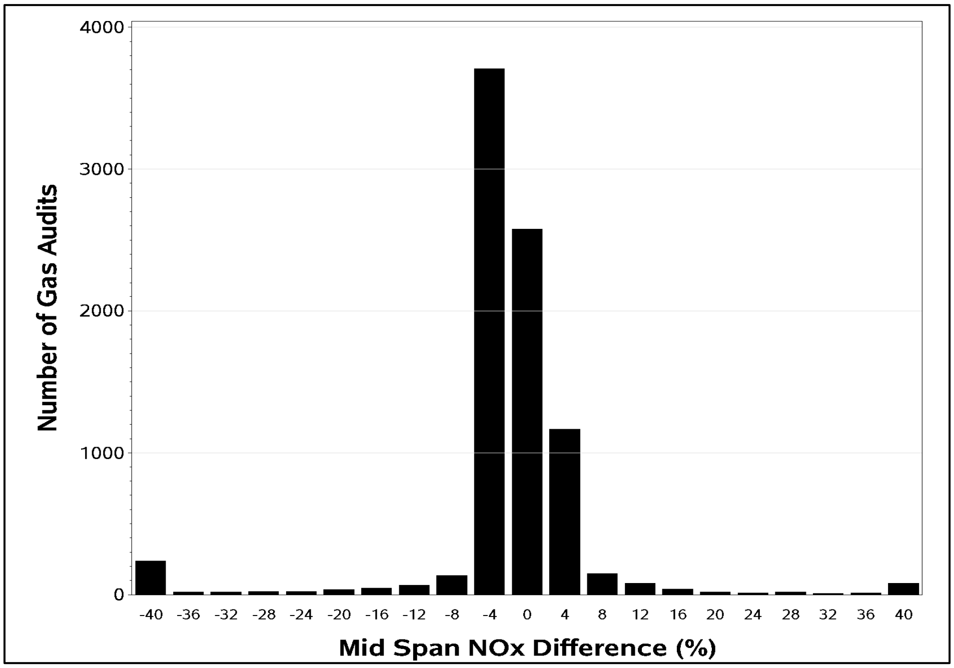


Table III-15 shows pass/fail results for gas audits at the low- and mid-span levels. The table includes the pass/fail results that were recorded in the TIMS as well pass/fail results calculated by ERG for this analysis (based on the labeled bottle gas value entered in the TIMS, the measured emissions concentration, and a 5.5% tolerance). Table III-15 shows 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 ten 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% different from the labeled bottle gas value, indicating that the discrepancy was probably caused by a slight difference in the rounding of results.

Table III-15. Span Gas Pass/Fail Results from TIMS Compared to Calculated Results

Calculated Results	TIMS Result			
	Pass	Fail	No Result	Total
Pass	6,112	0	0	6,112
Fail	10	2,463	0	10
Combined Pass & Missing	1	0	1	1
Entirely Missing	0	0	0	0
Total	**6,123**	**2,463**	**1**	**8,486**

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 taking place after the failed audits. In 34% of cases, an analyzer that failed an audit was calibrated or re-audited and passed within the next 60 minutes. In an additional 11% of cases, the failing analyzer was calibrated or re-audited and passed within 24 hours, and another 28% of failing analyzers were calibrated or re-audited and passed within one week. The remaining 27% 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 following list contains the calibration/verification requirements.

- 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 was 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 2018 or 2019 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-16. 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). 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, 6.5% of ASM inspections were performed at times that the dynamometer was overdue for calibration and should have been locked out, and 0.7% of ASM and TSI inspections were performed at times that the analyzer was overdue for calibration and should have been locked out. To reiterate, the table includes information for both ASM and TSI inspections. The first two rows of the table, for Span Gas Calibrations and Leak Checks, apply to both ASM and TSI inspections. The third row of the table, for Dynamometer Checks, applies only to ASM inspections.

Table III-16. 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	524	0.7%	78,412
Leak Check	135	0.2%	78,412
Dynamometer Check	3,971	6.5%	61,445

In order to determine why this occurred, 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-17. 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-17. 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	53,443	99.6%	0	0.0%	204	0.4%	0	0.0%	53,647	100.0%
JB	139	99.3%	0	0.0%	1	0.7%	0	0.0%	140	100.0%
SE	3,149	84.7%	463	12.4%	107	2.9%	3	0.0%	3,719	100.0%
WW	17,199	82.3%	3,469	16.6%	199	1.0%	39	0.2%	20,906	100.0%
Total for all analyzers	**73,930**	**94.3%**	**3,932**	**5.0%**	**511**	**0.7%**	**42**	**0.0%**	**78,412**	**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 rates of failure to communicate by:

- analyzer manufacturer;
- vehicle make;
- vehicle model; and
- vehicle model year.

Results are presented for the following four subsections.

Fourteen of the 18,096,110 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 14 records, 11 had an overall passing result (a "P" in the "OVERALL_RESULTS" field) and three had a null value in the "OVERALL_RESULTS" field. There were also 548,455 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 results, leaving 17,547,641 OBD records in the dataset.

Communication Rates by Vehicle Model Year - Table III-18 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, 94,587 OBD tests were conducted on model year 1996 vehicles, and only 229 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 99.9%.

Table III-18. 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 Year
	Count	Percent	Count	Percent	Count	Percent	
1996	43	0.05%	229	0.24%	94,315	99.71%	94,587
1997	64	0.04%	301	0.20%	146,774	99.75%	147,139
1998	71	0.04%	369	0.20%	185,214	99.76%	185,654
1999	92	0.04%	491	0.19%	252,871	99.77%	253,454
2000	108	0.03%	632	0.18%	341,548	99.78%	342,288
2001	147	0.03%	816	0.19%	425,548	99.77%	426,511
2002	140	0.03%	942	0.18%	512,100	99.79%	513,182
2003	198	0.03%	1,245	0.21%	578,243	99.75%	579,686
2004	213	0.03%	1,423	0.22%	658,363	99.75%	659,999
2005	246	0.03%	1,375	0.19%	734,341	99.78%	735,962
2006	241	0.03%	1,330	0.16%	823,083	99.81%	824,654
2007	211	0.02%	1,237	0.12%	1,013,868	99.86%	1,015,316
2008	154	0.01%	988	0.10%	1,026,054	99.89%	1,027,196
2009	108	0.02%	625	0.09%	709,738	99.90%	710,471
2010	102	0.01%	656	0.08%	867,807	99.91%	868,565
2011	111	0.01%	884	0.09%	977,522	99.90%	978,517
2012	120	0.01%	994	0.09%	1,157,434	99.90%	1,158,548
2013	103	0.01%	848	0.06%	1,372,143	99.93%	1,373,094
2014	122	0.01%	867	0.06%	1,470,910	99.93%	1,471,899
2015	134	0.01%	959	0.06%	1,640,100	99.93%	1,641,193
2016	109	0.01%	897	0.06%	1,499,095	99.93%	1,500,101
2017	77	0.01%	513	0.06%	870,626	99.93%	871,216
2018	20	0.01%	85	0.06%	146,255	99.93%	146,360
2019	1	0.00%	16	0.07%	21,471	99.92%	21,488
2020	0	0.00%	3	0.53%	558	99.47%	561
Total	**2,935**	**0.02%**	**18,725**	**0.11%**	**17,525,981**	**99.88%**	**17,547,641**

Communication Rates by Equipment Manufacturer –Table III-19 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-20 provides a summary of communication rates among the various vehicle makes. 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-21 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-21 is very long, in the text below, only vehicle makes through Audi are listed. The full table is provided in Appendix B.

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%, and all were below 0.8% except for Winnebago and Aston Martin. All other vehicles were below 0.5%.

Table III-19. 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	2,075	0.02%	14,043	0.11%	12,814,056	99.87%	12,830,174	73.12%
JB	3	0.07%	15	0.37%	3,983	99.55%	4,001	0.02%
SE	316	0.06%	1,066	0.19%	549,078	99.75%	550,460	3.14%
WW	541	0.01%	3,601	0.09%	4,158,864	99.90%	4,163,006	23.72%
Total	**2,935**	**0.02%**	**18,725**	**0.11%**	**17,525,981**	**99.88%**	**17,547,641**	**100.00%**

Table III-20. 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	28	0.01%	139	0.06%	234,943	99.93%	235,110	1.40%
AUDI	10	0.01%	95	0.08%	122,215	99.91%	122,320	0.73%
BMW	53	0.02%	473	0.14%	344,677	99.85%	345,203	2.05%
BUICK	27	0.01%	202	0.11%	180,648	99.87%	180,877	1.08%
CADILLAC	63	0.02%	428	0.16%	271,643	99.82%	272,134	1.62%
CHEVROLET	525	0.02%	3,163	0.14%	2,327,915	99.84%	2,331,603	13.86%
CHRYSLER	55	0.02%	264	0.10%	260,759	99.88%	261,078	1.55%
DODGE	168	0.02%	893	0.10%	886,885	99.88%	887,946	5.28%
FORD	512	0.02%	3,197	0.13%	2,411,749	99.85%	2,415,458	14.36%
GEO	2	0.17%	3	0.25%	1,206	99.59%	1,211	0.01%
GMC	114	0.02%	749	0.14%	527,763	99.84%	528,626	3.14%
HONDA	200	0.01%	989	0.07%	1,479,317	99.92%	1,480,506	8.80%
HUMMER	10	0.08%	27	0.21%	13,017	99.72%	13,054	0.08%
HYUNDAI	52	0.01%	433	0.09%	503,058	99.90%	503,543	2.99%
INFINITI	19	0.01%	180	0.07%	240,966	99.92%	241,165	1.43%
ISUZU	1	0.01%	50	0.34%	14,849	99.66%	14,900	0.09%
JAGUAR	8	0.02%	53	0.14%	36,634	99.83%	36,695	0.22%
JEEP	64	0.01%	481	0.09%	510,913	99.89%	511,458	3.04%
KIA	39	0.01%	240	0.06%	408,253	99.93%	408,532	2.43%
LAND ROVER	10	0.02%	64	0.11%	58,938	99.87%	59,012	0.35%
LEXUS	67	0.01%	502	0.09%	560,441	99.90%	561,010	3.34%
LINCOLN	56	0.04%	292	0.20%	142,283	99.76%	142,631	0.85%
MASERATI	2	0.04%	8	0.14%	5,576	99.82%	5,586	0.03%
MAZDA	57	0.02%	523	0.18%	288,561	99.80%	289,141	1.72%
MERCEDES	18	0.02%	132	0.18%	73,035	99.80%	73,185	0.44%
MERCURY	58	0.02%	327	0.09%	377,583	99.90%	377,968	2.25%
MITSUBISHI	42	0.04%	225	0.20%	114,225	99.77%	114,492	0.68%
NISSAN	161	0.01%	1,026	0.08%	1,354,191	99.91%	1,355,378	8.06%
OLDSMOBILE	2	0.02%	18	0.17%	10,514	99.81%	10,534	0.06%
PLYMOUTH	1	0.03%	6	0.16%	3,725	99.81%	3,732	0.02%
PONTIAC	27	0.03%	156	0.17%	89,758	99.80%	89,941	0.53%
PORSCHE	19	0.04%	169	0.32%	52,396	99.64%	52,584	0.31%
RAM	3	0.01%	19	0.09%	21,147	99.90%	21,169	0.13%
SAAB	1	0.02%	8	0.12%	6,650	99.86%	6,659	0.04%
SATURN	34	0.06%	242	0.41%	59,361	99.54%	59,637	0.35%

Table III-20. 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
SCION	7	0.01%	80	0.11%	70,677	99.88%	70,764	0.42%
SUBARU	13	0.01%	104	0.09%	116,682	99.90%	116,799	0.69%
SUZUKI	8	0.04%	43	0.22%	19,492	99.74%	19,543	0.12%
TOYOTA	237	0.01%	1,724	0.08%	2,279,113	99.91%	2,281,074	13.56%
VOLKSWAGEN	47	0.02%	303	0.13%	238,043	99.85%	238,393	1.42%
VOLVO	7	0.01%	65	0.09%	75,803	99.91%	75,875	0.45%
OTHER	107	0.02%	576	0.08%	701,657	99.90%	702,340	4.18%
Total	**2,827**	**0.02%**	**18,095**	**0.11%**	**16,795,604**	**99.88%**	**16,816,526**	**100.00**

Table III-21. OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
ACUR								
	4	0.03%	9	0.07%	12,357	99.89%	12,370	0.09%
3.2TL	3	0.05%	6	0.11%	5,564	99.84%	5,573	0.04%
CL	1	0.07%	1	0.07%	1,362	99.85%	1,364	0.01%
MDX	6	0.01%	25	0.04%	57,139	99.95%	57,170	0.39%
RDX	1	0.00%	12	0.04%	32,301	99.96%	32,314	0.22%
RL	1	0.03%	2	0.05%	3,681	99.92%	3,684	0.03%
RSX	1	0.03%	3	0.08%	3,733	99.89%	3,737	0.03%
RSX Type-S	1	0.05%	2	0.11%	1,840	99.84%	1,843	0.01%
TL	4	0.01%	37	0.08%	44,303	99.91%	44,344	0.31%
TLX	1	0.01%	9	0.06%	14,799	99.93%	14,809	0.10%
TSX	2	0.01%	12	0.04%	27,776	99.95%	27,790	0.19%
AUDI								
A4	1	0.04%	8	0.29%	2,744	99.67%	2,753	0.02%
A4/S4	1	0.00%	19	0.07%	26,649	99.93%	26,669	0.18%
A4/S4 Cabriolet	1	0.07%	8	0.58%	1,363	99.34%	1,372	0.01%

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, 2018 and December 31, 2019. 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. Downloaded OBD test pass/fail results are not enforced for HD vehicles (i.e., vehicles with a GVWR 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 one 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, 16,857,257 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-22.

Table III-22. Comparison of DLC Communication Status with Overall OBD Test Results

DLC Communication Status	Overall OBD Test Results	
	Fail	Pass
"D" (damaged)	1,124	0
"I" (DLC is inaccessible)	586	0
"L" (inspector cannot find DLC)	1,060	67
"N" (connected but will not communicate)	17,883	1
Total count of "D", "I", "L", and "N" Tests	20,653	68
"P" (communication successful)	645,637	16,190,899
Total	**666,290**	**16,190,967**

As can be seen in the table, 68 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 16,836,536 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 were 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-23 shows that only three tests were recorded with a "fail" in the OBD portion of the test but a "pass" for the overall test.

Table III-23. Comparison of OBD Test Result with Overall Test Result

Result of OBD Test	Overall Test Result				Total	
	Fail		Pass			
Fail	645,634	100.0%	3	0.0%	645,637	3.8%
Pass	234,178	1.4%	15,956,721	98.6%	16,190,899	96.2%
Total	**879,812**	**5.2%**	**15,956,724**	**94.8%**	**16,836,536**	**100.0%**

Inspector-Entered Malfunction Indicator Light (MIL) bulb check - This is also referred to as the Key On / Engine Off (KOEO) check. The inspector 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 34 records where a KOEO MIL result of "N" (fail) did not receive a failing OBD result. The results are presented in Table III-24 below.

Table III-24. 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)	14,451	34	1,247,334
K (pass)	25,430	1,221,904	14,485
Y (pass)	605,745	14,968,961	15,574,706
Total	**645,626**	**16,190,899**	**16,836,525**

Inspector-Entered Engine-Running MIL Illumination Status – The Key-On / Engine Running (KOER) 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-25 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 KOER 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-26, in 177,921 inspections a "pass" result was manually entered when the downloaded MIL status indicated a "fail" result, and a "fail" result was entered 7,273 times when the MIL status indicated a "pass" result. These latter cases are possible false failures; TCEQ should consider a specification change where passing MIL Status would result in a passing OBD result despite a KOER result of fail.

Table III-25. 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)	32,632	0	32,632
Y (Pass)	612,993	16,190,899	16,803,892
Total	**645,625**	**16,190,899**	**16,836,524**

Table III-26. 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	25,359	177,921	203,280
Pass	7,273	16,625,971	16,633,244
Total	**32,632**	**16,803,892**	**16,836,524**

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-27 provides the results of this review.

Table III-27. Comparison of Downloaded MIL Command Status with Overall OBD Test Result

Result of Downloaded MIL Status	Overall OBD Test Result				Total	
	Fail		Pass			
Fail	137,316	21.3%	65,966	0.4%	203,282	1.2%
Pass	508,321	78.7%	16,124,933	99.6%	16,633,254	98.8%
Total	**645,637**	**100.0%**	**16,190,899**	**100.0%**	**16,836,536**	**100.0%**

From Table III-27, it can be seen that 65,966 test records (0.4% of all OBD “pass” test records) have a MIL commanded on status yet receive an overall OBD pass result. However, 65,913 of the 65,966 tests had no stored DTCs, in which case it is appropriate to pass the test. The 53 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 based on 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 16,834,091 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-28 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-28. 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	6	610,175	183	13,631,413
1	2	249,972	13	1,740,010
2	2	83,020	209,820	831
3	20,311	0	136,673	0
4	12,716	0	94,687	0
5	7,782	0	34,376	0
6	336	0	1,678	0
8	11	0	66	0
Total	**41,166**	**943,167**	**477,496**	**15,372,254**

Results in Table III-28 show that a small number of tests (a total of 189) appear to have received an OBD "not ready" status despite having no unset monitors and another 17 not ready despite fewer monitors below the limit. Also, 831 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-29 shows these data in greater detail, separated by model year.

Table III-29. Unset Monitors vs. Test Readiness Status for Inspections, by Model Year

Model Year	Count of Unset Non-Continuous Monitors							
	0		1		2		3 or more	
	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready	OBD Not Ready	OBD Ready
1996	1	52,105	0	25,668	0	8,250	4,412	0
1997	0	82,358	0	38,673	0	13,437	6,312	0
1998	0	110,668	0	44,428	0	15,560	7,700	0
1999	2	152,751	0	61,953	1	19,756	10,062	0
2000	3	212,293	2	79,250	1	831	12,670	0
2001	2	273,135	1	108,390	15,035	135	14,414	0
2002	3	345,919	0	118,746	14,284	102	15,097	0
2003	0	391,365	0	136,829	14,887	101	14,941	0
2004	5	465,480	0	138,300	15,279	106	16,346	0
2005	5	536,917	1	137,875	15,988	110	18,471	0
2006	6	612,169	2	147,236	15,950	83	18,725	0
2007	12	780,177	1	161,073	15,461	64	21,110	0
2008	9	820,020	1	134,839	15,439	49	18,563	0
2009	7	584,177	1	78,697	9,688	23	12,041	0
2010	7	731,697	1	80,472	9,807	15	13,818	0
2011	13	830,385	2	85,760	10,630	15	14,454	0
2012	12	1,000,000	0	84,499	10,822	10	15,676	0
2013	16	1,210,000	0	81,804	10,363	8	16,896	0
2014	23	1,310,000	0	78,003	9,632	4	16,301	0
2015	26	1,470,000	1	75,778	11,020	4	17,078	0
2016	15	1,360,000	1	56,473	8,852	1	14,058	0
2017	18	763,157	1	28,494	4,973	0	7,151	0
2018	4	122,187	0	5,358	1,276	1	1816	0
2019	0	16,523	0	1,384	434	0	524	0
Total	**189**	**14,233,483**	**15**	**1,989,982**	**209,822**	**58,665**	**308,636**	**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 16,832,091 records in the dataset for this analysis. The results are shown in Table III-30.

Table III-30. Comparison of Readiness Status Field with Overall OBD Test Result

Readiness Status Check	Overall OBD Test Result				Total	
	Fail		Pass			
Fail (Not Ready)	517,694	80.2%	968	0.0%	518,662	3.1%
Pass (Ready)	127,705	19.8%	16,187,724	100.0%	16,315,429	96.9%
Total	**645,399**	**100.0%**	**16,188,692**	**100.0%**	**16,834,091**	**100.0%**

As can be seen in Table III-30, 968 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%; therefore, the value in Table III-30 is 0.0%. 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 TIMS data from January 1, 2018 through December 31, 2019 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 retest. 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 were documented on paper and not electronically, LIRAP repairs were not included in this analysis.

In previous reports, repair information collected from the DPS RERF program was also included. However, because the RERF program ended in the spring of 2019, only 286 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 dropped slightly from 670,246 fails in the 2018 report to 636,020 fails in this report (34,226 fewer 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	423	1.2%	0.3%
	1996-1999	2,902	8.0%	2.0%
	2000-2006	15,827	43.5%	11.1%
	post-2007	17,236	47.4%	12.0%
	Total	*36,388*	*100.0%*	*25.4%*
Ignition / Electrical system	1990-1995	301	2.7%	0.2%
	1996-1999	1,005	9.0%	0.7%
	2000-2006	4,802	42.9%	3.4%
	post-2007	5,091	45.5%	3.6%
	Total	*11,199*	*100.0%*	*7.8%*
Emissions system	1990-1995	1,358	3.6%	0.9%
	1996-1999	3,173	8.4%	2.2%

Repair Type	Model Year	Number of Repairs	% of Repair Type	% of Total
	2000-2006	16,149	42.8%	11.3%
	post-2007	17,032	45.2%	11.9%
	Total	*37,712*	*100.0%*	*26.3%*
Engine Mechanical	1990-1995	46	2.3%	0.0%
	1996-1999	189	9.6%	0.1%
	2000-2006	802	40.8%	0.6%
	post-2007	929	47.3%	0.6%
	Total	*1,966*	*100.0%*	*1.4%*
Miscellaneous	1990-1995	1,179	2.1%	0.8%
	1996-1999	4,311	7.7%	3.0%
	2000-2006	24,124	43.2%	16.9%
	post-2007	26,247	47.0%	18.3%
	Total	*55,861*	*100.0%*	*39.0%*
	Grand Total	**143,126**		**100.0%**

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. Note that the number of repaired vehicles, particularly for TSI inspections, is now very small, so the average results may be noisier than in previous evaluations. 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 for TSI inspections. Average emissions for both inspections prior to and following repair cycles are shown, along with the average change between the two. Pollutant concentrations are abbreviated “Conc.”

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

Repair Category	ASM Mode	Counts	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	687	160	80	-80	-50.2%	0.8	0.31	-0.49	-61.0%	1613	821	-792	-49.1%
Engine Mechanical	5015	20	191	243	52	27.1%	1.07	0.89	-0.17	-16.0%	1789	520	-1270	-71.0%
Emissions System	5015	874	148	70	-78	-52.6%	0.85	0.26	-0.59	-69.6%	1642	667	-975	-59.4%
Emissions System & Misc.	5015	39	153	85	-68	-44.4%	0.76	0.21	-0.55	-72.2%	1722	529	-1193	-69.3%
Ignition/Electrical System	5015	186	255	112	-142	-55.9%	1.38	0.51	-0.88	-63.3%	1115	658	-457	-41.0%
Ignition/Electrical & Emissions System	5015	24	155	96	-59	-38.2%	1.63	0.75	-0.89	-54.3%	1508	587	-921	-61.1%
Fuel System	5015	238	142	85	-56	-39.9%	1.08	0.41	-0.67	-62.0%	1308	623	-685	-52.4%
All Repairs	5015	2068	162	81	-80	-49.8%	0.92	0.33	-0.59	-64.3%	1548	707	-840	-54.3%
Miscellaneous	2525	687	134	65	-69	-51.8%	0.77	0.26	-0.5	-65.7%	1430	696	-734	-51.3%
Engine Mechanical	2525	20	193	216	23	12.1%	1.05	0.86	-0.2	-18.7%	1653	462	-1191	-72.1%
Emissions System	2525	874	130	57	-73	-56.3%	0.76	0.27	-0.5	-65.0%	1502	578	-924	-61.5%
Emissions System & Misc.	2525	39	137	70	-67	-48.8%	0.65	0.24	-0.41	-63.0%	1594	422	-1172	-73.5%
Ignition/Electrical System	2525	186	231	99	-132	-57.1%	1.24	0.5	-0.75	-60.0%	977	548	-429	-43.9%
Ignition/Electrical & Emissions System	2525	24	160	91	-69	-42.8%	1.97	0.58	-1.39	-70.5%	1143	498	-646	-56.5%
Fuel System	2525	238	126	73	-53	-41.9%	1.06	0.4	-0.66	-62.3%	1186	525	-661	-55.7%
All Repairs	2525	2068	141	67	-74	-52.3%	0.86	0.31	-0.55	-63.7%	1394	603	-790	-56.7%

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

			HC (ppm)				CO (%)			
					Change				Change	
Repair Category	TSI Mode	Counts	Before Repair	After Repair	Conc.	(%)	Before Repair	After Repair	Conc.	(%)
Miscellaneous	curb idle	122	377	199	-178	-47.3%	1.5	0.71	-0.82	-53.5%
Engine Mechanical	curb idle	8	648	178	-470	-72.5%	1.3	0.25	-1.09	-81.2%
Emissions System	curb idle	93	432	106	-326	-75.4%	1.6	0.49	-1.13	-69.6%
Emissions System & Misc.	curb idle	5	130	76	-54	-41.4%	1.2	0.63	-0.54	-46.5%
Ignition/Electrical System	curb idle	46	534	213	-320	-60.0%	1.6	0.60	-1.01	-62.8%
Fuel System	curb idle	6	902	277	-625	-69.3%	0.6	0.09	-0.51	-84.4%
Fuel System & Emissions System	curb idle	66	411	185	-226	-55.0%	1.0	0.55	-0.45	-44.9%
All Repairs	curb idle	346	431	172	-259	-60.0%	1.4	0.58	-0.85	-59.4%
Miscellaneous	high idle	122	208	158	-51	-24.3%	1.1	0.73	-0.41	-36.2%
Engine Mechanical	high idle	8	539	147	-391	-72.6%	1.8	0.32	-1.44	-81.9%
Emissions System	high idle	93	230	60	-170	-73.9%	1.6	0.30	-1.26	-80.6%
Emissions System & Misc.	high idle	5	128	32	-96	-74.7%	1.0	0.08	-0.91	-92.3%
Ignition/Electrical System	high idle	46	371	246	-125	-33.8%	1.6	0.63	-0.94	-59.8%
Fuel System	high idle	6	357	204	-153	-42.9%	0.7	0.16	-0.50	-76.3%
Fuel System & Emissions System	high idle	66	249	104	-144	-58.1%	0.7	0.37	-0.34	-47.7%
All Repairs	high idle	346	252	132	-121	-47.9%	1.2	0.50	-0.73	-59.1%

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 are collected and stored may alleviate many of these issues. These issues are described below and are very similar to those listed in previous reports.

Repair data in the TIMS are 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. Most repair entries in the TIMS are made by inspectors who either work in the same facility where the re-inspection takes place or make the repairs themselves.

The TIMS repair data include 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 almost 40% 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 that 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 were being properly repaired. ERG performed an analysis of the TIMS data for OBD failures and the presence of an illuminated MIL and DTCs 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 retest. For example, after DTCs are cleared, it might be possible to pass a retest if the monitor associated with the DTC has not reset to ready. 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 the electronic OBD information is not used to determine the pass or fail status of HD vehicles during OBD inspections, the records from their inspections were excluded from this analysis. This left a dataset of 16,836,624 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 tailpipe 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 either passed the overall inspection or 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 or received a waiver, or the evaluation period ended. 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, 2019, 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, 2019, and there would be no information for those inspections. Using these criteria, the dataset contained 16,042,346 OBD I/M cycles (including single-OBD-test passes) that started before October 1, 2019.

After grouping by I/M cycle for vehicles with OBD failures (as previously defined), 112,091 I/M cycles were seen to include at least one failed OBD test. Of these cycles, 60,660 (54%) 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 51,431 vehicles never passed a subsequent OBD test; for these vehicles it was learned that 51,248 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, 2019, which would increase the overall "repaired" numbers. Additionally, 183 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 is 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 retest (which could result in a false pass) can be quantified. In this analysis, the extent of this potential masking is quantified along with the overall repair rates (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 that 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 retests, the following distinctions of "repaired" vehicles were made:

- Total Repaired – This is the count of all vehicles that had at least one fail test with the final test classified as repaired. No regard is given to which (if any) monitors remain unset.
- Repaired with Unset Monitors – This is the count of all "repaired" vehicles that have an unset monitor that may be masking the failure mode seen in the initial fail test. For example, if a vehicle fails for an 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 might have been due to DTCs being generated by a continuous monitor. 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 was failed, it seems that incorrect reporting of monitor status is truly the cause as opposed to potential inspection fraud through clean-scanning.

Regarding 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 ten DTCs may be stored in the test record, and all stored DTCs were used for this analysis. Therefore, some vehicles were

[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.

included in more than one set of results. For example, repair results for vehicles with both oxygen sensor DTCs and catalytic converter DTCs were 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, 2018 through December 31, 2019, it is possible that some of the un-repaired vehicles were repaired in 2020. 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	30,733	25,342	82.5%	11,363	37.0%	13,979	45.5%
O_2 Sensor	6,772	5,244	77.4%	363	5.4%	4,881	72.1%
EGR System	6,772	5,244	77.4%	363	5.4%	4,881	72.1%
AI System	1,268	937	73.9%	126	9.9%	811	64.0%
Catalyst	23,230	18,424	79.3%	2,483	10.7%	15,941	68.6%
Totals	**68,775**	**55,191**	**80.2%**	**14,698**	**26.6%**	**40,493**	**73.4%**

From these data, it can be seen that roughly 83% of vehicles that failed an OBD test received a passing OBD test. 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 5-37% of vehicles that pass OBD retests based on MIL status with these types of failures. I/M program modifications that would require confirmation of specific failure-mode monitors being set 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	16,381,545	98.6%	63,886	0.4%	16,445,431
Fail	162,473	1.0%	1,863	0.0%	164,336
Total	**16,544,018**	**99.6%**	**65,749**	**0.4%**	**16,609,767**

As can be seen from this table, approximately 1.0% of the tests had failed the OBD portion of the test with evaporative system DTCs, and gas cap failures were seen in 0.4% 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 (less than 1%) 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	48,975	38.8%	122	34.5%	687	32.6%
Emissions System	32,325	25.6%	93	26.3%	874	41.4%
Fuel System	31,959	25.3%	66	18.6%	238	11.3%
Ignition/Electrical System	9,709	7.7%	46	13.0%	186	8.8%
Engine Mechanical	1,709	1.4%	8	2.3%	20	0.9%
Fuel System & Miscellaneous	599	0.5%	0	0.0%	0	0.0%
Emissions System & Miscellaneous	360	0.3%	5	1.4%	39	1.8%
Ignition/Electrical & Emissions System		0.0%	6	1.7%	24	1.1%
Other	662	0.5%	8	2.3%	42	2.0%
Total	**126,298**	**100.0%**	**354**	**100.0%**	**2,110**	**100.0%**

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

DTC Name	DTC Description	Repair Type										Total
		Fuel System		Ignition/ Electrical System		Emissions System		Engine Mechanical		Miscellaneous		
		Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count
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
P0401	Exhaust Gas Recirculation Flow Insufficient Detected	362	17%	155	7%	929	44%	48	2%	621	29%	2,115

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

DTC Name	DTC Description	Repair Type										Total
		Fuel System		Ignition/ Electrical System		Emissions System		Engine Mechanical		Miscellaneous		
		Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count
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

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 one of the table, 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. In some cases, the inspectors are not choosing the correct repair type. For example, most misfire DTCs should involve ignition system repairs.

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 99.9% of all vehicle and I/M cycle combinations. These categories are presented in Table IV-8.

Almost two-thirds (62.2%) 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 retest 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 some categories listed contained about 20-40% $0 repair costs, but the most common repair types of emissions system, fuel system, and miscellaneous repairs contained a much higher percentage, at 59% or more. All these percentages are comparable to those in the 2014, 2016, and 2018 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 $2,000, 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 $2,000.

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

Repair Category	Cost > $0	Cost = $0	Total	% of Cost = 0
Fuel System and Emissions System	350	81	431	18.8%
Emissions System & Miscellaneous	303	364	667	54.6%
Engine Mechanical	1,283	559	1,842	30.3%
Ignition / Electrical System	6,598	4,017	10,615	37.8%
Fuel System	12,547	21,671	34,218	63.3%
Miscellaneous	14,428	21,086	35,514	59.4%
Emissions System	15,794	36,746	52,540	69.9%
Total	**51,303**	**84,524**	**135,827**	**62.2%**

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 >$2,000 repair costs found in the dataset (unedited), and once without (edited). According to the unedited dataset, vehicle owners performed 136,000 repairs while spending approximately $24.8 million. According to the edited dataset, which leaves out $0 cost and greater than $2,000 cost observations, vehicle owners performed 51,000 repairs while spending approximately $11.9 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 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 $2,000

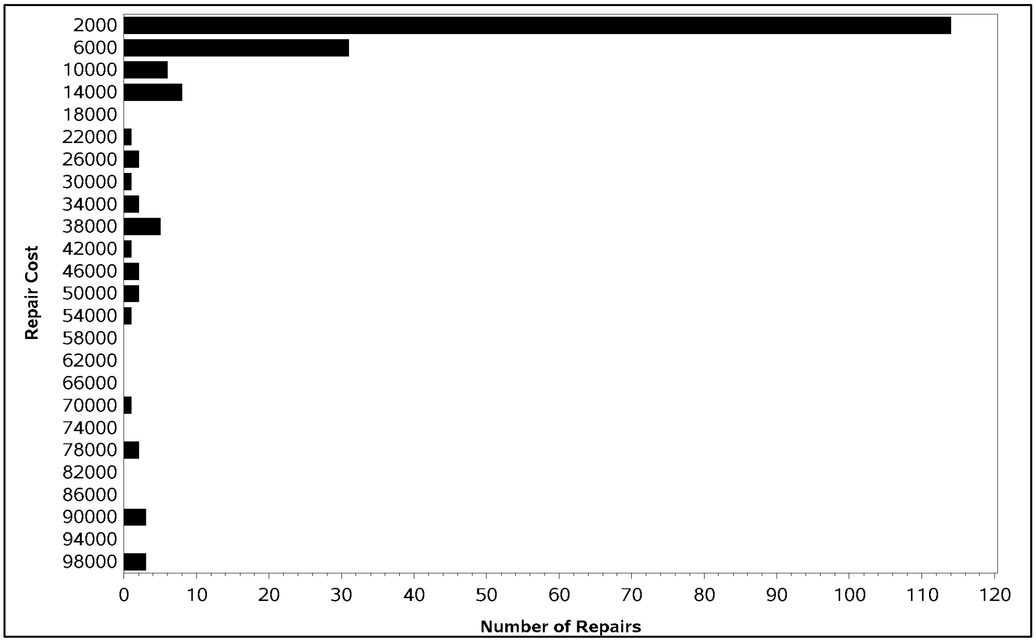


Table IV-9. Average Repair Costs

Year of Inspection	Repair Category	Original Dataset			Costs Between $0 and $2,000		
		Number of Repairs	Median Repair Cost	Mean Repair Cost	Number of Repairs	Median Repair Cost	Mean Repair Cost
2018	Fuel System and Emissions System	183	$99	$525	124	$214	$326
2018	Emissions System & Miscellaneous	244	$200	$258	203	$220	$253
2018	Engine Mechanical	994	$130	$301	672	$244	$318
2018	Ignition / Electrical System	5640	$75	$154	3,492	$140	$195
2018	Fuel System	18,070	$0	$91	6,814	$100	$171
2018	Emissions System	17,206	$0	$135	8,034	$200	$267
2018	Miscellaneous	26,548	$0	$40	8,278	$45	$95
2019	Fuel System and Emissions System	167	$50	$199	101	$226	$329
2019	Emissions System & Miscellaneous	187	$200	$269	143	$245	$307
2019	Engine Mechanical	848	$150	$254	588	$250	$307
2019	Ignition / Electrical System	4,975	$75	$122	3,090	$140	$192
2019	Fuel System	16,148	$0	$68	5,692	$100	$150
2019	Emissions System	18,308	$0	$108	6,340	$217	$266
2019	Miscellaneous	25,992	$0	$33	7,478	$50	$99

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

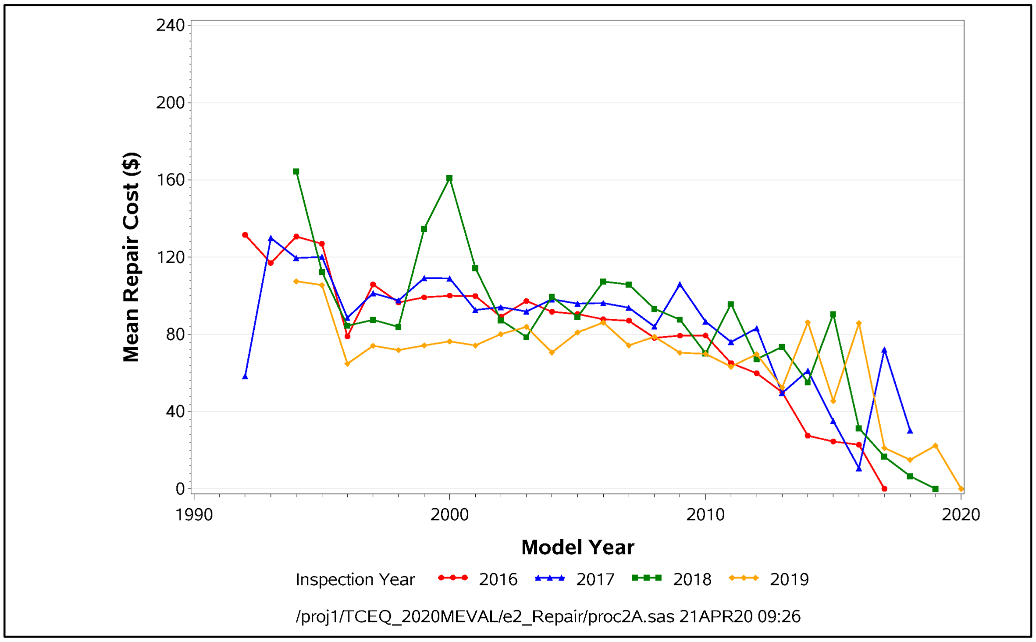


Figure IV-3. Mean Repair Costs by Model Year and Inspection Year (Edited Dataset)

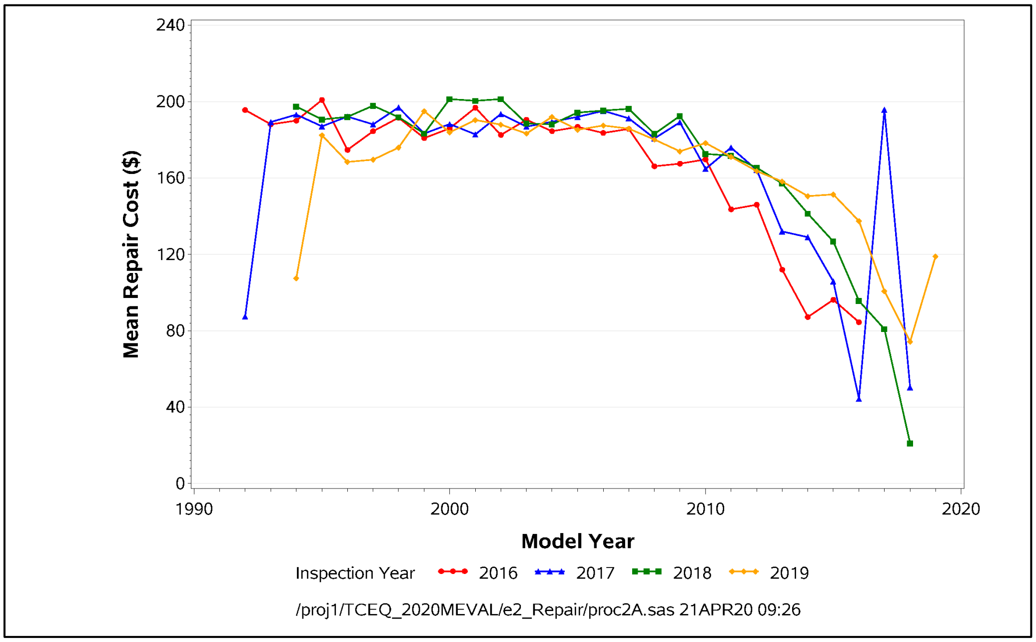


Figure IV-4 and Figure IV-5 present the percentile distribution of repair costs for the most common TIMS repair categories, for both the unedited and edited datasets. The unedited dataset contains repairs with an average cost of $0 for all repair slates, but miscellaneous repairs costing $0 extend close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

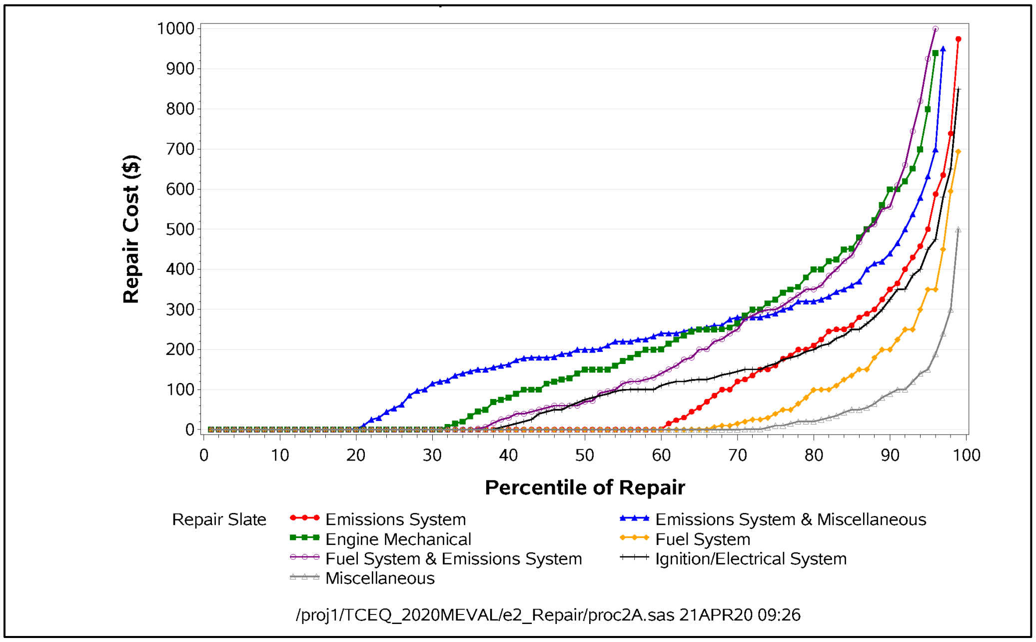
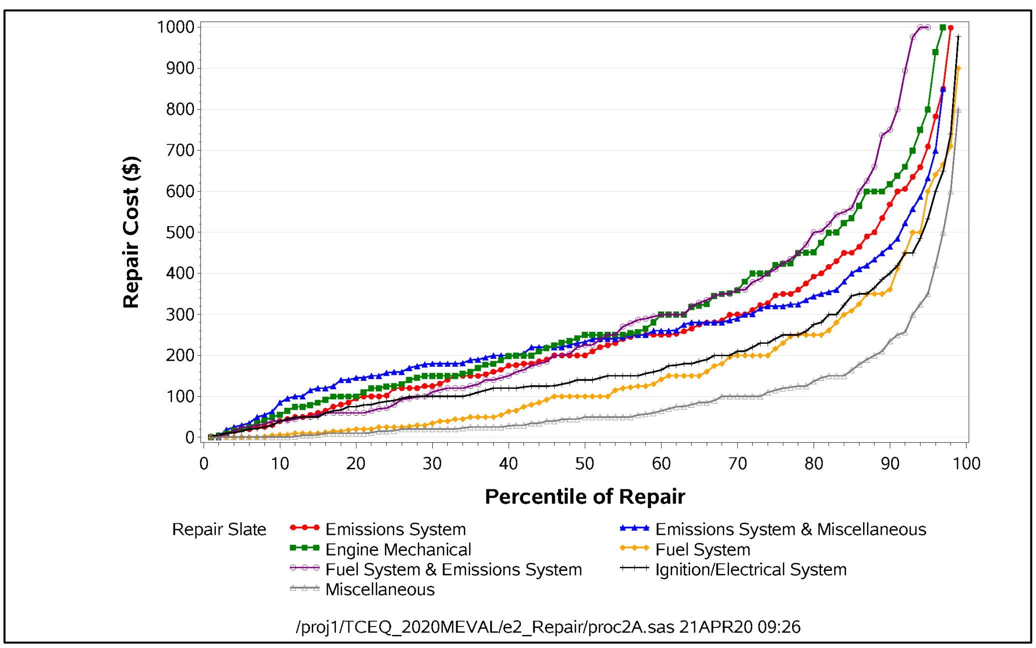


Figure IV-5. Distribution of Repair Costs by Category (Edited Dataset)



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. In previous years of performing this I/M evaluation, a thousand or more RERF records were available for each year of analysis. For the 2018-2019 period, there were 239 available records from 2018 and 45 records from 2019. No records were collected after April 2019. In past I/M Evaluations, comparisons were made between the data reported in the RERF records and in the general TIMS repair information. However, these 284 records do not provide enough information for the performance of an analysis in the I/M evaluation.

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 were 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 a 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 contain 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 is 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 95% of all sequences. The FP sequences are the next most common and make up about 4% of all sequences. The 1F and FF sequences are less common and make up the remaining 1% of the sequences. Since vehicles with 1P and 1F sequences are tested only initially (because there is only one test), the final emissions values equal the initial emissions values. Consequently, vehicles with 1P and 1F sequences do not contribute to the calculated annual I/M benefit. The vehicles with FF sequences do have different values for the initial and final average emissions; however, the values are not greatly different, which is probably because repairs to these vehicles were not entirely successful.

ERG calculated the average emission values using completed I/M cycles and 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 2020 report covering 2018 and 2019 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 10-12%, ASM CO decreased 18-20%, ASM NO_X decreased 15-18%, TSI HC decreased 17-19%, and TSI CO decreased 12-14%. 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 Table V-1 and Table V-2 show 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% of the I/M sequences in the datasets. The table shows that, of course, for the 1P category the change in emissions is 0% since these vehicles simply initially pass. However, for the FP category, the ASM measurements and TSI measurements show large emissions decreases from 50-80%. 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-1. 2020 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	17,826	61.4	61.4	0.0%	39.9	39.9	0.0%
	FP	2,298	124.1	58.3	-53.0%	100.5	43.0	-57.2%
	1P+FP	21,289	75.9	69.1	-8.9%	54.2	48.5	-10.6%
HGB	1P	17,079	57.8	57.8	0.0%	38.7	38.7	0.0%
	FP	1,955	129.0	57.8	-55.2%	110.8	41.3	-62.7%
	1P+FP	19,602	68.8	61.5	-10.7%	50.1	43.0	-14.2%
DFW & HGB	1P	34,905	59.6	59.6	0.0%	39.3	39.3	0.0%
	FP	4,253	126.3	58.1	-54.0%	105.3	42.2	-59.9%
	1P+FP	40,891	72.5	65.4	-9.7%	52.2	45.8	-12.3%
ASM CO (%)								
DFW	1P	17,826	0.1876	0.1876	0.0%	0.1424	0.1424	0.0%
	FP	2,298	0.6230	0.1955	-68.6%	0.5708	0.1649	-71.1%
	1P+FP	21,289	0.2820	0.2356	-16.4%	0.2369	0.1936	-18.3%
HGB	1P	17,079	0.1872	0.1872	0.0%	0.1475	0.1475	0.0%
	FP	1,955	0.7241	0.1855	-74.4%	0.6666	0.1567	-76.5%
	1P+FP	19,602	0.2683	0.2155	-19.7%	0.2282	0.1787	-21.7%
DFW & HGB	1P	34,905	0.1874	0.1874	0.0%	0.1449	0.1449	0.0%
	FP	4,253	0.6694	0.1909	-71.5%	0.6148	0.1611	-73.8%
	1P+FP	40,891	0.2754	0.2260	-17.9%	0.2328	0.1864	-19.9%
ASM NOx (ppm)								
DFW	1P	17,826	494	494	0.0%	384	384	0.0%
	FP	2,298	1143	518	-54.7%	1000	431	-56.9%
	1P+FP	21,289	620	552	-10.9%	503	442	-12.2%
HGB	1P	17,079	428	428	0.0%	330	330	0.0%
	FP	1,955	1134	443	-60.9%	1008	357	-64.6%
	1P+FP	19,602	526	457	-13.0%	425	360	-15.2%
DFW & HGB	1P	34,905	462	462	0.0%	357	357	0.0%
	FP	4,253	1139	483	-57.6%	1004	397	-60.5%
	1P+FP	40,891	575	507	-11.8%	465	403	-13.5%

Table V-2. 2020 Report Annual I/M Benefit Using TIMS Data for TSI Emissions

Area	Seq.	Count	Curb Initial	Curb Final	Curb % Change	High Initial	High Final	High % Change
TSI HC (ppm)								
DFW	1P	5,519	79.7	79.7	0.0%	38.8	38.8	0.0%
	FP	486	371.2	92.9	-75.0%	200.1	45.6	-77.2%
	1P+FP	6,170	112.0	96.4	-13.9%	55.7	47.5	-14.7%
HGB	1P	5,832	70.8	70.8	0.0%	39.9	39.9	0.0%

Table V-2. 2020 Report Annual I/M Benefit Using TIMS Data for TSI Emissions

Area	Seq.	Count	Curb			High		
			Initial	Final	% Change	Initial	Final	% Change
	FP	435	321.5	84.9	-73.6%	208.4	48.6	-76.7%
	1P+FP	6,378	90.9	78.9	-13.1%	53.7	45.3	-15.6%
DFW & HGB	1P	11,351	75.1	75.1	0.0%	39.4	39.4	0.0%
	FP	921	346.8	89.1	-74.3%	204.2	47.0	-77.0%
	1P+FP	12,548	101.2	87.5	-13.5%	54.7	46.4	-15.1%
TSI CO (%)								
DFW	1P	5,519	0.1923	0.1923	0.0%	0.2173	0.2173	0.0%
	FP	486	1.2782	0.2482	-80.6%	1.1349	0.2529	-77.7%
	1P+FP	6,170	0.3084	0.2497	-19.0%	0.3088	0.2604	-15.7%
HGB	1P	5,832	0.1755	0.1755	0.0%	0.1837	0.1837	0.0%
	FP	435	1.0586	0.2303	-78.2%	0.9817	0.2398	-75.6%
	1P+FP	6,378	0.2479	0.2068	-16.6%	0.2461	0.2093	-15.0%
DFW & HGB	1P	11,351	0.1837	0.1837	0.0%	0.2000	0.2000	0.0%
	FP	921	1.1702	0.2397	-79.5%	1.0595	0.2467	-76.7%
	1P+FP	12,548	0.2775	0.2279	-17.9%	0.2768	0.2344	-15.3%

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 allow this slow increase in emissions to be observed as initially passing vehicles (89% of the fleet) go through the Texas I/M program and their emissions gradually increase each year. This is often called emission creep or deterioration. 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 to 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 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 vs. 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 2.3 million records, collected between July 1, 2017, and February 29, 2020, with about 1.2 million records coming from the HGB area, about 900,000 records from the DFW area, and another 200,000 records coming from out of the IM areas.

The RS 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 [EPA, 2004] 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 754,000 records in the dataset: 409,000 records in the DFW program area and 344,000 records in the HGB program area.

The number of RS observations collected per year has decreased dramatically over the last several years, beginning in 2014, and continuing to decrease through 2018, record counts for 2019, however, saw a substantial increase. Decreases in the number of available RS observations result in much smaller groups of vehicles when the RS observations are paired with close-in-time I/M inspections, but the 2019 increase will help improve the pairing results.

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. [EPA, 2004] 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, one month before the initial test, two months before the initial test, three months before initial, one1 month after the final test, two months after the final test, three 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 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 six months before and six 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% confidence level (indicated by the lines).

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

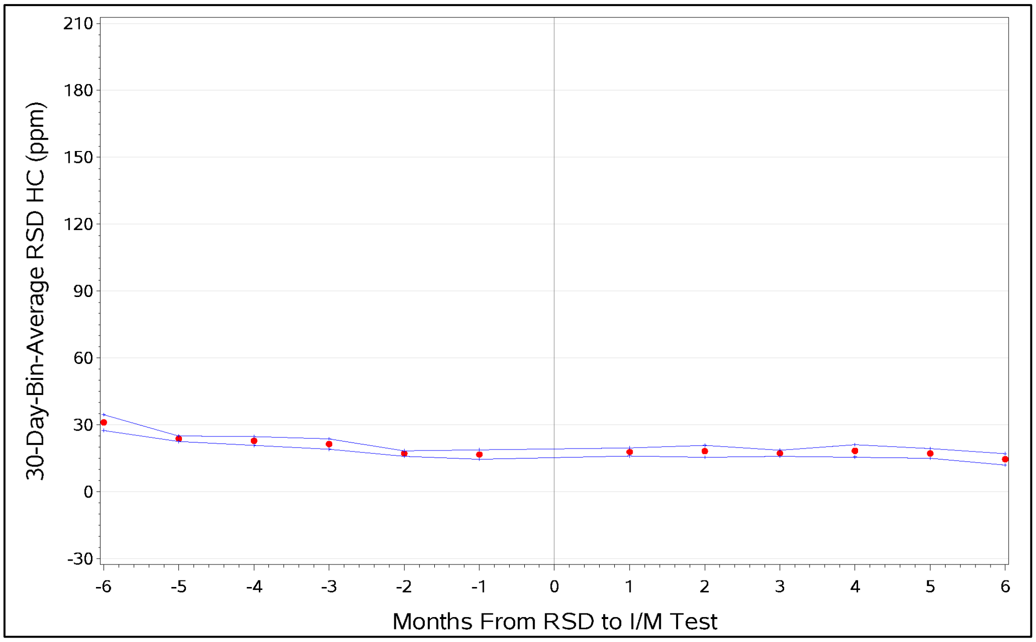


Figure V-2. Average RS CO vs. Month from the I/M Test RS Readings from the HGB Program Area

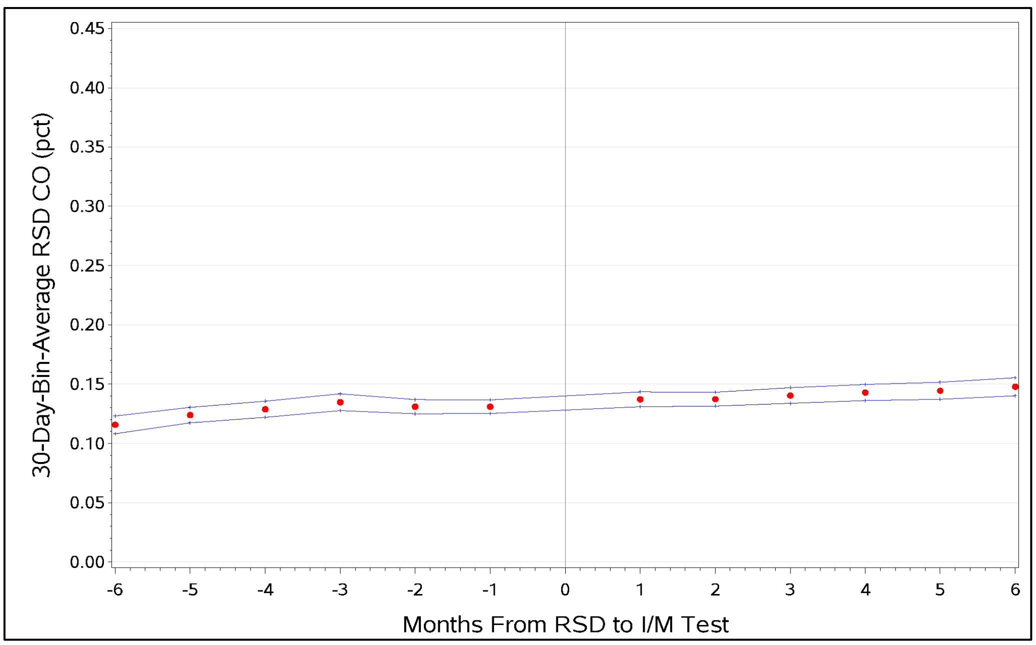


Figure V-3. Average RS NO_X vs. Month from the I/M Test RS Readings from the HGB Program Area

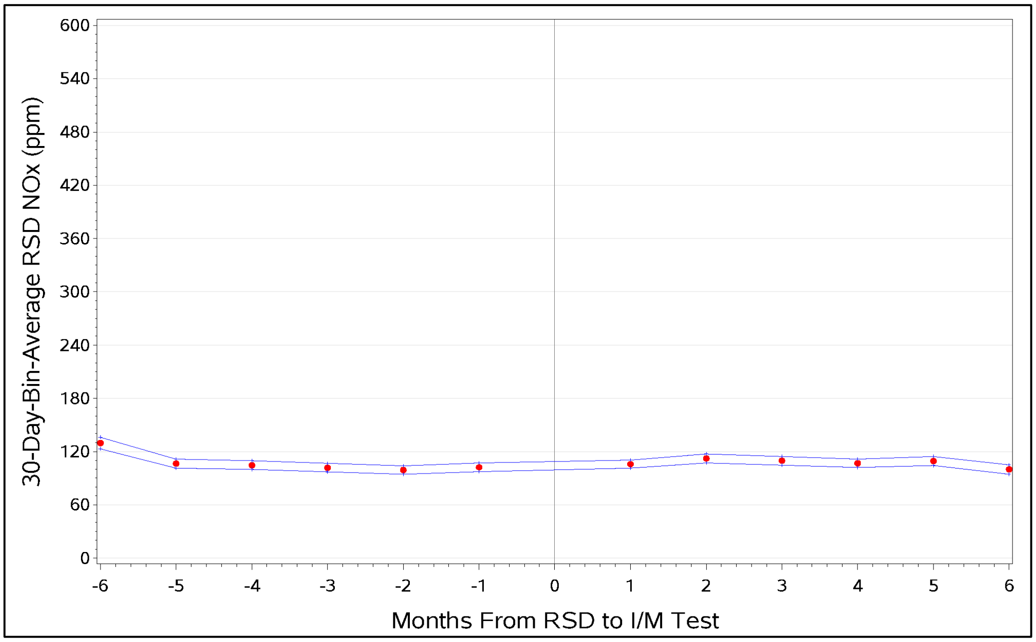


Figure V-4. Average RS HC vs. Month from the I/M Test RS Readings from the DFW Program Area

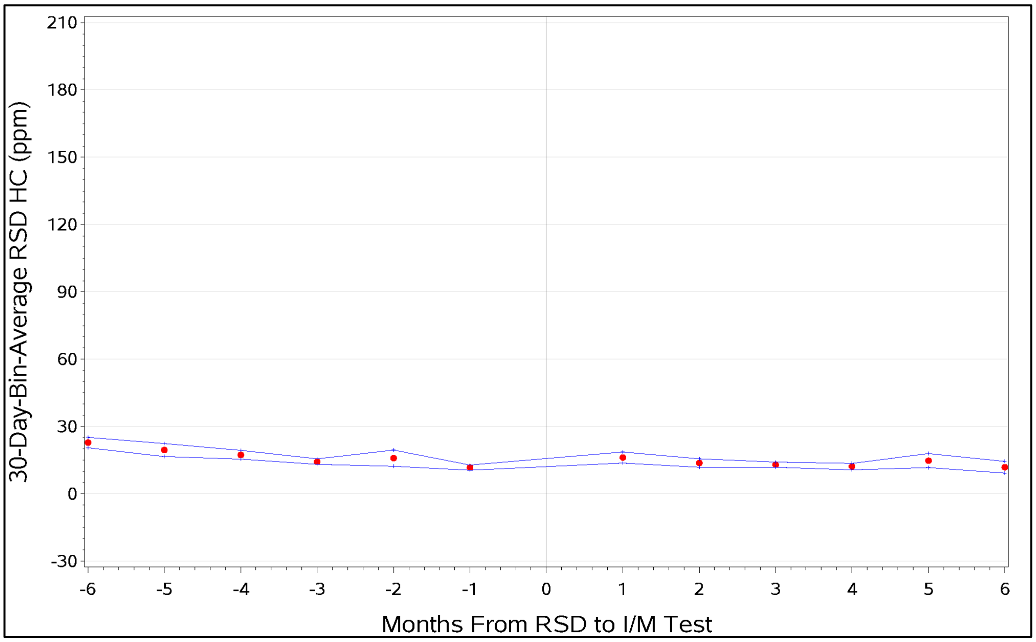


Figure V-5. Average RS CO vs. Month from the I/M Test RS Readings from the DFW Program Area

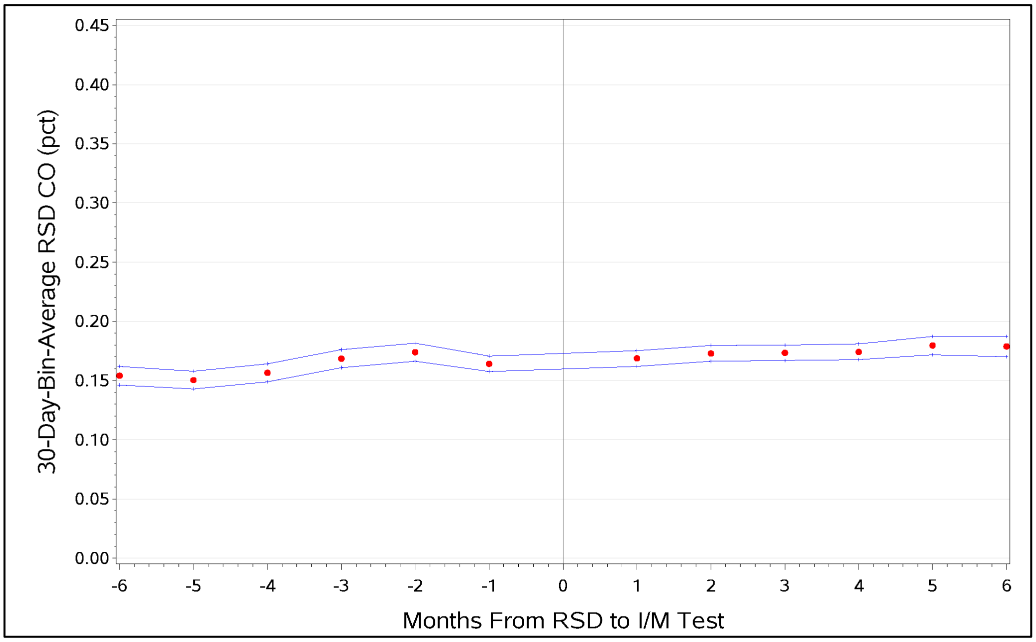
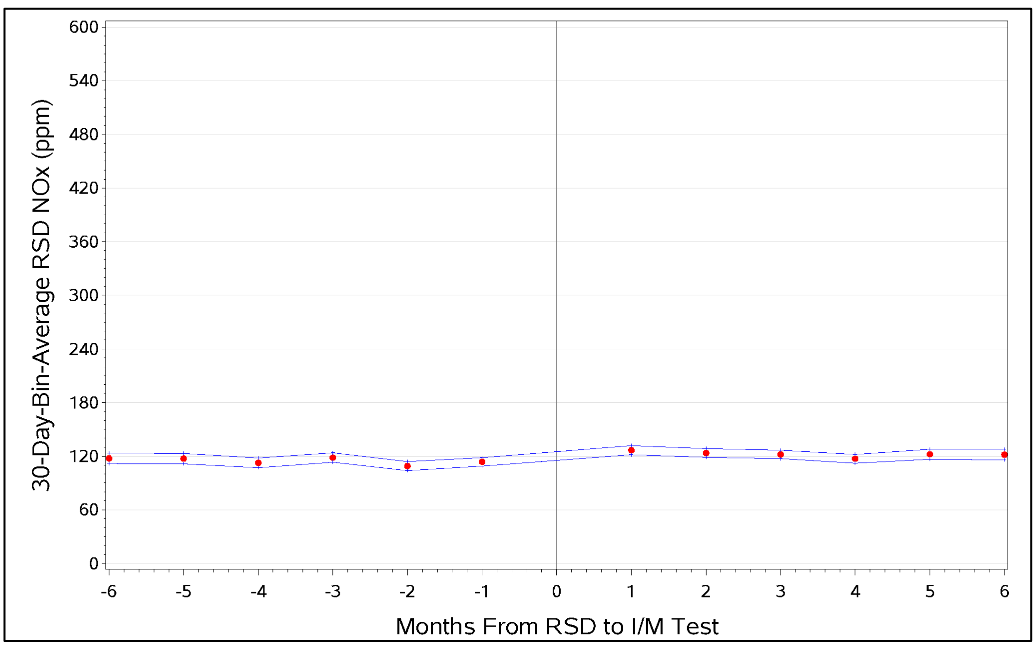


Figure V-6. Average RS NO_X vs. Month from the I/M Test RS Readings from the DFW Program Area



It is difficult to assess the impact of I/M testing from these figures as the HC readings are relatively constant around 20 ppm for both program areas, the CO readings are also similar in the HGB and DFW program areas near 0.15%, and the NO_X values are similar around 120 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-3 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.

Table V-3. 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)	150,910	95.6%	182,537	95.7%
Fail Initial (1F)	366	0.2%	421	0.2%
Fail Initial, Fail Final (FF)	41	0.0%	64	0.0%
Fail Initial, Pass Final (FP)	6,518	4.1%	7,619	4.0%
Other Misc. Sequences	7	0.0%	9	0.0%
Total	**157,842**	**100.0%**	**190,650**	**100.0%**

The plots of mean RS concentrations vs. 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% 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 4.1% 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 creep, 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

4.1% of the HGB fleet. An additional 95.6% of the fleet is made up of 1P vehicles that have slight emissions increases, as an expected result of general long-term creep. 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

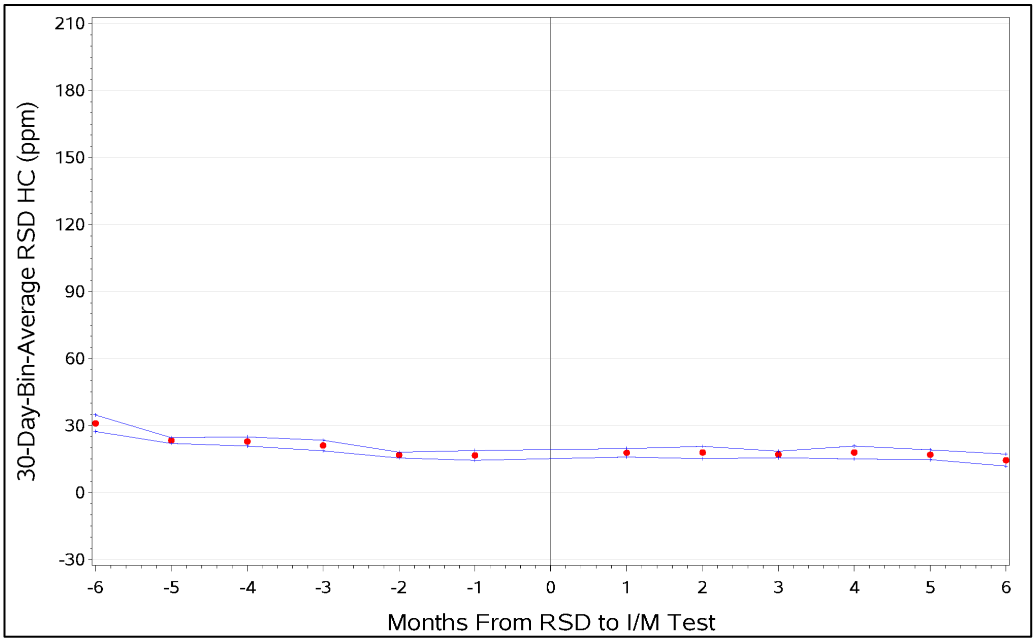


Figure V-8. Average RS HC vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = FP

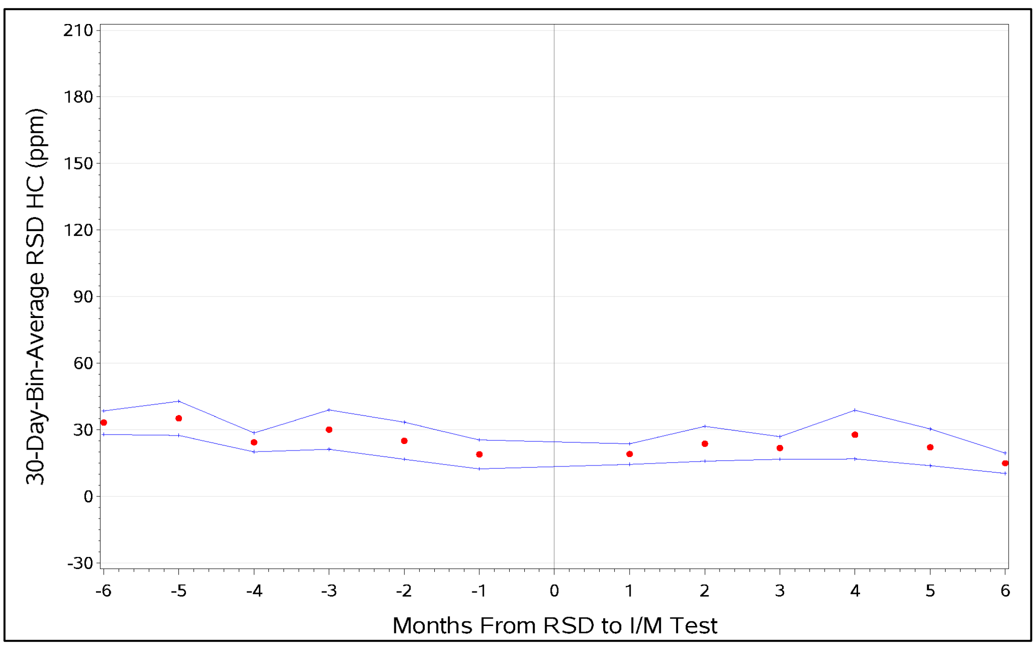


Figure V-9. Average RS CO vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = 1P

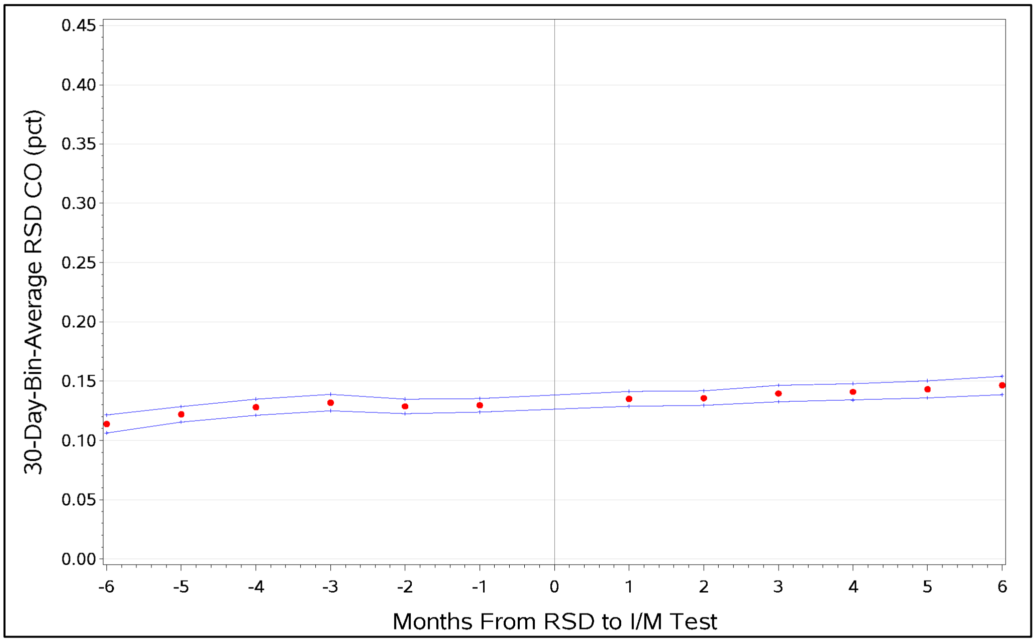


Figure V-10. Average RS CO vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = FP

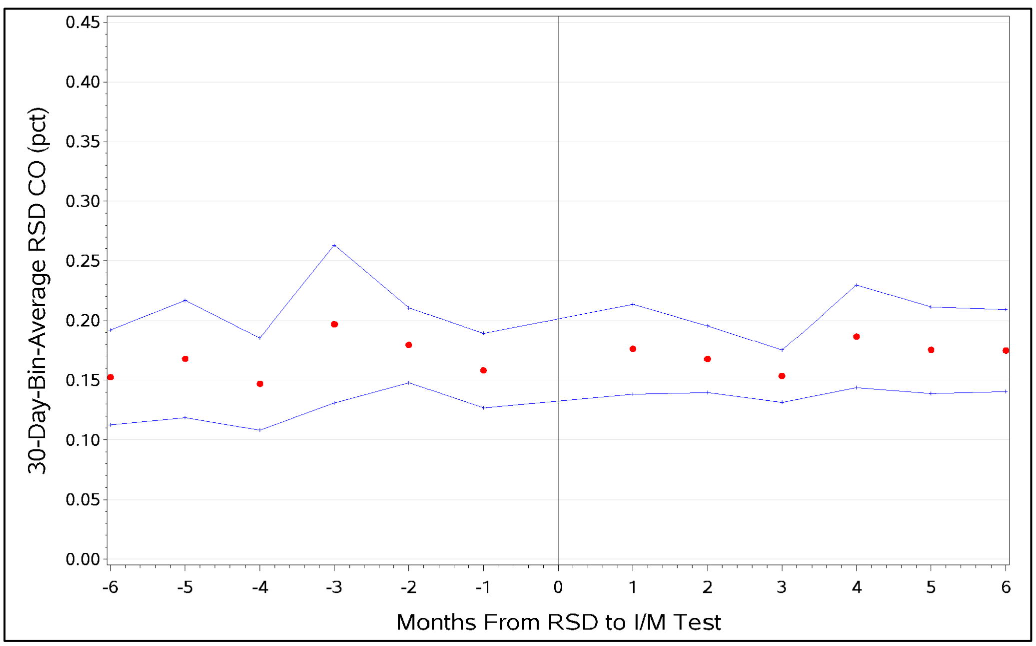


Figure V-11. Average RS NO_X vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = 1P

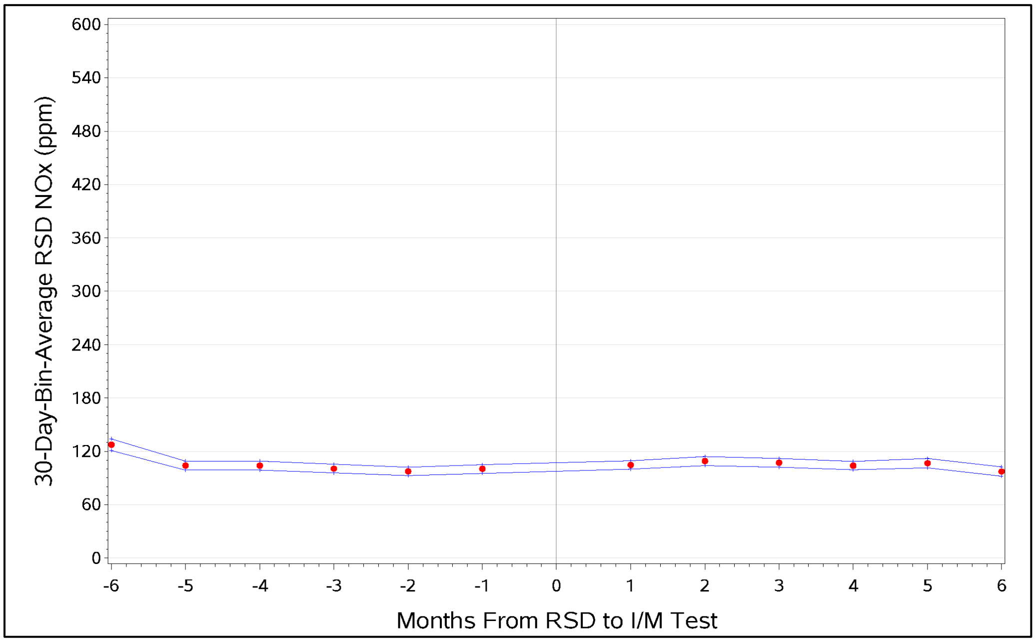
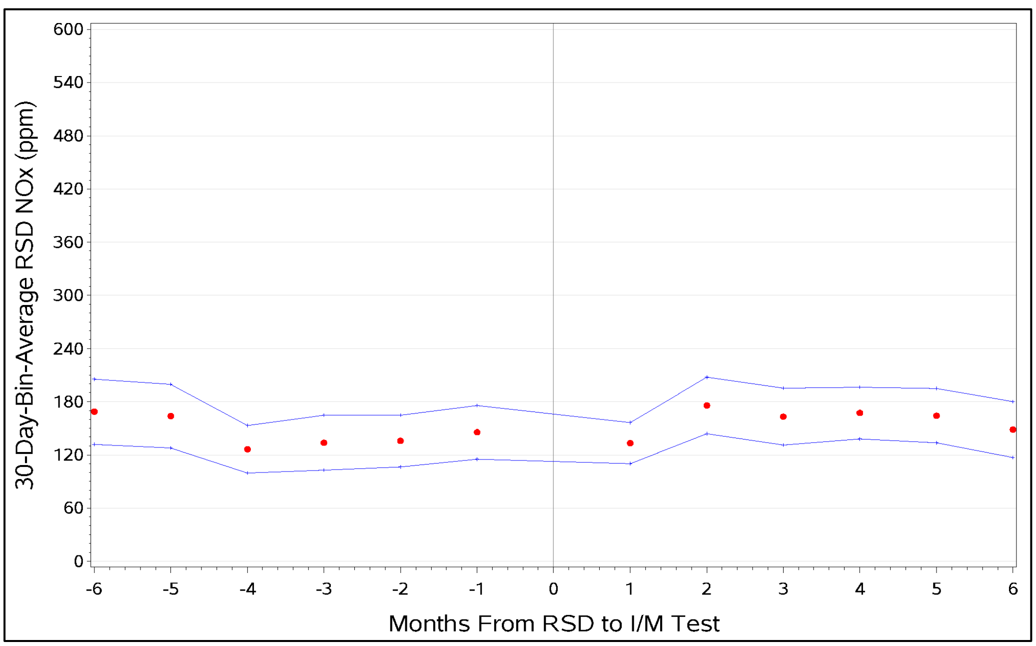


Figure V-12. Average RS NO_X vs. Month After the I/M Test for HGB Vehicles with I/M Sequence Category = FP



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 1-30 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 one 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 was 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% 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

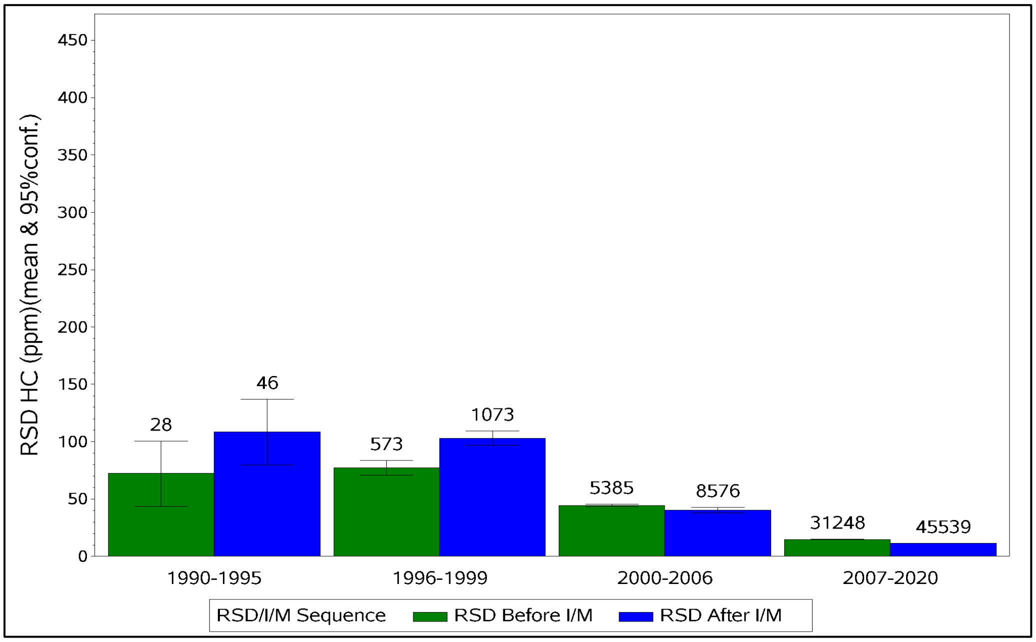


Figure V-14. Average FP RS HC by Model Year Group Before and After I/M Test for HGB Vehicles

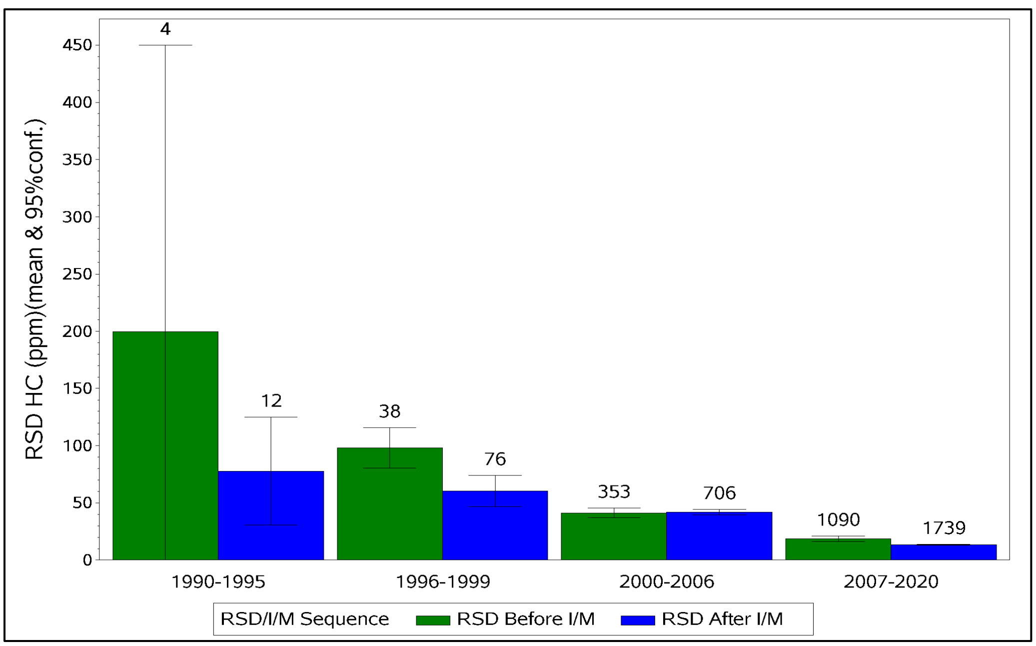


Figure V-15. Average 1P RS HC by Model Year Group Before and After I/M Test for DFW Vehicles

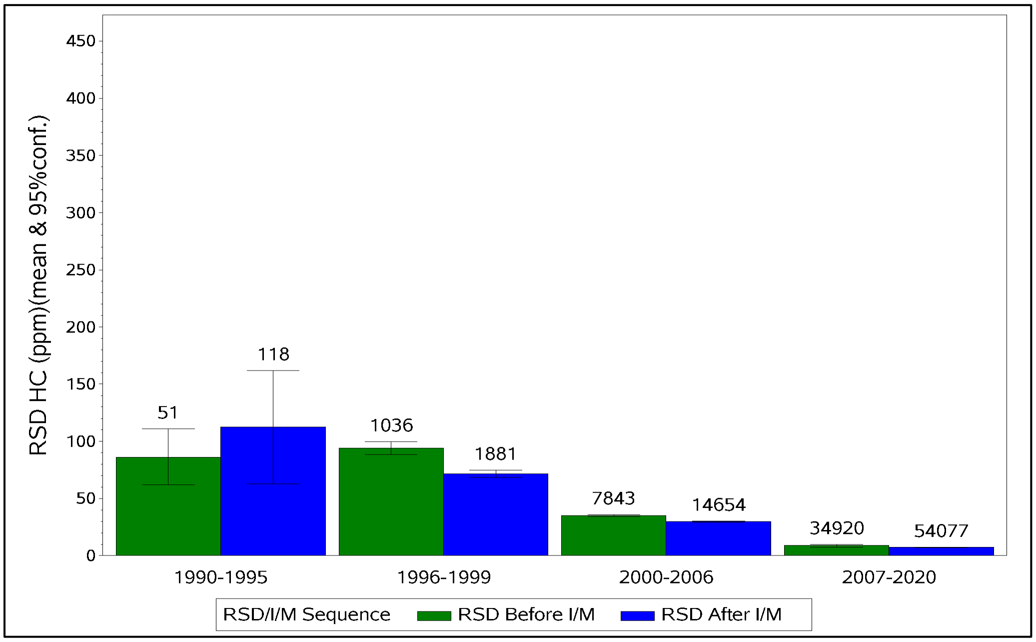


Figure V-16. Average FP RS HC by Model Year Group Before and After I/M Test for DFW Vehicles

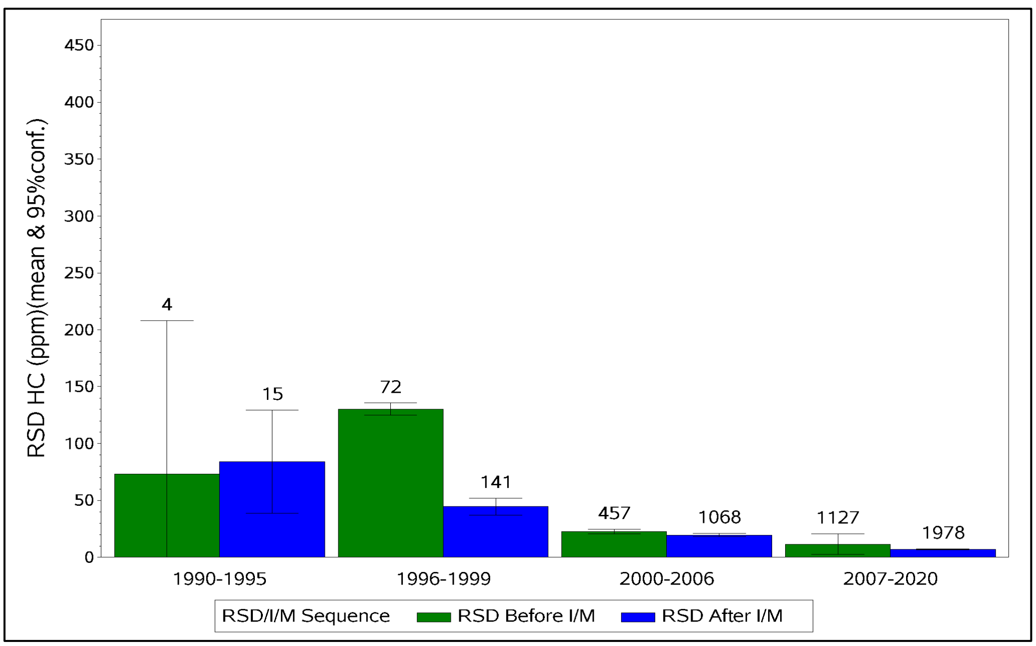


Figure V-17. Average 1P RS CO by Model Year Group Before and After I/M Test for HGB Vehicles

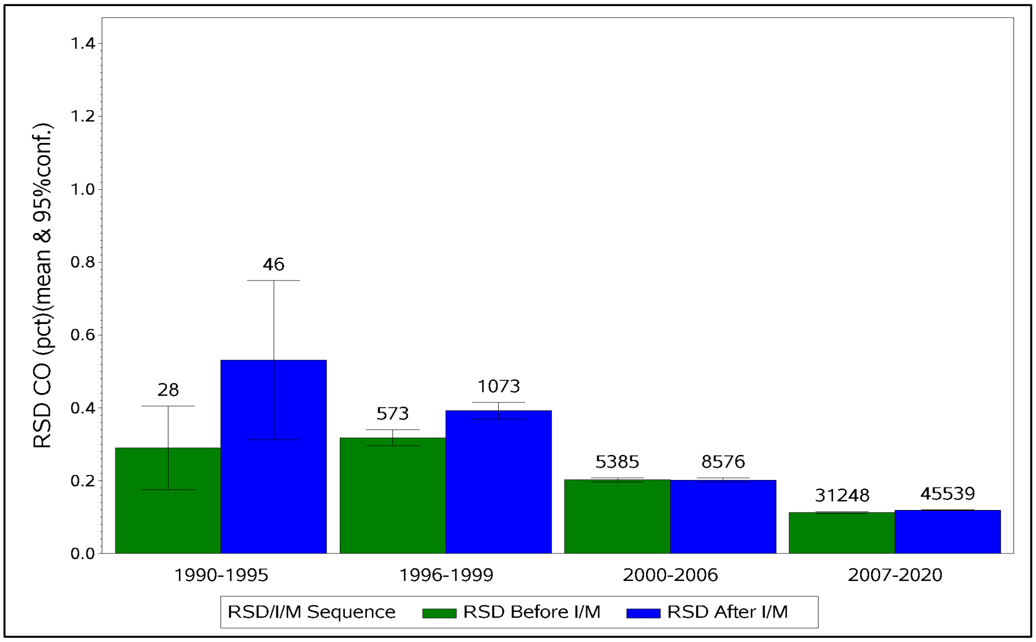


Figure V-18. Average FP RS CO by Model Year Group Before and After I/M Test for HGB Vehicles

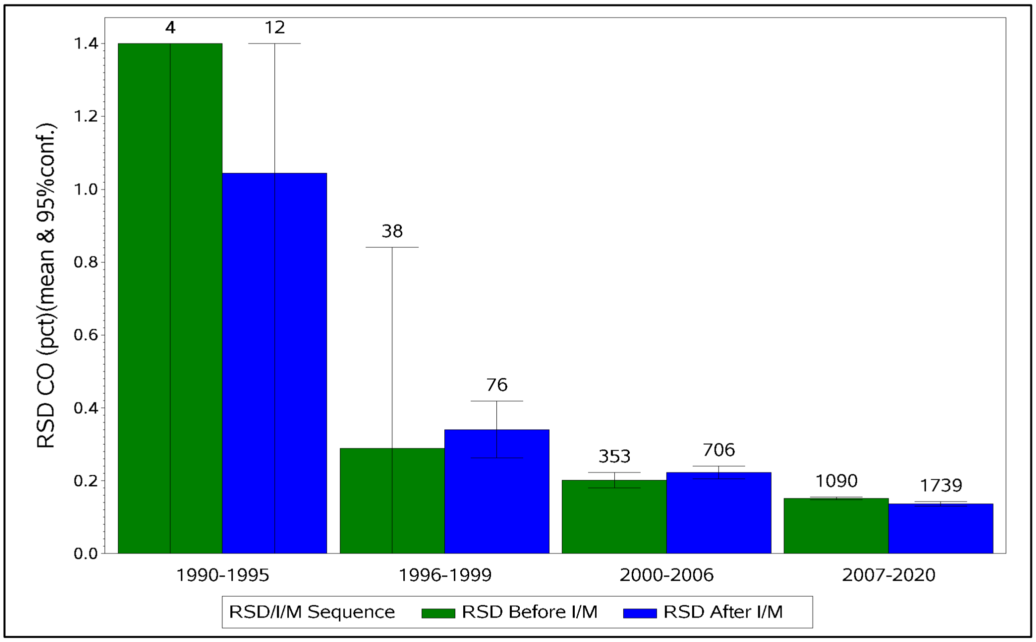


Figure V-19. Average 1P RS CO by Model Year Group Before and After I/M Test for DFW Vehicles

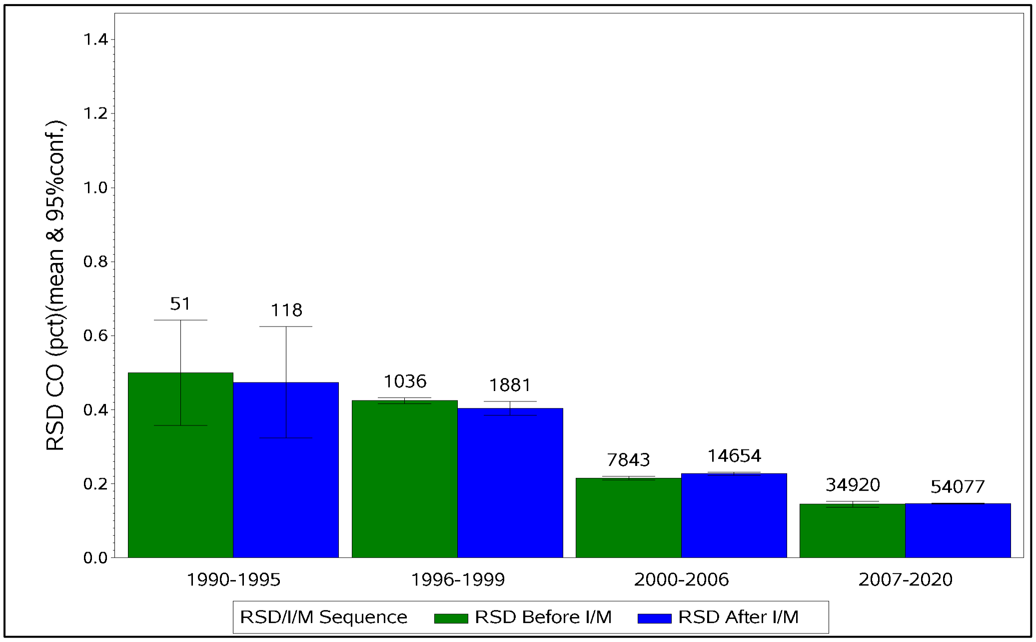


Figure V-20. Average FP RS CO by Model Year Group Before and After I/M Test for DFW Vehicles

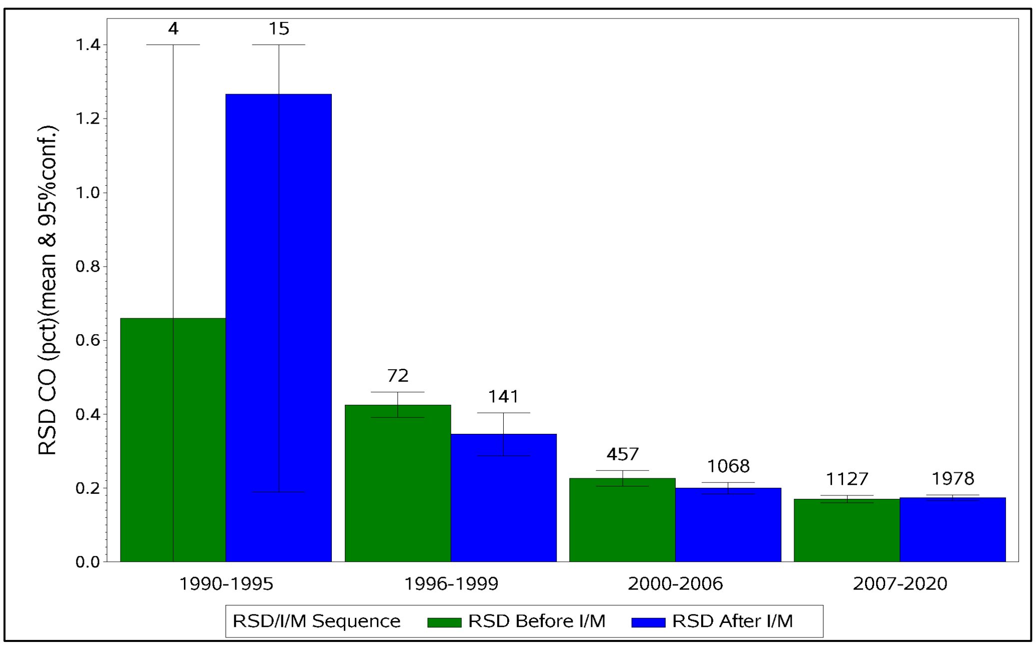


Figure V-21. Average 1P RS NO_X by Model Year Group Before and After I/M Test for HGB Vehicles

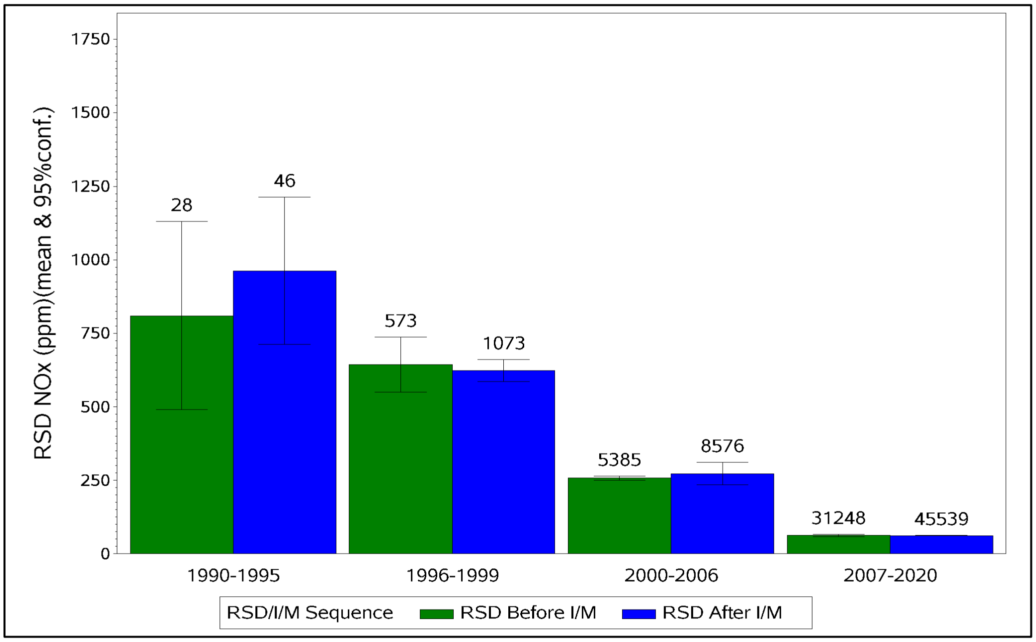


Figure V-22. Average FP RS NO_X by Model Year Group Before and After I/M Test for HGB Vehicles

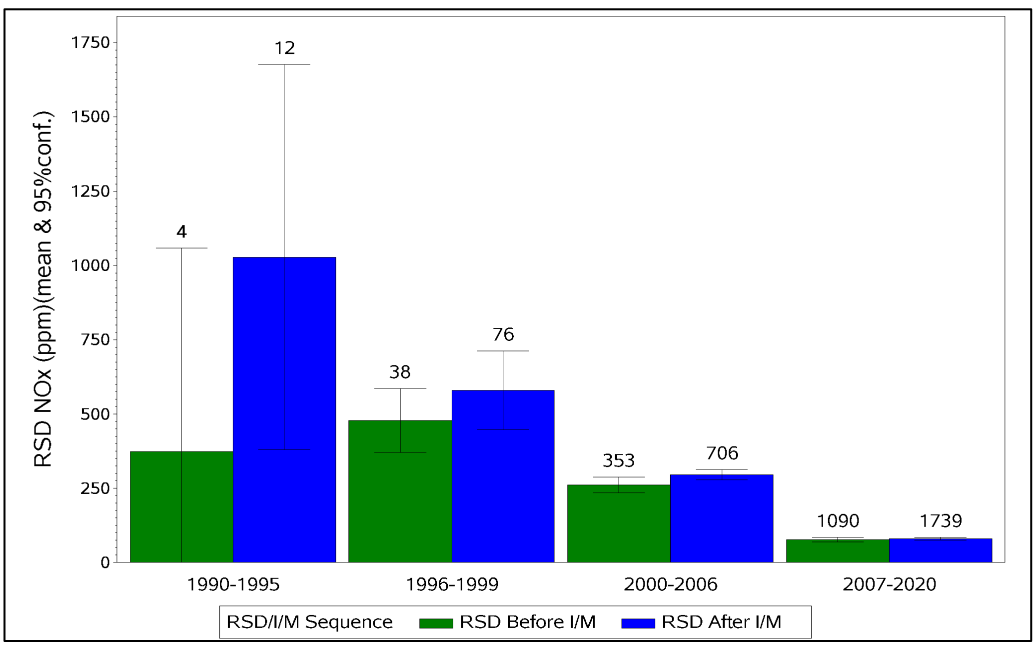


Figure V-23. Average 1P RS NO_X by Model Year Group Before and After I/M Test for DFW Vehicles

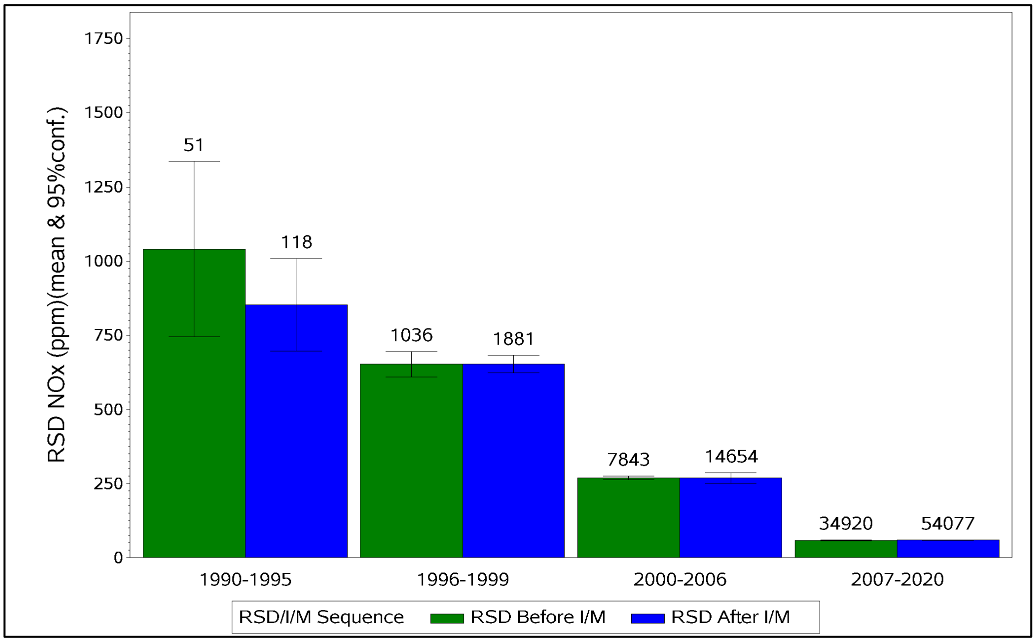
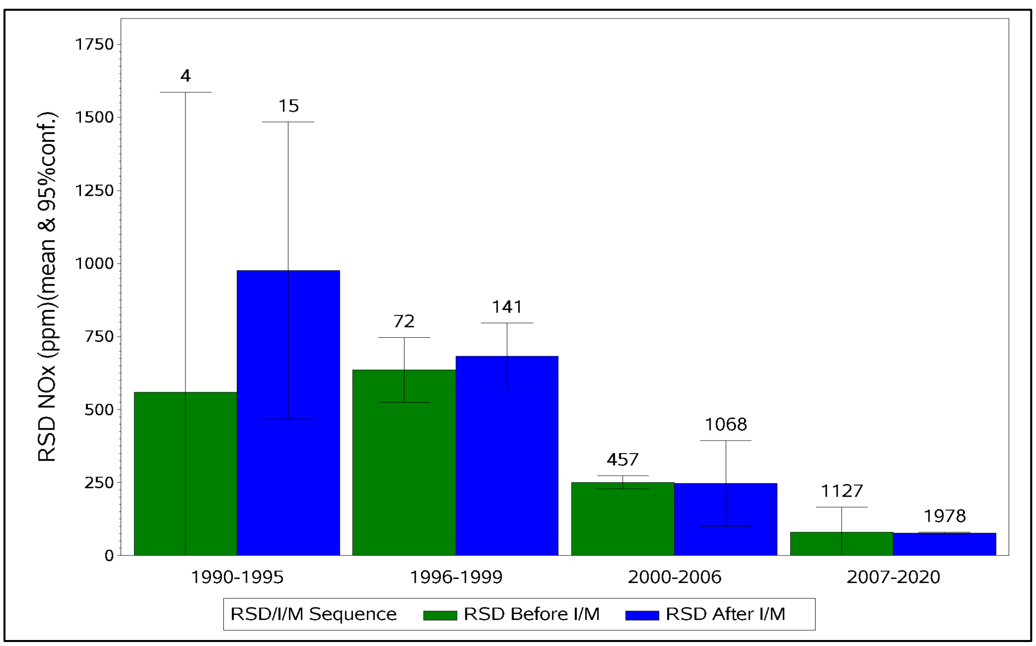


Figure V-24. Average FP RS NO_X by Model Year Group Before and After I/M Test for DFW Vehicles



The RS average concentrations shown in the figures above are summarized in Table V-4 and Table V-5. The values in Table V-4 show that for vehicles that failed and then passed, HC emissions were somewhat reduced (particularly for the populous 2007-2020 model year group), while CO and NO_X levels generally remained constant from before to after the I/M inspection. Table V-5 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-4. RS Averages Before and After an I/M Test for HGB and DFW for I/M Sequence Category = FP

MY Group	RS HC (ppm) Before I/M	RS HC (ppm) After I/M	RS CO (%) Before I/M	RS CO (%) After I/M	RS NOx (ppm) Before I/M	RS NOx (ppm) After I/M
HGB Program Area						
1990-1995	199.8	77.8	3.052	1.044	373	1028
1996-1999	98.0	60.4	0.289	0.340	479	580
2000-2006	41.2	41.9	0.202	0.223	261	295
2007-2020	18.6	13.4	0.151	0.136	77	80
DFW Program Area						
1990-1995	73.3	84.1	0.660	1.266	559	976
1996-1999	130.3	44.6	0.426	0.346	636	683
2000-2006	22.7	19.7	0.227	0.200	251	247
2007-2020	11.7	7.0	0.170	0.174	80	77

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

MY Group	RS HC (ppm) Before I/M	RS HC (ppm) After I/M	RS CO (%) Before I/M	RS CO (%) After I/M	RS NOx (ppm) Before I/M	RS NOx (ppm) After I/M
HGB Program Area						
1990-1995	72.2	108.5	0.291	0.532	810	963
1996-1999	77.4	103.1	0.318	0.392	644	623
2000-2006	44.5	40.2	0.202	0.202	258	273
2007-2020	14.9	11.3	0.113	0.119	63	62
DFW Program Area						
MY Group	**RS HC (ppm) Before I/M**	**RS HC (ppm) After I/M**	**RS CO (%) Before I/M**	**RS CO (%) After I/M**	**RS NOx (ppm) Before I/M**	**RS NOx (ppm) After I/M**
1990-1995	86.3	112.5	0.500	0.474	1040	853
1996-1999	93.9	71.8	0.424	0.404	653	653
2000-2006	35.0	29.8	0.215	0.227	269	269
2007-2020	8.8	7.2	0.145	0.147	58	59

The results in Table V-4 and Table V-5 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-6, 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-7. 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-6. 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	Percent	Number	Percent	Number	Percent	Number	Percent
1990-1995	289	0.2%	31,353	0.4%	162	0.1%	28,953	0.4%
1996-1999	4,893	2.6%	329,198	3.9%	2,870	1.8%	277,586	3.7%
2000-2006	38,081	20.0%	1,949,641	23.1%	24,496	15.5%	1,684,600	22.7%
2007-2020	147,387	77.3%	6,114,727	72.6%	130,314	82.6%	5,443,396	73.2%
Total	**190,650**	**100.0%**	**8,424,919**	**100.0%**	**157,842**	**100.0%**	**7,434,535**	**100.0%**

Table V-7. 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	84,229	17.9	18.9	17.0		0.150	0.153	0.147		108	110	106	
	1P+FP	After	131,699	15.6	16.3	14.9	-13.1%	0.158	0.160	0.155	5.1%	116	118	114	7.7%
	1P	Before	81,084	17.7	18.7	16.7		0.149	0.152	0.146		106	108	104	
	1P	After	125,964	15.5	16.2	14.7	-12.6%	0.156	0.159	0.154	5.3%	114	116	112	7.1%
	FP	Before	3,145	23.1	26.2	20.0		0.187	0.205	0.169		143	155	131	
	FP	After	5,735	17.6	19.6	15.6	-23.8%	0.184	0.196	0.173	-1.4%	163	172	153	13.7%
DFW	1P+FP	Before	45,510	15.8	17.3	14.3		0.166	0.170	0.162		113	116	110	
	1P+FP	After	73,932	13.7	14.7	12.8	-12.8%	0.172	0.175	0.169	3.6%	122	124	119	8.1%
HGB	1P+FP	Before	38,719	20.4	21.5	19.3		0.131	0.135	0.127		102	105	99	
	1P+FP	After	57,767	17.9	19.0	16.8	-12.3%	0.139	0.142	0.136	6.1%	109	111	106	6.7%
DFW	1P	Before	43,850	15.6	17.1	14.1		0.165	0.169	0.160		111	114	108	
	1P	After	70,730	13.8	14.7	12.8	-11.8%	0.171	0.174	0.168	3.7%	120	122	117	7.8%
	FP	Before	1,660	20.0	24.4	15.6		0.198	0.221	0.175		153	170	135	
	FP	After	3,202	13.3	15.3	11.2	-33.7%	0.195	0.211	0.179	-1.5%	165	178	151	8.0%
HGB	1P	Before	37,234	20.2	21.3	19.1		0.129	0.133	0.126		101	103	98	
	1P	After	55,234	17.7	18.8	16.5	-12.4%	0.138	0.141	0.134	6.4%	106	109	104	5.6%
	FP	Before	1,485	26.5	30.9	22.2		0.175	0.202	0.148		132	149	115	
	FP	After	2,533	23.1	26.8	19.4	-13.0%	0.171	0.188	0.154	-2.3%	160	174	145	20.9%

* - 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 were 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 for potential clean-scanning (Section VI.A)
    - VIN from vehicle does not match eVIN (VI.A.1)
    - eVIN is missing (VI.A.2)
    - Powertrain Control Module (PCM), Parameter ID (PID), VIN, and/or not ready status changes between inspections (VI.A.3)
    - Communications Protocol differs from expected (VI.A.4)
  - Additional Inspection Manipulation (Section VI.B)
    - Retest too soon to have performed repairs: a passing retest 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% CO_2 (VI.E.1)
    - ASM or TSI Inspection results with greater than 20.5% 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 eVIN, 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. Fleet inspection stations may also exhibit a different range of results than public stations, but since it is possible that a fleet might have incentive to perform clean-scanned inspections, the fleet inspection stations were retained for this analysis.

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, its possible that clean-scanning has occurred.

Mismatch Between Inspector-Entered VIN and Vehicle-Downloaded eVIN

A majority of the vehicles receiving OBD tests report the VIN electronically. These VINs downloaded with a Mode $09 request from the engine control module are referred to as eVINs. All light-duty 2005 and newer vehicles are required to report eVINs, most 2002-2004 vehicles also report eVINs, and some 1996-2001 vehicles do as well. A comparison of the inspector-entered VIN against the eVIN via the OBD connection can help verify that all OBD inspections are performed on the correct vehicle. Both the inspector-entered VIN and the eVIN are recorded in each vehicle inspection record of the TIMS.

For this analysis, only those OBD inspection records that contained a valid eVIN were used (valid eVINs were confirmed using the checkdigit for the eVIN). This left 14.3 million records in the dataset. For each of these records, the eVIN was compared with the VIN entered (either via keyboard or barcode scan) during the vehicle inspection. Of these, approximately 1% (136,507 records) were found to have VIN-to-eVIN discrepancies. 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 85% of vehicle records containing a discrepancy. Rates were very low for the later model years, largely 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.

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

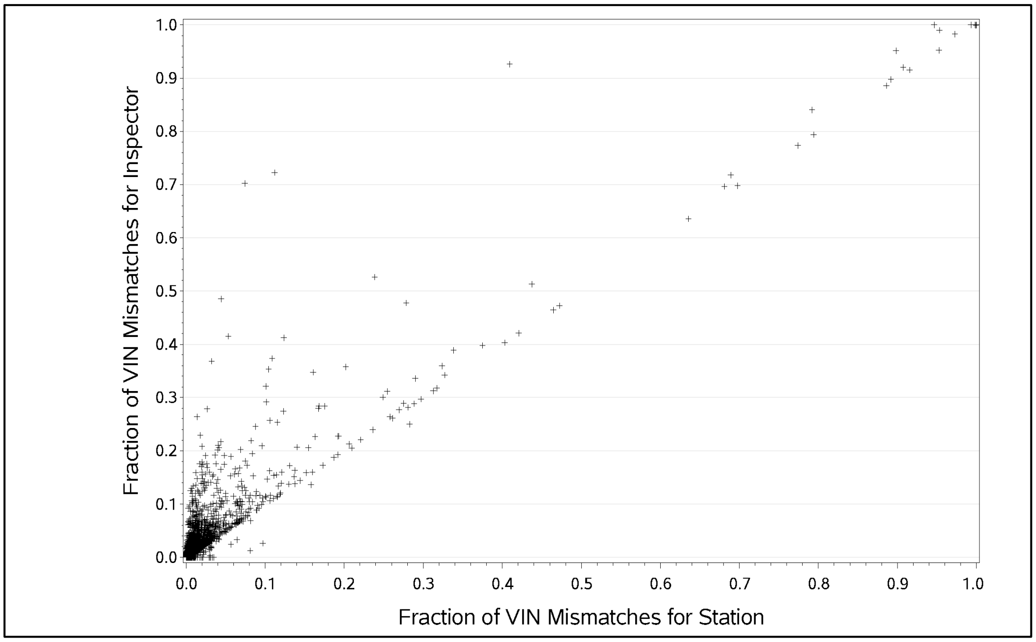
Model Year	Number of OBD Inspections with valid eVIN but VIN Mismatch	Percent of OBD Inspections with VIN Mismatch	Total Inspections With valid eVINs
1996	1,307	84.8%	1,542
1997	2,001	83.4%	2,398
1998	2,409	81.9%	2,940
1999	3,144	77.5%	4,059
2000	4,855	12.9%	37,588
2001	6,947	4.7%	147,140
2002	7,903	4.1%	193,722
2003	8,461	3.6%	237,458
2004	9,171	2.9%	312,466
2005	11,294	1.9%	581,734
2006	11,696	1.7%	675,088
2007	11,837	1.4%	851,170
2008	10,167	1.1%	900,146
2009	5,664	0.9%	639,045

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 eVINs
2010	5,720	0.7%	798,726
2011	5,619	0.6%	919,672
2012	5,861	0.5%	1,106,559
2013	5,662	0.4%	1,327,061
2014	5,321	0.4%	1,436,310
2015	5,320	0.3%	1,629,077
2016	4,373	0.3%	1,493,769
2017	2,298	0.3%	872,176
2018	467	0.3%	147,087
2019	121	0.6%	21,998
2020	3	0.5%	556
Total	**137,621**	**1.0%**	**14,339,487**

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 one 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 eVIN (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 analysis identified that some stations were downloading the same eVIN during different OBD inspections and revealed that Station 1P51942 had downloaded the same eVIN in over 4,700 inspections

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 ten worst offending stations are listed below in Figure VI-2. The table shows the rate at which there was a disagreement between the entered VIN and the eVIN, 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:				
1P53581	100.0%	265	265	100.0
1P51942	99.9%	1,750	1,749	100.0
1P52940	99.9%	4,889	4,729	100.0
1P51856	99.3%	1,184	1,177	99.9
1P52160	97.3%	2,244	831	99.9
1P53353	95.3%	150	77	99.9
1P52601	95.2%	105	79	99.9
1P49682	94.7%	1,853	535	99.9
1P53460	91.6%	273	100	99.9
1P52731	90.7%	1,413	650	99.8

eVIN is Missing

Vehicles of model years 2005 and newer are required to provide an eVIN that is downloaded during every OBD inspection. For this analysis, 14.7 million inspection records for 2005 and newer vehicles that received OBD inspections during the 2-year evaluation period were used. For each of these records, the eVIN was checked and the record flagged if the eVIN was missing. Of the OBD inspections for 2005 and newer vehicles, 1.3 million inspections had a missing eVIN (entirely blank, or entered as "N/A").The counts by model year are given in Table VI-3. Rates are low for the newest model years, and much higher for the older model years, indicating that clean-scanning may be occurring.

Table VI-3. Rates of OBD Inspections without eVIN, by Model Year

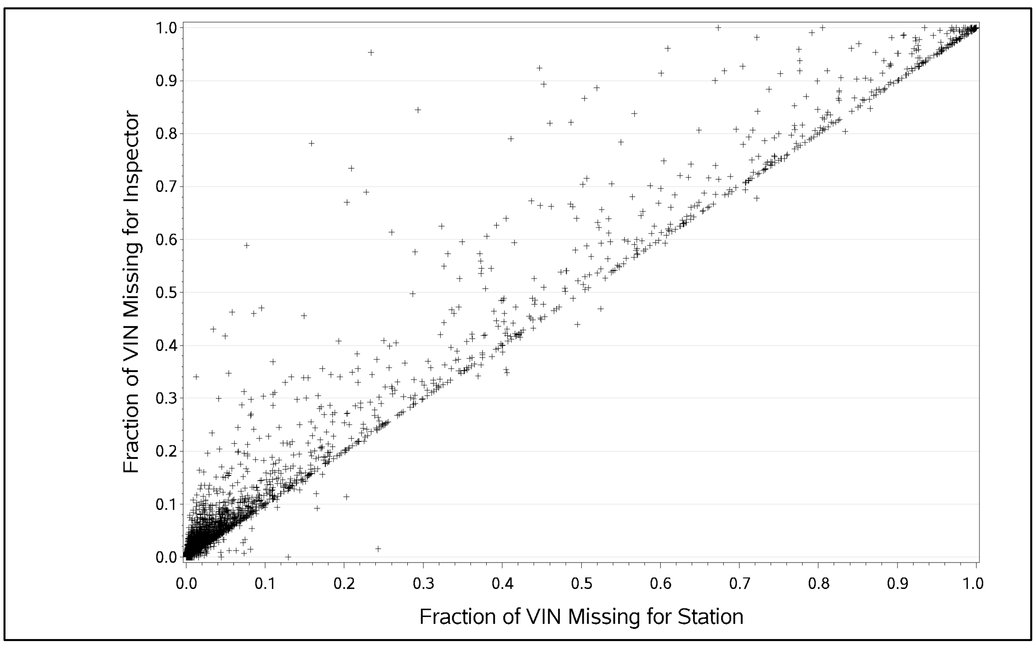
Model Year	Number of OBD Inspections with Missing eVIN	Percent of OBD Inspections with Missing eVIN	Total OBD Inspections
2005	174,741	23.0%	759,816
2006	176,918	20.7%	853,044
2007	189,449	18.2%	1,041,782
2008	155,715	14.7%	1,057,030
2009	86,810	11.9%	726,553
2010	82,443	9.3%	881,807
2011	83,271	8.3%	1,003,773
2012	79,720	6.7%	1,187,156
2013	72,537	5.2%	1,400,460
2014	61,473	4.1%	1,498,537
2015	54,260	3.2%	1,683,959
2016	40,954	2.7%	1,535,080
2017	20,635	2.3%	892,902

Table VI-3. Rates of OBD Inspections without eVIN, by Model Year

Model Year	Number of OBD Inspections with Missing eVIN	Percent of OBD Inspections with Missing eVIN	Total OBD Inspections
2018	3,922	2.6%	151,013
2019	807	3.5%	22,805
2020	34	5.8%	590
Total	**1,283,689**	**8.7%**	**14,696,307**

The rate at which eVINs were missing was calculated for each station that performed OBD inspections, and for each inspector. These are compared graphically in Figure VI-2. The horizontal axis shows the fraction of OBD inspections that contained no eVIN for each station, while the vertical axis shows the fraction of OBD inspections that contained no eVIN 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 OBD inspections almost always included an eVIN. The points closer to one on the horizontal or vertical axis indicate stations or inspectors that almost never performed OBD inspections that contained an eVIN.

Figure VI-2. Rates of OBD Inspections without eVIN, by Station and Inspector



These findings of missing eVINs were condensed into a rank for each station based on the fraction of inspections that did not include an eVIN. 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 missing-eVIN rates for the ten worst offending stations are listed below in Table VI-4. The table shows the rate at which the eVIN was missing from OBD inspections performed on model year 2005 and newer vehicles at the station.

Table VI-4. Stations with Highest Rates of Inspections without Downloaded eVINs

Station ID7	Percent of Inspections Without eVIN	Total Number of Inspections Performed at Station	Percentile Rank for Station
Ten worst stations:			
2P53085	100.0%	1,278	100.0
1P54102	100.0%	779	100.0
1P54067	100.0%	687	100.0
1P54059	100.0%	251	99.9
1P53797	100.0%	710	99.9
1P53259	100.0%	225	99.9
1P53027	100.0%	275	99.9
1P52830	100.0%	124	99.9
1P52349	100.0%	4,979	99.9
1P52184	100.0%	800	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 retests of that same vehicle. Certain types of OBD information may be combined to create unique "electronic profiles" for each vehicle, and the electronic profile should be the same at the initial inspection and at subsequent inspections. If the electronic profile changes from one inspection to the next, inspection fraud may be suspected. For this analysis, only those vehicle inspection cycles that included an initial test and at least one retest were used, and only records where readiness monitor values were present were used, reducing the dataset from 18 million OBD inspections to 1.6 million inspections. This includes 765,000 initial inspections, and 842,000 retests.

In earlier years of performing this I/M Evaluation (2016 and earlier), three variables were used to create the first "electronic profile" for each vehicle: the eVIN, the PCM ID, and the PID Count. For the 2018 analysis and this current 2020 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:

- eVIN: eVINs (valid or invalid) were only available in 76% of the test records. The eVIN or the manually entered VIN was missing in the remaining 24% of the OBD test records. The 24% that did not download correctly could be due to factors other than inspection fraud, including the vehicles age, i.e. older vehicles with nonstandard eVINs. Because of this, use of the eVIN alone would not be sufficient to positively identify clean-scanning.

- PCM ID: The PCM ID was available in all but 66 of the test records. Eighty-one unique PCM IDs were seen, but 47% of all PCM IDs had a value of "E8" and 33% had a value of "10." One other PCM ID represented another 39% of records, three other PCM IDs each comprised an additional 1-3% of the test records, and the remaining test records were distributed among the other PCM IDs. Because of this, as with the eVIN, use of PCM ID alone would not be sufficient to positively identify clean-scanning (a substituted vehicle could easily have a value of "E8" or one of the other most common PCM IDs).
- PID Count: There were 83 unique PID Count values were seen, and all but 1,550 OBD test records contained a value for PID Count. Seven PID Count values were seen in 54% of all OBD test records, while the remaining test records contained one of the remaining PID Count values. Therefore the use of the PID Count alone would not be sufficient to positively identify clean-scanning.
- COMM_PROT: There were seven unique values were seen, and all but three OBD test records contained a value for the COMM_PROT. Two COMM_PROT values were used for 72% 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 60% of the OBD records, meaning that the other 40% of OBD records have the same values (missing) for these variables, and the CVN and CAL_ID combination alone would not be sufficient to positively identify clean-scanning.
- When the PCM ID, PID Count, COMM_PROT, CAL_ID, and CVN are looked at in combination, the three most common combinations of these variables comprise 4, 3, and 3% of inspections respectively, 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 for identifying when a different vehicle is being substituted for the test.

The second electronic profile that was created was an "enabled profile." For this analysis, OBD readiness monitors were identified that are commonly found to be both "monitored" and "not monitored," depending on the make/model/model year of vehicle being inspected. For example, very few vehicles have monitored positive crankcase ventilation or air conditioning systems, so these would be poor indicators of potential clean-scanning since the monitored status is almost surely the same for two different vehicles. Similarly, catalysts and oxygen sensors are almost always monitored, so these too would be poor indicators of potential clean-scanning. Again, two different vehicles will likely both have these monitored. As shown below, EGR systems, 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: There were 32% not monitored, 68% monitored;
- Evaporative systems: There were 3% not monitored, 97% monitored;
- Heated O_2 systems: There were 2% not monitored, 98% monitored;
- Secondary air systems: There were 94% not monitored, 6% monitored; and
- When the status of the four monitors is looked at together, two combinations of monitor status dominated the dataset, with 63% and 26% of vehicles. Smaller numbers of vehicles comprised the remaining 16 combinations and 11% 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 retest inspection were excluded from the analysis.

Occasionally, analyzer hardware upgrades or software updates could result in OBD system PID count mismatches between multiple tests on the same vehicle, and the eVIN 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 765,000 initial inspections and 842,000 retests. Retests that took place on an analyzer from a different manufacturer than the initial test were excluded from the results, leaving 755,000 retests for analysis. The results of the analysis were:

- There were 605,332 (80.2%) retests that had matches for both the electronic profile and the readiness profile between initial test and subsequent retests on the same analyzer. These tests very likely indicate compliant testing.

- There were 33,287 (4.4%) retests that had a mismatch for both the electronic profile info and the readiness profile, between the initial test and at least one retest on the same analyzer. Test pairs where both computer ID information and readiness profile differ are likely to be performed on two different vehicles (i.e., an indication of clean-scanning).
- There were 616 (0.1%) retests that had a "readiness profile" mismatch between the initial test and at least one retest on the same analyzer, but the electronic profile matched between the initial test and all subsequent retests on the same analyzer. This scenario is difficult to interpret, since the readiness profile is based on "monitored 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 these difficulties in interpreting these 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.
- There were 115,431 (15.3%) retests that had an electronic profile mismatch info between the initial test and at least one retest on the same analyzer, but the "readiness profile" matched between the initial test and all subsequent retests on the same analyzer. Since the computer ID serves as a unique identifier for any vehicle, this information should always match for retests on the same vehicle. A mismatch could occur only if another vehicle was substituted for a retest (clean-scanning), if an anomaly in the analyzer software interpreted the computer ID information two different ways on subsequent retests for the same vehicle, or if a vehicle repair was performed in which the vehicle's PCM was re-programmed with new ID information 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 thought to be a good indicator of clean-scanning.

A summary of this information is provided in Table VI-5.

Table VI-5. Percentages of Tests with Various OBD Fraud Indicators

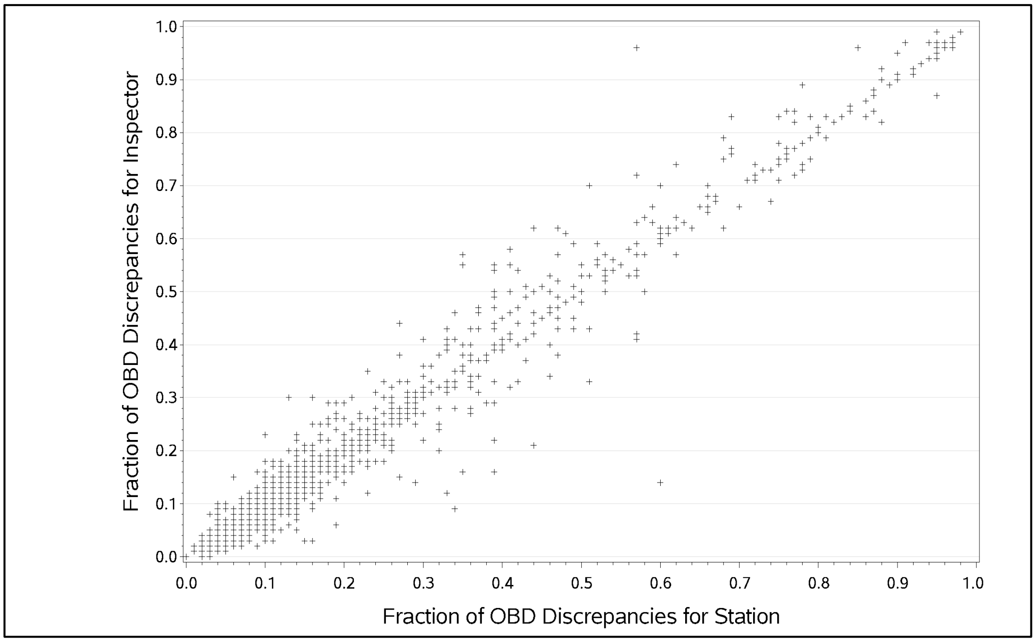
Retest Match Scenario	Retest-only Dataset
All match (compliant)	80.2 %
Readiness mismatch (ambiguous)	0.1 %
PCM ID info mismatch (fraud likely)	15.3 %
Both mismatch (fraud very likely)	4.4 %
Estimated % of clean-scanning	4% to 19%

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.

- From January 1, 2018 through December 31, 2019, 94% of the 5,869 inspection stations had at least one test record with either a readiness profile or computer ID information mismatch between an initial test and a subsequent test for the same vehicle (tested using the same analyzer as the initial test). The maximum number of mismatch retest records for any one station was 1,821 records over the two-year period, and another 81 stations had more than 200 records with a mismatch. Some stations had mismatch rates as high as 90%, meaning 90% of the retest inspections performed at the station showed a mismatch in the readiness profile or computer ID information. These stations are almost certainly using clean-scanning to help failing vehicles to pass the retest.
- From January 1, 2018 through December 31, 2019, 63% of the 32,924 inspectors had at least one test record with either a readiness profile or computer ID information mismatch between an initial test and a subsequent test on the same vehicle using the same analyzer. The maximum number of mismatch retest records for any one inspector was 732 records over the two-year period, while an additional 28 inspectors had more than 200 mismatch retest records. Inspector mismatch rates as high as 85% were identified.

The distribution of station and inspector mismatch rates is shown in Figure VI-3. The horizontal axis shows the fraction of retest records that contained an electronic profile or readiness profile mismatch for each station. The vertical axis shows the fraction for each inspector. The large concentration of data points in the lower left corner are stations and inspectors that produced retest records that rarely had a mismatch when compared to the information from the initial inspection. In contrast, the stations/inspectors in the upper right-hand portion of the chart are those that are most likely to be clean-scanning.

Figure VI-3. Rates of Retest Discrepancies in OBD Computer and Readiness Information, by Station and Inspector



These results were condensed into a rank for each station, based on the fraction of retest inspections performed at that station that included both an electronic profile mismatch and a readiness profile mismatch. Stations with fewer than 100 OBD retest inspections over the two-year period were excluded from the results, due to the possibility of spurious results from the small sample size. The ten stations with the highest rates of profile mismatches are listed in Table VI-6. Some electronic profile and/or readiness mismatches are to be expected, and as mentioned above, 95% 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% of retest inspections resulted in a readiness profile and electronic profile mismatch. When stations with a mismatch in as many as 90% of their inspections are seen, it suggests fraudulent testing is being performed.

Table VI-6. 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:			
1P49384	93.1%	173	100.0
1P53266	92.6%	108	100.0
1P50856	91.2%	171	99.9
1P51619	87.6%	226	99.9
1P51856	86.7%	623	99.8
1P49313	86.0%	471	99.8

Table VI-6. 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:			
2P52905	82.4%	108	99.7
2P44831	75.9%	166	99.7
1P48652	74.5%	919	99.7
1P49388	73.5%	166	99.6

Comparison of Downloaded and Expected Communication Protocol

This year, as an additional OBD-based inspection analysis, the OBD communications protocol indicator (TX96_COMM_PROT) was evaluated. This variable will have one of seven values, representing the six EPA approved communications protocols for vehicles sold in the U.S., or "N"one, as shown in Table VI-7.

Table VI-7. OBD Communications Protocol Codes

Code	Protocol
C	CAN
D	CAN
P	PWM
I	ISO
V	VPW
K	KWP
N	(none found)

In theory, each type of vehicle that is manufactured uses one of the protocols, and all vehicles of the same type use the same protocol[6].

ERG's subcontractor, de la Torre Klausmeier Consulting, Inc. (dKC) has worked extensively with comparisons of expected communication protocols with the communication protocols recorded during the OBD test, for various I/M areas. For such comparisons, dKC constructed a look-up table of communication protocols by VIN stem (digits 1-8 plus digits 10 and 11), using reliable data from a highly controlled, centralized I/M inspection program.

ERG matched the dKC look-up table to the two-year inspection dataset. The VIN stems in the look-up table cover about 2/3 of 1996-2009 model year vehicles in the dataset. Results by model year are shown in Table VI-8. The overall mismatch rate was much higher for passing tests than failing tests: 16% vs. 1%. The mismatch rate is very high

[6] It is known that Chrysler vehicles from model years 1999-2005 have exhibited unreliable communications protocol values, so 1999-2005 Dodge, Jeep, and Chrysler makes were excluded from analysis in this section.

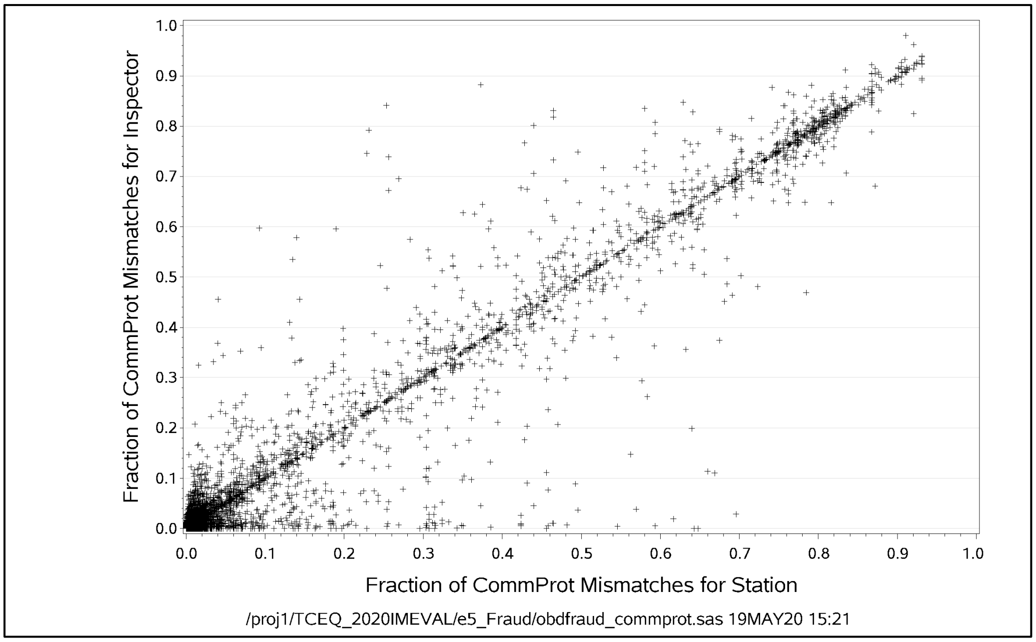
for vehicles with older model years where inspection fraud might be used to help the vehicle pass the inspection.

Table VI-8. Rates of Communication Protocol Mismatches, by Model Year

Model Year	Mismatches: Failed Inspections		Mismatches: Passed Inspections	
	Number of Fails with Mismatch	Percent of Fails that had Mismatch	Number of Passes with Mismatch	Percent of Passes that had Mismatch
1996	4,953	1.5%	45,315	23.5%
1997	7,410	1.3%	75,240	21.1%
1998	8,378	1.3%	101,243	18.2%
1999	8,990	1.2%	113,178	18.3%
2000	13,525	1.2%	173,938	19.2%
2001	23,796	1.2%	201,813	21.1%
2002	23,295	1.2%	233,428	18.5%
2003	25,583	1.2%	291,386	16.8%
2004	26,408	1.1%	338,012	15.9%
2005	27,620	1.1%	366,972	15.4%
2006	32,998	1.2%	459,759	16.5%
2007	30,501	1.1%	533,129	14.9%
2008	29,277	1.0%	567,578	13.9%
2009	17,728	0.8%	411,190	11.1%
Total	**280,462**	**1.1%**	**3,912,181**	**16.0%**

The rate at which communication protocol mismatches were recorded was calculated for each station that performed OBD inspections and for each inspector. These are compared graphically in Figure VI-4. The horizontal axis shows the fraction of OBD inspections that contained a communication protocol mismatch for each station, while the vertical axis shows the fraction of OBD inspections with a mismatch 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 very low rate of communication protocol discrepancies. The points closer to one on the horizontal or vertical axis indicate stations or inspectors that almost always produced OBD records with a communication protocol discrepancy.

Figure VI-4. Rates of Communication Protocol Mismatches, by Station and Inspector



These results were condensed into a rank for each station, based on the fraction of inspections at that station that included a communication protocol mismatch. Stations with fewer than 100 OBD 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 ten stations with the highest rates of mismatches are listed in Table VI-9. Some mismatches are to be expected, and most stations had at least one case of a mismatch. However, most of those stations had only one or a few mismatches. Overall, about 16% of inspections resulted in a communication protocol mismatch. As stated earlier, when stations have this high a level of mismatch it suggests fraudulent testing.

Table VI-9. Stations with Highest Percent of Communication Protocol Mismatches

Station ID	Percent of Inspections with Communication Protocol Mismatch	Number of Inspections at Station	Percentile Rank for Station
Ten worst stations:			
2P48302	93.1%	9054	100.0
1P51546	93.1%	144	100.0
1P54059	92.5%	358	100.0
1P42139	92.4%	2937	99.9
1P52539	92.1%	812	99.9
2P51438	92.1%	2981	99.9
2P53738	91.5%	989	99.9
1P54125	91.3%	985	99.9
1P51708	91.2%	5127	99.9
1P52170	91.1%	2036	99.8

B. ADDITIONAL INSPECTION MANIPULATION

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 overall but are relatively common for a handful of stations.

- Short Time Interval Between Inspections: 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 or clean-scanning.
- Changing from ASM to TSI Inspection to Pass: Occasionally, a vehicle receives an initial inspection that is an ASM test and is followed by a retest inspection that is a TSI test. When such switches occur a large number of times at a single station, and when the test results also show that most of the ASM tests were failed for high NO_X levels (NO_X is not measured in a TSI test), it is likely to indicate a version of inspection fraud.
- Changing from Light-Duty to Heavy-Duty to Pass: 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, but much more frequently at some stations.
- Pass/Fail Outliers: 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 retest (or retests) usually follows a day or several days after the initial failed inspection. Presumably, repairs are performed during that interval between inspections. However, some failing inspections are followed by a passing inspection within minutes, raising concern as to how the vehicle was successfully repaired so quickly, or if instead clean-piping or clean-scanning occurred for the passing retest. The dataset shows that many stations have one or a few cases of a passing retest following a failing initial test within a short time.

These occasional cases may be the real result of a simple fix: a reconnection of a loose line or wire or other simple change, or from retesting a vehicle that previously had not been properly warmed-up. Some vehicles that 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 18.1 million observations in the dataset. In addition, only time differences on retest inspections that were conducted at the same inspection station as the initial inspection were used. This resulted in a dataset of about 664,798 retest observations.

The distribution of the number of times that a failed initial inspection was followed by a passing retest within 15 minutes at a given station over a 2-year period is listed in Table VI-10. The table shows that this happened rarely or never for most stations. However, for 81 stations, it happened 20 or more times (up to 69 times for the highest station, not shown in the table).

Table VI-10. Number of Close-in-Time Retests per Station

Number of Close-In-Time Retests	Number of Stations	Percent of Stations
0	2,048	35.1%
1	1,180	20.2%
2	743	12.7%
3	515	8.8%
4	328	5.6%
5	251	4.3%
6	156	2.7%
7	117	2.0%
8	77	1.3%
9	63	1.1%
10	45	0.8%
11	48	0.8%
12	37	0.6%
13	34	0.6%
14	22	0.4%
15	33	0.6%
16	19	0.3%
17	16	0.3%
18	14	0.2%
19	9	0.2%
20 or more	81	1.4%
Total	**5,836**	**100.0%**

The ten stations with the highest rate of close-in-time retests are listed in Table VI-11. The percentage was calculated from the number of close-in-time retests and the total number of retests at that station. Stations that performed fewer than 100 retest inspections over the 2-year period are excluded from the results. From the Table VI-11, the highest ranked stations performed a third of their retest inspections within the short time period of 15 minutes or less after the initial passed inspection.

Table VI-11. Percent of Close-In-Time Retest Inspections for Ten 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	40.6%	43	106	100.0
1P49313	33.3%	47	141	99.9
1P52940	31.4%	50	159	99.9
2P50838	22.2%	38	171	99.8
2P45169	20.4%	33	162	99.8
1P33099	18.9%	36	190	99.7
2P38998	18.6%	26	140	99.7
2P52536	17.8%	28	157	99.6
2P27671	17.7%	25	141	99.6
1P28886	17.2%	23	134	99.5

Changing Vehicle Type from Light-Duty to Heavy-Duty 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. However, this analysis could not be performed this year, as the number of tailpipe inspections in the dataset has become too small to be useful.

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 18.1 million inspection records. Only inspection cycles where the initial inspection and the retest inspection were conducted at the same station were used. This left 664,819 retest inspections in the dataset.

Overall, it was found that only 0.23% of inspections that were initially failed as a light-duty vehicle were followed by a passing retest as a heavy-duty vehicle. However, these inspections were clustered at a handful of stations, shown below in Table VI-12. The table shows the ten inspection stations with the highest frequency of retests that involved a vehicle that failed as a light-duty vehicle on the initial inspection followed by a passed retest of the same vehicle as a heavy-duty vehicle. At the first station on the list, about 14% of vehicles that failed as a light-duty vehicle passed the retest when the inspector entered it as a heavy-duty vehicle.

Table VI-12. Percent of Retest Inspections Switched from Light-Duty to Heavy-Duty, for Ten 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
1P48501	13.8%	18	130	100.0
1P02394	10.9%	29	265	99.9
2P40519	9.8%	12	123	99.9
2P50138	7.4%	10	136	99.8
2P33039	6.9%	19	274	99.8
1P50995	6.9%	18	260	99.7
2P50479	6.3%	11	174	99.7
1P44732	5.8%	7	120	99.6
1P42030	5.6%	11	196	99.6
1P51241	5.6%	15	269	99.5

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 previously 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. This year, it was found that the number of ASM inspection stations has become so small that it is not meaningful to rank them, so the current analysis was only performed for OBD inspections.

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% rank for the station at the mean and the 100% rank for the station with the highest failure rate. The stations with a failure rate that was below the mean were ranked with the 0% rank for the station at the mean, and the 100% rank for the station with the lowest failure rate. Thus, each station gets one rank, either for being high or being low. The highest OBD failure rate stations are listed in Table VI-13, with failure rates for OBD inspections listed separately. The lowest failure rate stations are listed in Table VI-14 with failure rates for OBD and ASM inspections listed separately. Stations with fewer than 100 inspections are excluded from the results.

Table VI-13. Stations with Highest OBD Failure Rates

Station ID	Failure Rate (%)	Number of Failed Inspections	Total Number of Inspections	Percentile Rank for Station
OBD Inspection Results:				
1P52793	31.5%	41	130	100.0
2P22761	28.9%	52	180	100.0
2P53253	25.7%	48	187	99.9
2P32154	23.4%	701	2991	99.9
1P48662	22.9%	136	593	99.8
1P51765	22.8%	37	162	99.8
1P50869	22.0%	38	173	99.7
1P39937	21.6%	30	139	99.7
1P45546	21.6%	74	343	99.7
1P53788	20.9%	23	110	99.6

Table VI-14. Stations with Lowest OBD Failure Rates

Station ID	Failure Rate (%)	Number of Failed Inspections	Total Number of Inspections	Percentile Rank for Station
OBD Inspection Results:				
2P54068	0.0%	0	284	100.0
2P53885	0.0%	0	380	100.0
2P53404	0.0%	0	662	99.9
2P53326	0.0%	0	135	99.9
2P53020	0.0%	0	332	99.9
2P50833	0.0%	0	335	99.8
2P49229	0.0%	0	127	99.8
2P41885	0.0%	0	111	99.8
1P54197	0.0%	0	170	99.8
1P53662	0.0%	0	134	99.7

C. REPEATED USE OF ANALYZERS WITH LESS-THAN-OPTIMAL FUNCTIONALITY

The accuracy of vehicle inspection results and the quality of the data stored in the TIMS database depend 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% of stations were found to have had at least one or more calibrations on initially out-of-tolerance analyzers; however, the worst stations that are shown in Table VI-15 had all or almost all calibrations on out-of-tolerance analyzers.

Table VI-15. 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
2P51111	ES922344	100.0%	52	52	100.0
1P45494	ES419444	100.0%	59	59	99.9
2P33169	ES315210	99.0%	95	96	99.7
1P06811	ES212909	98.9%	90	91	99.6
2P53250	ES317050	98.8%	79	80	99.5
2P48302	ES213051	97.9%	142	145	99.3
1P34166	ES212764	97.9%	47	48	99.2
2P45712	ES315076	97.7%	42	43	99.1
1P44334	ES214034	97.7%	42	43	98.9
2P48685	ES213054	97.6%	40	41	98.8

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 their audits. The ten stations with the highest span gas audit failure rates are shown below in Table VI-16.

Table VI-16. 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
1P50375	ES821659	100.0%	6	6	100.0
1P47578	ES315095	100.0%	6	6	99.9
1P46034	WW510188	100.0%	7	7	99.7
1P41962	SE430022	100.0%	6	6	99.6
1P06605	ES112525	90.0%	9	10	99.5
1P48117	ES520470	87.5%	7	8	99.4
1P50613	SE910126	85.7%	6	7	99.2
1P45105	ES922009	85.7%	6	7	99.1
1P30479	ES212914	85.7%	6	7	99.0
1P52955	SE490330	83.3%	5	6	98.9

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. The analysis in Section III.D identified 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-17, 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-17. 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
1P31791	WW510401	25.8%	470	1,822	100.0
1P39100	WW510502	17.1%	42	246	99.9
2P31529	WW510301	16.6%	352	2,117	99.9
2P38578	WW510565	14.7%	236	1,608	99.8
2P40148	WW510619	14.6%	291	1,988	99.7
2P39188	WW510141	14.3%	202	1,415	99.7
2P38915	WW510330	12.3%	226	1,837	99.6
2P12485	SE450109	11.6%	17	147	99.6
1P38474	WW510509	10.6%	128	1,209	99.5
1P31631	SE110629	10.4%	251	2,415	99.4

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 were 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% 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-18. Stations that performed fewer than 100 inspections following repairs are excluded from the results.

Table VI-18. Miscellaneous Repair Percentage

Station ID	Percent of “Misc” repairs	Number of “Misc” repairs	Total Repairs	Percentile Rank for Station
1P31791	100.0%	140	140	100.0
1P39423	100.0%	232	232	99.9
1P48945	100.0%	113	113	99.9
2P42066	99.5%	205	206	99.8
1P50734	99.2%	253	255	99.8
2P03448	99.2%	123	124	99.7
1P11407	99.2%	117	118	99.7
2P39787	99.0%	102	103	99.6

Table VI-18. Miscellaneous Repair Percentage

Station ID	Percent of "Misc" repairs	Number of "Misc" repairs	Total Repairs	Percentile Rank for Station
2P40123	97.9%	138	141	99.6
2P36730	97.1%	101	104	99.5

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-19. Stations that performed fewer than 100 inspections following repairs are excluded from the results.

Table VI-19. Zero-Cost Repair Percentage

Station ID	Percent of $0 Repairs	Number of $0 Repairs	Total Number of Repairs	Percentile Rank for Station
1P00552	100.0%	173	173	100.0
1P11407	100.0%	118	118	99.7
1P17052	100.0%	194	194	99.4
1P18013	100.0%	225	225	99.0
1P27010	100.0%	627	627	98.7
1P31791	100.0%	140	140	98.4
1P31959	100.0%	153	153	98.1
1P33509	100.0%	172	172	97.8
1P36648	100.0%	364	364	97.5
1P39332	100.0%	101	101	97.1

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. In the 2018 analysis, records with a bad check digit in the VIN comprised fewer than 0.001% of inspections (483 total bad check digits out of 9.6 million inspections), so the check digit analysis was dropped from further program evaluations and was not performed for the 2020 evaluation.

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% of the vehicles that participate in the program have a repair sequence of either pass (P) or fail-repair-pass with three or fewer retests 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-20 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-20. 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	13.2%	47	356	100.0
1P51817	7.1%	11	154	100.0
1P52185	6.2%	932	15,037	100.0
1P52261	4.9%	7	143	99.9
1P32891	4.9%	5	103	99.9
1P52520	4.7%	7	148	99.9
1P53857	4.6%	5	108	99.9
1P53706	4.5%	7	157	99.9
1P52789	4.4%	10	226	99.8
1P39565	4.4%	10	227	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%, 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-21 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-21. Percent of Inspections with CO_2 Greater Than 16%

Station ID	Percent of Inspections with CO_2 Greater Than 16%	Number of Inspections with CO_2 Greater Than 16%	Total Number of Inspections for Station	Percentile Rank for Station
1P26940	18.1%	43	238	100.0
2P50456	17.2%	27	157	99.6
1P29282	8.8%	16	182	99.2
1P17230	8.3%	11	132	98.8
1P44782	8.3%	11	133	98.4
2P41898	7.5%	13	173	98.1
2P22796	6.7%	13	193	97.7

Table VI-21. Percent of Inspections with CO_2 Greater Than 16%

Station ID	Percent of Inspections with CO_2 Greater Than 16%	Number of Inspections with CO_2 Greater Than 16%	Total Number of Inspections for Station	Percentile Rank for Station
2P01268	6.6%	8	121	97.3
1P31916	5.8%	10	173	96.9
1P36334	5.6%	8	144	96.5

Tailpipe Inspections with O_2 Greater than 20.5%

Table VI-22 presents stations with a high percentage of vehicles whose ASM or TSI tests produced O_2 readings greater than 20.5%, which is outside the normal combustion range and is very close to the ambient O_2 concentration of 20.9%. Stations that performed fewer than 100 inspections are excluded from the table.

Table VI-22. Percent of Inspections with O_2 Greater Than 20.5%

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
1P31631	95.6%	280	293	100.0
2P39391	94.4%	167	177	99.6
2P10331	90.8%	109	120	99.2
2P31968	89.5%	111	124	98.8
1P02394	82.0%	146	178	98.4
2P40140	81.4%	96	118	98.1
2P48727	80.7%	146	181	97.7
1P40377	80.0%	124	155	97.3
1P34604	77.9%	95	122	96.9
1P26940	71.0%	169	238	96.5

Tailpipe Inspections with High DCF Differences

Table VI-23 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. The table lists the top ten stations that had differences between the two DCFs for every inspection. It should be noted that there is overlap between the results in this section and the results in the previous two sections (CO_2 greater than 16% and O_2 greater than 20.5%), 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-23. 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

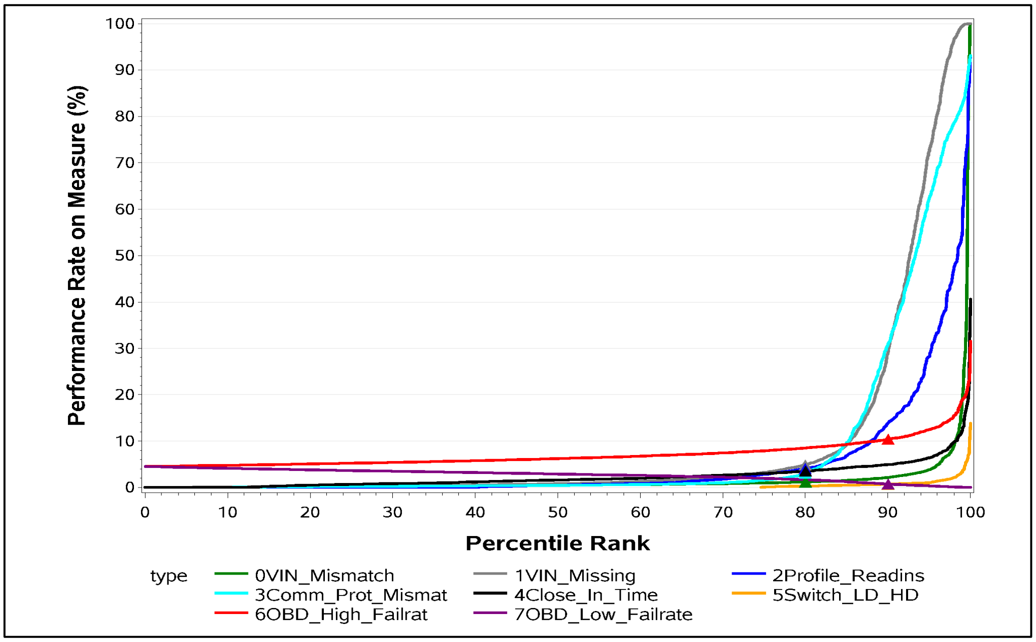
F. COMPILATION OF PERCENTILE RANKINGS

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

Some of the details of the ranking procedure and the resulting ranks make it challenging to combine the ranks for an overall score. First, most stations did not perform enough inspections of one type or another (i.e., OBD retests, ASM inspections, etc.) to receive a rank for all of the measures. Secondly, it is known from the measures listed in the previous sections that the range of results was not the same for each measure. For example, for the eVIN mismatch section, about 80% of stations had very low VIN mismatch rates. The remaining 20% had VIN mismatch rates that might be cause for concern, or about the top 20 percentiles in the ranking. In contrast, for the high OBD inspection failure rates, at least 90% of stations had reasonably low rates, and only the top 10% of stations would lead one to suspect possible fraud. Figure VI-5 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 line for the eVIN mismatch shows that the stations from zero to the 80th percentile had a very low percentage of mismatches. Above the 80th percentile, the mismatch rate quickly increases. Similarly, the blue line for the OBD electronic readiness profile shows that stations up to the 80th percentile had a low rate of mismatches. For the other measures, missing eVIN, rate of OBD communication protocol mismatch, the rate of overly close in time inspections, and retests switched from light-duty to heavy-duty, the stations below about the 80th percentile also had very low results. Above the 80th 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.

Figure VI-5. 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-5, it is probably not likely that the station is performing the 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 stations were then sorted in descending order according to the number of flags received to create a final list ordered from most suspicious to least suspicious. The results for the top 50 most suspicious stations are given in Table VI-24. Table VI-25 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 other analysis tools or audits). For example, the first station, 2P48434, had a very high rate of eVIN mismatches, high rates of OBD readiness and electronic profile mismatches, and a high rate of OBD communication protocol 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, as well as a very high OBD inspection failure rate. 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 station 2P48434 would be a good candidate for an audit. By contrast, in the second line, station 2P37659 had high rates of eVIN mismatches, OBD readiness and electronic profile mismatches, and OBD communication protocol 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-6 shows the distribution of the results vs. the percentiles for each of the measures. Some of the "break" points are difficult to discern, such as that for the green line, which is for calibrations that began with the analyzer out of tolerance. After consideration of Figure VI-6, 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 80th percentile for stations entering repair types as "Misc," the 40th 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.

The results for the top 50 worst-performing stations for errors of omission are listed in Table VI-24. 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% and O_2 greater than 20.5%. Again, the table could be used to identify different types of enforcement that are indicated by the combinations of results on each line.

Finally, one additional 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-7. Each of the eight different types of errors of commission is shown on the plot (this is the same group of categories as was shown in Figure VI-5). 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 green line (VIN/eVIN mismatch), we can see that at the zero-percentile group, the fraction of stations in that group is 69% DFW (and by inference, 31% HGB). At the 10th decile group, we see about 66% of stations are from the DFW program area (and so 34% from the HGB program area). By contrast, at the 90th decile groups, the percentage of stations from the DFW program area is about 25% (so the HGB program area would be 75%). 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 dark blue line, for the OBD electronic profile comparisons, and on the light blue line, for the OBD communication protocol mismatches. For the other measures, it is much more difficult to see any sort of meaningful trend. However, it does appear that for the three major OBD fraud checks, the VIN/eVIN, the electronic profile, and the communication protocol, 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-24. Top 50 Most Suspicious Stations for Errors of Commission

Station ID	Sum of Rank Flags	Max Rank for Station	Individual Ranks							
			eVIN Mismatch	OBD eVIN Missing	OBD Profile/ Readiness	OBD Communication Protocol Mismatch	Tailpipe Close-In-Time	Switch LD to HD	OBD High Fail Rate	OBD Low Fail Rate
2P48434	7	99.4	96.4	83.4	87.7	84.7	94.3	92.3	99.4	.
2P36383	7	96.9	81.2	81.8	85.0	82.7	96.9	91.4	.	92.7
1P52940	6	100.0	100.0	96.9	98.2	99.0	99.9	36.5	.	94.9
1P51241	6	99.5	98.5	78.1	89.8	84.0	96.7	99.5	94.8	.
2P42042	6	99.4	98.0	90.6	98.6	90.8	99.4	98.8	88.1	.
2P41186	6	99.3	99.2	80.4	94.3	86.5	96.1	99.3	76.9	.
1P52617	6	98.9	97.3	37.9	83.9	80.4	88.0	98.9	97.6	.
2P37659	5	100.0	44.5	93.6	92.8	93.7	100.0	93.9	.	88.7
1P51942	5	100.0	100.0	96.0	98.9	96.1	.	.	.	97.2
1P49313	5	99.9	81.6	95.3	99.8	95.6	99.9	28.7	.	70.4
1P51856	5	99.9	99.9	98.2	99.8	98.2	.	.	.	97.1
1P52160	5	99.9	99.9	96.0	99.2	97.2	.	.	.	93.8
1P52601	5	99.9	99.9	98.6	99.5	99.8	.	.	.	96.8
2P50838	5	99.8	97.7	83.3	89.9	83.5	99.8	69.3	69.4	.
1P33099	5	99.7	98.8	90.5	98.4	90.6	99.7	8.1	16.5	.
1P50669	5	99.7	99.7	98.4	99.1	99.5	.	.	.	93.4
2P50479	5	99.7	99.5	78.6	94.3	87.4	96.4	99.7	55.1	.
1P48652	5	99.7	98.7	95.8	99.7	95.8	99.5	27.2	.	76.3
2P41848	5	99.3	99.3	75.3	95.3	86.3	99.3	98.3	60.9	.
2P41057	5	98.8	87.0	96.5	97.6	98.8	.	.	.	97.7
2P33289	5	98.8	84.7	86.8	88.1	84.3	35.3	98.8	60.0	.
1P50605	5	98.7	92.2	98.3	98.7	97.5	.	.	.	91.4
2P45863	5	98.4	98.4	88.8	87.3	88.1	17.9	61.9	91.4	.
1P52050	5	98.4	81.4	98.1	98.4	98.2	.	.	.	97.6
2P32413	5	98.3	78.1	93.5	82.3	93.4	98.3	78.3	.	94.8
2P36194	5	98.2	86.1	87.0	91.9	85.7	31.7	49.6	98.2	.
1P50808	5	98.2	87.4	98.2	97.1	97.7	.	.	.	94.5
2P51348	5	97.8	88.7	97.1	97.8	97.4	.	.	.	92.1
2P42253	5	97.7	90.0	94.0	97.7	93.3	95.6	57.9	.	75.5

Table VI-24. Top 50 Most Suspicious Stations for Errors of Commission

Station ID	Sum of Rank Flags	Max Rank for Station	Individual Ranks							
			eVIN Mismatch	OBD eVIN Missing	OBD Profile/ Readiness	OBD Communication Protocol Mismatch	Tailpipe Close-In-Time	Switch LD to HD	OBD High Fail Rate	OBD Low Fail Rate
2P48055	5	97.7	84.8	93.9	93.3	94.0	97.7	63.8	.	72.7
2P29837	5	97.6	80.1	80.5	83.3	82.5	97.6	43.2	.	84.9
1P44369	5	97.3	41.9	83.0	88.8	83.6	96.1	97.3	46.1	.
2P35801	5	96.8	83.0	94.6	87.0	94.2	.	.	.	96.8
2P22729	5	96.7	36.2	88.7	92.7	85.9	83.2	96.7	13.5	.
1P49768	5	96.7	86.7	91.0	96.7	90.4	95.8	29.8	30.2	.
2P30395	5	96.3	96.3	89.0	94.4	88.5	93.2	43.5	37.8	.
1P36835	5	95.6	80.8	92.6	95.6	92.1	.	.	.	91.8
2P38991	5	95.6	94.2	62.0	87.2	78.0	81.2	95.1	95.6	.
1P32785	5	95.1	81.5	84.0	90.0	83.8	69.4	95.1	43.0	.
2P36709	5	94.8	86.3	91.3	94.8	90.5	87.5	49.9	89.2	.
1P45536	5	94.2	87.5	93.8	94.2	93.3	90.7	23.3	.	77.3
2P38594	5	93.5	88.5	93.5	88.0	93.0	83.9	52.2	.	59.8
2P48934	5	92.8	45.2	90.4	90.3	90.9	91.9	65.1	92.8	.
1P42459	5	91.3	83.0	87.5	91.3	86.8	27.9	19.8	90.5	.
2P50456	5	91.2	72.3	83.7	88.4	83.8	85.5	91.2	49.7	.
2P42548	5	91.1	91.1	84.0	89.2	84.5	87.6	58.8	87.7	.
1P49384	4	100.0	.	99.5	100.0	98.6	.	.	.	98.8
2P48302	4	100.0	.	98.9	96.8	100.0	94.7	64.0	.	89.5
1P53266	4	100.0	.	99.2	100.0	99.3	.	.	.	98.9
1P02394	4	99.9	91.7	83.6	0.9	33.0	95.0	99.9	75.4	.

Table VI-25. 50 Mid-Range Stations for Errors of Commission

Station ID	Sum of Rank Flags	Max Rank for Station	Individual Ranks							
			eVIN Mismatch	OBD eVIN Missing	OBD Profile/ Readiness	OBD Communication Protocol Mismatch	Tailpipe Close-In-Time	Switch LD to HD	OBD High Fail Rate	OBD Low Fail Rate
1P44634	1	80.7	80.3	70.9	.	37.5	.	.	80.7	.
1P49888	1	80.7	41.1	80.7	.	59.0	.	.	.	20.2
2P51324	1	80.7	79.6	75.0	.	80.7	.	.	34.8	.
2P49698	1	80.7	80.7	59.1	.	39.8	.	.	.	80.3
2P46105	1	80.6	80.6	4.2	.	57.9	.	.	.	44.8
1P41776	1	80.6	70.0	80.6	.	79.6	.	.	.	1.8
2P42346	1	80.6	42.4	80.6	33.6	48.2	74.8	58.3	.	9.3
1P49677	1	80.6	48.4	74.7	.	80.6	.	.	.	69.0
2P33579	1	80.6	43.4	80.6	.	17.2	.	.	.	30.1
1P41365	1	80.6	31.3	72.9	12.7	50.7	80.6	17.9	.	10.4
1P49160	1	80.6	47.0	40.8	80.6	50.9	29.1	28.3	.	24.6
1P52692	1	80.5	80.5	2.2	.	70.3	.	.	.	2.2
1P48170	1	80.5	34.8	80.5	63.7	24.9	28.9	25.9	.	74.0
1P37945	1	80.5	80.5	61.3	.	1.4	.	.	80.4	.
2P32162	1	80.5	63.3	70.6	.	80.5	.	.	.	25.2
2P52881	1	80.5	80.5	57.1	.	76.2	.	.	9.7	.
2P44773	1	80.5	79.5	77.1	.	80.5	.	.	26.6	.
1P53558	1	80.5	51.5	80.5	.	50.6	.	.	52.5	.
2P52551	1	80.5	74.2	76.9	80.5	75.8	.	.	66.3	.
2P46281	1	80.5	65.4	77.3	35.3	33.6	80.5	63.1	.	44.2
1P53740	1	80.5	80.5	79.9	.	56.4	.	.	56.9	.
1P00385	1	80.4	80.4	26.9	0.1	79.4	20.3	0.2	44.6	.
1P47525	1	80.4	80.4	9.2	59.7	60.2	.	.	11.4	.
1P52886	1	80.4	48.9	15.8	24.8	68.6	80.4	36.4	13.6	.
1P44656	1	80.4	65.9	80.4	.	79.0	.	.	35.7	.
1P51654	1	80.3	40.4	41.7	80.3	72.7	63.4	79.2	39.4	.
1F29063	1	80.3	80.3	79.3	.	0.1	.	.	.	.
1P45944	1	80.3	35.6	19.9	46.6	34.4	80.3	24.5	.	66.0
1P44257	1	80.3	45.0	80.3	.	60.0	.	.	.	72.1

Table VI-25. 50 Mid-Range Stations for Errors of Commission

Station ID	Sum of Rank Flags	Max Rank for Station	Individual Ranks							
			eVIN Mismatch	OBD eVIN Missing	OBD Profile/ Readiness	OBD Communication Protocol Mismatch	Tailpipe Close-In-Time	Switch LD to HD	OBD High Fail Rate	OBD Low Fail Rate
1P36499	1	80.3	80.3	14.0	.	64.6	.	.	61.8	.
2P51430	1	80.3	44.3	80.3	38.8	35.9	55.3	71.0	62.7	.
1P41083	1	80.3	37.4	15.2	12.4	21.1	80.3	17.7	3.4	.
2P30796	1	80.2	46.7	80.2	.	36.2	.	.	.	20.1
2P30388	1	80.2	80.2	58.0	75.0	65.3	41.4	78.7	.	24.8
2P48246	1	80.2	65.0	48.2	.	80.2	.	.	.	23.8
1P51658	1	80.2	67.1	80.2	22.9	18.6	79.6	33.9	54.1	.
1P39728	1	80.2	73.1	5.4	67.1	56.8	80.2	15.7	8.9	.
2P51895	1	80.2	35.2	73.4	.	80.2	.	.	4.7	.
1P49078	1	80.2	80.2	33.5	.	72.7	.	.	.	33.0
1P52690	1	80.2	26.5	75.2	.	80.2	.	.	74.2	.
1P49191	1	80.2	80.2	33.9	.	9.9	.	.	.	66.4
2P42345	1	80.2	80.2	18.5	.	40.0	.	.	.	4.0
1P33934	1	80.2	70.9	27.6	49.3	43.0	80.2	8.8	.	27.6
1P51662	1	80.1	80.1	60.2	.	62.8	.	.	28.7	.
1P42655	1	80.1	38.1	80.1	14.0	47.3	75.9	20.0	39.8	.
1P45688	1	80.1	26.4	80.1	16.6	17.5	.	.	59.0	.
2P53180	1	80.1	80.1	13.2	.	51.7	.	.	38.1	.
2P04038	1	80.1	47.1	80.1	25.3	19.8	20.4	37.6	73.5	.
1P27999	1	80.1	80.1	22.8	69.9	36.3	55.8	5.3	.	36.5
2P50567	1	80.1	80.1	62.5	73.7	73.8	62.1	68.8	67.9	.

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

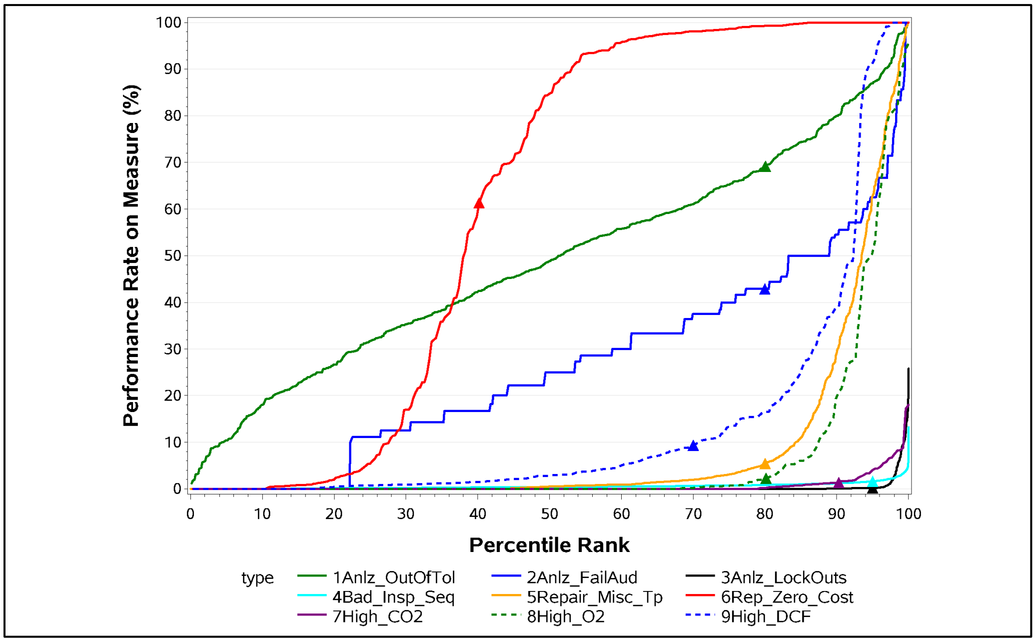


Figure VI-7. Fraction of Stations from the DFW Program Area, by Rank Decile, for VIN Mismatch and Profile Reading Errors of Commission

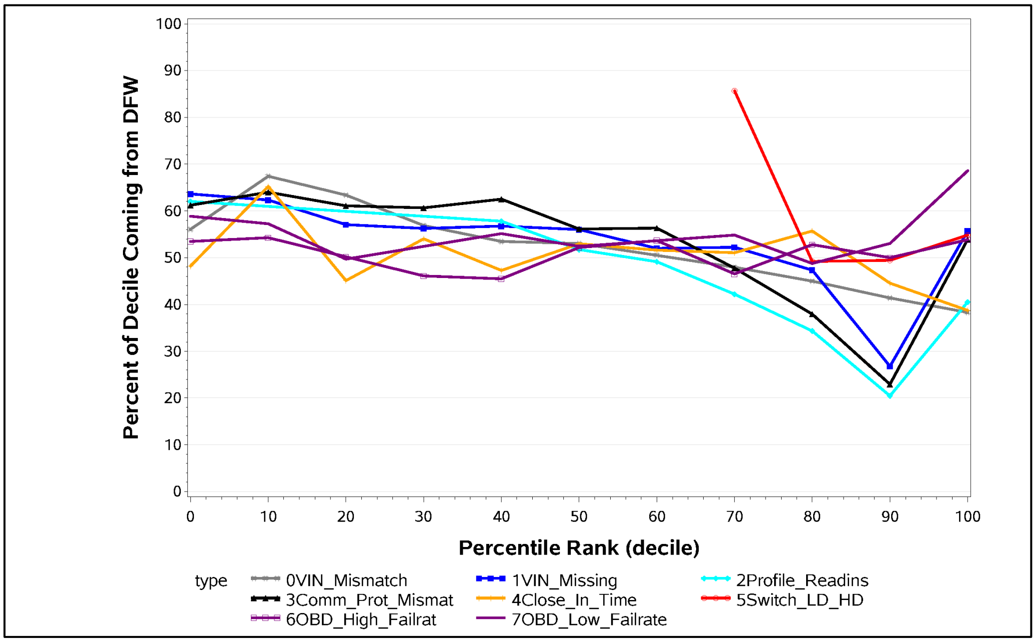


Table VI-26. Top 50 Stations with Errors of Omission

Station ID	Sum of Rank Flags	Max Rank for St.	Individual Ranks								
			Analyzer Out of Tolerance	Analyzer Locked Out	Analyzer Fail Audits	Bad P/F Seq	Repair Type "Misc."	Repair Cost $0	CO_2 Greater Than 16%	O_2 Greater Than 20.5%	DCF Disagreement
1P31631	6	100.0	17.2	99.4	49.8	95.6	97.9	84.8	11.7	100.0	98.4
1P02394	6	98.4	80.8	1.5	.	69.2	94.0	75.3	91.1	98.4	97.7
1P38169	6	97.2	93.8	20.4	97.2	24.1	96.0	16.1	91.8	94.6	94.2
2P36090	6	96.2	85.0	96.2	33.5	26.0	85.7	.	93.0	85.2	86.4
1P26940	5	100.0	27.2	98.7	83.8	13.0	3.1	.	100.0	96.5	95.7
2P30558	5	99.4	96.9	99.4	14.0	19.1	98.0	55.7	49.8	46.3	87.5
2P01268	5	97.3	90.7	44.5	51.3	53.4	82.4	.	97.3	91.4	87.9
2P39391	4	99.6	19.6	97.9	.	22.0	87.0	7.0	63.8	99.6	99.6
1P29282	4	99.2	97.2	8.9	35.8	61.3	62.2	.	99.2	92.2	88.7
2P10331	4	99.2	80.5	46.9	37.6	25.3	86.1	21.2	43.2	99.2	97.3
2P51792	4	98.9	12.2	98.9	22.1	95.1	93.6	42.4	78.6	68.1	33.5
1P00274	4	98.6	95.9	98.6	30.7	91.4	96.5	71.8	0.4	0.4	64.2
1P32538	4	98.5	96.2	11.8	98.5	69.8	92.2	50.6	.	.	.
2P10389	4	97.9	88.3	47.0	48.1	80.3	97.9	52.2	43.6	38.9	92.6
2P32950	4	97.5	83.2	97.5	15.3	75.1	92.8	40.5	79.4	69.3	54.5
1P40377	4	97.3	23.8	23.3	7.7	77.0	94.7	59.2	27.6	97.3	93.4
1P50667	4	96.3	94.4	37.5	.	96.3	75.0	.	39.3	80.9	85.6
2P49175	4	96.0	25.3	96.0	40.9	39.0	.	.	94.9	84.4	79.0
1P39417	4	94.6	80.1	21.9	7.2	88.7	94.6	1.6	25.7	88.7	77.8
2P33162	4	92.6	88.1	89.4	15.5	82.2	90.3	74.4	92.6	48.6	54.1
1P49905	4	91.8	91.2	36.5	91.4	83.5	20.9	.	37.7	91.1	91.8
1P31791	3	100.0	37.9	100.0	45.5	74.9	99.9	87.7	12.1	9.7	53.7
2P48727	3	100.0	81.0	80.9	30.6	68.4	53.9	.	83.3	97.7	100.0
2P31529	3	99.9	2.4	99.9	14.6	92.3	98.4	95.6	51.4	47.1	48.2
1P50734	3	99.8	.	.	.	97.0	99.8	54.7	.	.	.
2P50456	3	99.6	92.7	94.9	41.1	67.6	41.8	.	99.6	67.3	80.2
1P49768	3	99.2	84.7	35.9	28.6	53.0	20.4	.	89.5	93.0	99.2
2P50768	3	99.2	30.2	99.2	35.0	46.8	90.0	61.7	.	.	.
2P50486	3	99.1	47.2	.	82.0	81.8	99.1	84.5	.	.	.
1P40163	3	99.1	4.3	99.1	62.6	74.3	46.6	.	27.2	96.1	96.5

Table VI-26. Top 50 Stations with Errors of Omission

Station ID	Sum of Rank Flags	Max Rank for St.	Individual Ranks								
			Analyzer Out of Tolerance	Analyzer Locked Out	Analyzer Fail Audits	Bad P/F Seq	Repair Type "Misc."	Repair Cost $0	CO_2 Greater Than 16%	O_2 Greater Than 20.5%	DCF Disagreement
1P30479	3	99.0	96.3	9.5	99.0	27.8	86.6	.	.	.	.
1P00841	3	98.8	30.9	98.8	22.8	85.7	53.8	.	92.2	1.2	71.6
2P12686	3	98.4	45.3	96.5	12.3	71.9	98.4	68.0	45.5	72.8	26.8
2P44736	3	98.3	.	.	.	98.3	94.4	45.3	.	.	.
2P22796	3	98.2	23.4	98.2	48.2	37.3	28.6	.	97.7	72.4	81.3
1P40392	3	98.2	.	98.2	78.1	47.1	80.9	89.6	.	.	.
1P47573	3	98.0	.	98.0	81.4	14.3	86.7	.	.	.	.
2P44665	3	98.0	98.0	96.0	.	65.6	52.6	63.0	.	.	.
1P17220	3	97.8	5.4	96.7	58.7	28.9	97.8	79.4	4.3	3.5	19.8
2P35061	3	97.7	.	97.7	16.2	48.6	89.5	54.4	.	.	.
1P42433	3	97.7	32.1	92.1	8.4	90.3	97.7	60.1	30.4	70.4	75.5
2P28704	3	97.5	1.5	95.9	.	78.0	97.5	51.3	48.6	44.7	10.5
2P35894	3	97.5	88.6	97.0	33.3	97.5	32.1	.	.	.	.
2P42177	3	97.4	92.1	74.5	40.1	17.2	97.4	83.2	.	.	.
2P03889	3	97.3	12.3	97.3	.	82.2	95.3	82.0	42.8	38.5	39.3
1P39741	3	97.0	.	.	.	95.4	97.0	77.2	.	.	.
1P40391	3	97.0	.	97.0	.	90.2	90.7	82.6	.	.	.
2P32595	3	96.8	17.1	96.8	.	87.2	94.6	67.7	.	.	.
2P50966	3	96.8	.	.	.	96.8	95.1	44.9	.	.	.
2P39685	3	96.8	77.9	96.8	18.4	36.6	34.5	83.5	64.2	58.0	82.1

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Appendix A- DTC Groups

Table A-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 A-2. Catalyst DTCs[7]

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 A-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

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

Table A-4. O_2 System DTCs[8]

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

[8] Includes oxygen sensor and oxygen sensor heater.

Table A-4. O_2 System DTCs[8]

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 A-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

Appendix B- OBD Communication Rates by Vehicle Model Code for Elevated Miscommunications

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
ACUR								
	4	0.03%	9	0.07%	12,357	99.89%	12,370	0.09%
3.2TL	3	0.05%	6	0.11%	5,564	99.84%	5,573	0.04%
CL	1	0.07%	1	0.07%	1,362	99.85%	1,364	0.01%
MDX	6	0.01%	25	0.04%	57,139	99.95%	57,170	0.39%
RDX	1	0.00%	12	0.04%	32,301	99.96%	32,314	0.22%
RL	1	0.03%	2	0.05%	3,681	99.92%	3,684	0.03%
RSX	1	0.03%	3	0.08%	3,733	99.89%	3,737	0.03%
RSX Type-S	1	0.05%	2	0.11%	1,840	99.84%	1,843	0.01%
TL	4	0.01%	37	0.08%	44,303	99.91%	44,344	0.31%
TLX	1	0.01%	9	0.06%	14,799	99.93%	14,809	0.10%
TSX	2	0.01%	12	0.04%	27,776	99.95%	27,790	0.19%
AUDI								
A4	1	0.04%	8	0.29%	2,744	99.67%	2,753	0.02%
A4/S4	1	0.00%	19	0.07%	26,649	99.93%	26,669	0.18%
A4/S4 Cabriolet	1	0.07%	8	0.58%	1,363	99.34%	1,372	0.01%
A6/S6	2	0.08%	3	0.12%	2,475	99.80%	2,480	0.02%
A6/S6/A7/RS7/S7	1	0.01%	2	0.02%	11,135	99.97%	11,138	0.08%
Q5	1	0.00%	8	0.04%	21,863	99.96%	21,872	0.15%
Q7	2	0.02%	8	0.07%	11,198	99.91%	11,208	0.08%
BMW								
	1	0.01%	25	0.17%	14,420	99.82%	14,446	0.10%
320i	1	0.02%	6	0.11%	5,610	99.88%	5,617	0.04%
323iC	1	0.50%	1	0.50%	200	99.01%	202	0.00%

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Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
325i	2	0.02%	13	0.14%	9,022	99.83%	9,037	0.06%
328i	6	0.01%	43	0.10%	42,264	99.88%	42,313	0.29%
328i SA	2	0.02%	3	0.03%	9,631	99.95%	9,636	0.07%
328xi SULEV	1	0.41%	1	0.41%	241	99.18%	243	0.00%
330Ci	1	0.03%	11	0.32%	3,433	99.65%	3,445	0.02%
335i	1	0.01%	23	0.18%	12,611	99.81%	12,635	0.09%
428i	1	0.01%	5	0.07%	6,838	99.91%	6,844	0.05%
528i	3	0.01%	35	0.16%	21,242	99.82%	21,280	0.15%
530i	3	0.06%	6	0.13%	4,628	99.81%	4,637	0.03%
530iA	1	0.06%	3	0.19%	1,589	99.75%	1,593	0.01%
535i	2	0.01%	28	0.16%	17,027	99.82%	17,057	0.12%
550i	1	0.02%	8	0.19%	4,245	99.79%	4,254	0.03%
750Li	2	0.04%	10	0.18%	5,599	99.79%	5,611	0.04%
M3	2	0.04%	16	0.29%	5,558	99.68%	5,576	0.04%
Mini Cooper	1	0.03%	4	0.10%	3,881	99.87%	3,886	0.03%
X1	1	0.04%	4	0.16%	2,443	99.80%	2,448	0.02%
X3	4	0.02%	22	0.12%	17,585	99.85%	17,611	0.12%
X5	5	0.02%	38	0.14%	27,298	99.84%	27,341	0.19%
X5 3.0i	2	0.04%	10	0.21%	4,771	99.75%	4,783	0.03%
Z3	2	0.05%	19	0.51%	3,674	99.43%	3,695	0.03%
Z4 Roadster 3.0si	1	0.18%	1	0.18%	548	99.64%	550	0.00%
BUIC								
	1	0.04%	1	0.04%	2,594	99.92%	2,596	0.02%
Century Custom	1	0.01%	12	0.12%	10,264	99.87%	10,277	0.07%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Century Limited	1	0.07%	1	0.07%	1,424	99.86%	1,426	0.01%
Enclave	2	0.01%	9	0.03%	34,334	99.97%	34,345	0.24%
Enclave FWD	2	0.03%	2	0.03%	5,859	99.93%	5,863	0.04%
LaCrosse CX	1	0.01%	6	0.09%	6,741	99.90%	6,748	0.05%
LaCrosse CXL	2	0.04%	13	0.26%	10,923	199.70%	10,938	0.08%
LeSabre Custom	4	0.03%	35	0.26%	13,652	99.72%	13,691	0.09%
LeSabre Limited	2	0.03%	13	0.22%	5,914	99.75%	5,929	0.04%
Park Avenue	3	0.08%	10	0.25%	3,985	99.67%	3,998	0.03%
Rainier	1	0.08%	5	0.39%	1,262	99.53%	1,268	0.01%
Rendezvous 2WD	6	0.10%	32	0.52%	6,097	99.38%	6,135	0.04%
Verano	1	0.01%	1	0.01%	10,550	99.98%	10,552	0.07%
CADI								
1500 Suburban 4WD Luxury	2	0.09%	11	0.50%	2,192	99.41%	2,205	0.02%
CTS	2	0.02%	4	0.03%	12,655	99.95%	12,661	0.09%
CTS Auto RWD	2	0.04%	1	0.02%	5,165	99.94%	5,168	0.04%
CTS Luxury	3	0.03%	3	0.03%	11,801	99.95%	11,807	0.08%
CTS Premium	1	0.02%	1	0.02%	5,538	99.96%	5,540	0.04%
CTS V6	2	0.02%	4	0.05%	8,005	99.93%	8,011	0.06%
DeVille	1	0.01%	23	0.19%	11,818	99.80%	11,842	0.08%
DTS	1	0.01%	3	0.03%	9,737	99.96%	9,741	0.07%
Escalade	5	0.02%	43	0.21%	20,375	99.76%	20,423	0.14%
Escalade 1500 2WD	5	0.08%	41	0.62%	6,520	99.30%	6,566	0.05%
Escalade 1500 2WD Luxury	5	0.09%	36	0.64%	5,548	99.27%	5,589	0.04%
Escalade 1500 4WD	8	0.07%	58	0.53%	10,900	99.40%	10,966	0.08%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Escalade 1500 4WD Luxury	9	0.11%	62	0.75%	8,237	99.15%	8,308	0.06%
Escalade 4WD	4	0.35%	11	0.96%	1,135	98.70%	1,150	0.01%
Escalade ESV	1	0.01%	27	0.24%	11,065	99.75%	11,093	0.08%
SRX	4	0.01%	32	0.06%	57,670	99.94%	57,706	0.40%
STS	2	0.06%	2	0.06%	3,313	99.88%	3,317	0.02%
XTS Premium	1	0.04%	1	0.04%	2,399	99.92%	2,401	0.02%
CHEV								
	5	0.02%	58	0.22%	26,586	99.76%	26,649	0.18%
1500 2WD	52	0.03%	340	0.17%	203,260	99.81%	203,652	1.41%
1500 4WD	9	0.03%	62	0.19%	33,344	99.79%	33,415	0.23%
2500 2WD	3	0.01%	23	0.09%	25,056	99.90%	25,082	0.17%
3500 Van 2WD	1	0.22%	3	0.67%	441	99.10%	445	0.00%
Astro 2WD	4	0.04%	44	0.40%	11,029	99.57%	11,077	0.08%
Avalanche LTZ	1	0.03%	5	0.15%	3,398	99.82%	3,404	0.02%
Aveo	1	0.01%	12	0.12%	9,614	99.86%	9,627	0.07%
Aveo LT	1	0.04%	9	0.37%	2,425	99.59%	2,435	0.02%
Blazer / Trailblazer 2WD	14	0.05%	53	0.21%	25,554	99.74%	25,621	0.18%
Blazer / Trailblazer 4WD	2	0.04%	16	0.29%	5,452	99.67%	5,470	0.04%
Blazer 2WD	4	0.03%	27	0.21%	12,642	99.76%	12,673	0.09%
C1500 Pickup 2WD	47	0.04%	219	0.18%	119,410	99.78%	119,676	0.83%
C1500 Silverado 2WD	26	0.04%	230	0.35%	64,993	99.61%	65,249	0.45%
C1500 Suburban 2WD	25	0.04%	167	0.28%	60,065	99.68%	60,257	0.42%
C2500 Pickup 2WD	6	0.11%	8	0.14%	5,515	99.75%	5,529	0.04%
C3500 Pickup 2WD	1	0.10%	4	0.40%	993	99.50%	998	0.01%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Camaro 1LT	3	0.03%	2	0.02%	9,689	99.95%	9,694	0.07%
Camaro 2LS	1	0.01%	6	0.06%	9,695	99.93%	9,702	0.07%
Camaro 2LT	1	0.01%	11	0.06%	18,245	99.93%	18,257	0.13%
Camaro 2SS	2	0.01%	12	0.06%	18,646	99.92%	18,660	0.13%
Camaro LS	1	0.01%	3	0.04%	7,355	99.95%	7,359	0.05%
Camaro LT	2	0.01%	6	0.04%	14,250	99.94%	14,258	0.10%
Cavalier	6	0.04%	37	0.25%	14,794	99.71%	14,837	0.10%
Cavalier LS	1	0.68%	1	0.68%	144	98.63%	146	0.00%
Cobalt	14	0.05%	75	0.25%	29,674	99.70%	29,763	0.21%
Cobalt 1LT	1	0.03%	2	0.07%	2,981	99.90%	2,984	0.02%
Colorado / SSR 2WD	1	0.02%	14	0.28%	5,019	99.70%	5,034	0.03%
Colorado / Trailblazer 2WD	1	0.01%	19	0.18%	10,553	99.81%	10,573	0.07%
Colorado 1LT	1	0.01%	1	0.01%	9,963	99.98%	9,965	0.07%
Colorado Work Truck	1	0.01%	4	0.05%	7,500	99.93%	7,505	0.05%
Corvette	5	0.02%	37	0.13%	27,795	99.85%	27,837	0.19%
Corvette Stingray 2LT w/Z51	1	0.04%	2	0.08%	2,535	99.88%	2,538	0.02%
Cruze	2	0.01%	13	0.07%	17,735	99.92%	17,750	0.12%
Cruze 1LT	2	0.01%	18	0.06%	30,883	99.94%	30,903	0.21%
Cruze 2LT	2	0.02%	4	0.03%	12,992	99.95%	12,998	0.09%
Cruze LS	1	0.01%	4	0.05%	8,788	99.94%	8,793	0.06%
Equinox 1LT	3	0.01%	18	0.04%	41,004	99.95%	41,025	0.28%
Equinox 2LT	2	0.01%	12	0.05%	24,379	99.94%	24,393	0.17%
Equinox 2WD	1	0.01%	7	0.07%	10,337	99.92%	10,345	0.07%
Equinox LS	2	0.01%	9	0.04%	23,013	99.95%	23,024	0.16%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Equinox LS 2WD	1	0.04%	2	0.07%	2,733	99.89%	2,736	0.02%
Equinox LT 2WD	1	0.04%	8	0.30%	2,657	99.66%	2,666	0.02%
Equinox LTZ	3	0.02%	11	0.09%	12,575	99.89%	12,589	0.09%
Express 1500	1	0.02%	11	0.18%	5,995	99.80%	6,007	0.04%
Express 1500 2WD	7	0.05%	30	0.22%	13,676	99.73%	13,713	0.09%
Express 2500	1	0.07%	11	0.78%	1,390	99.14%	1,402	0.01%
Express 2500 2WD	2	0.06%	6	0.18%	3,241	99.75%	3,249	0.02%
Express 3500	1	0.13%	3	0.38%	777	99.49%	781	0.01%
G1500 Van 2WD	1	0.04%	2	0.08%	2,562	99.88%	2,565	0.02%
G2500 Van 2WD	3	0.56%	1	0.19%	528	99.25%	532	0.00%
HHR	14	0.07%	40	0.20%	19,936	99.73%	19,990	0.14%
Impala	2	0.01%	18	0.10%	17,376	99.89%	17,396	0.12%
Impala LS	2	0.01%	18	0.10%	17,940	99.89%	17,960	0.12%
Impala LS Sedan	8	0.04%	13	0.07%	18,328	99.89%	18,349	0.13%
Impala LT	3	0.01%	17	0.06%	26,489	99.92%	26,509	0.18%
Impala LT Fleet	3	0.02%	12	0.08%	14,712	99.90%	14,727	0.10%
Impala LT Sedan	4	0.02%	19	0.10%	19,964	99.88%	19,987	0.14%
Impala LTZ	2	0.01%	12	0.07%	18,377	99.92%	18,391	0.13%
K1500 Pickup 4WD	9	0.04%	54	0.23%	23,084	99.73%	23,147	0.16%
K1500 Silverado 4WD	4	0.05%	26	0.31%	8,409	99.64%	8,439	0.06%
K1500 Suburban 4WD	6	0.04%	46	0.32%	14,314	99.64%	14,366	0.10%
K2500 Pickup 4WD	2	0.14%	4	0.27%	1,457	99.59%	1,463	0.01%
K3500 Pickup 4WD	1	0.92%	1	0.92%	107	98.17%	109	0.00%
Malibu	3	0.02%	22	0.17%	12,640	99.80%	12,665	0.09%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Malibu 1LS	2	0.03%	19	0.32%	5,862	99.64%	5,883	0.04%
Malibu 2LT	1	0.01%	16	0.09%	18,572	99.91%	18,589	0.13%
Malibu 2LT Eco	1	0.09%	1	0.09%	1,155	99.83%	1,157	0.01%
Malibu Classic	1	0.05%	5	0.24%	2,114	99.72%	2,120	0.01%
Malibu Fleet	1	0.02%	4	0.07%	5,656	99.91%	5,661	0.04%
Malibu LS	12	0.02%	46	0.09%	49,026	99.88%	49,084	0.34%
Malibu LT	5	0.01%	45	0.09%	49,203	99.90%	49,253	0.34%
Malibu LTZ	1	0.01%	9	0.07%	13,368	99.93%	13,378	0.09%
Monte Carlo SS	1	0.05%	3	0.14%	2,077	99.81%	2,081	0.01%
S Series Pickup 2WD	6	0.05%	25	0.19%	12,980	99.76%	13,011	0.09%
S10 Pickup 2WD	3	0.03%	15	0.15%	9,810	99.82%	9,828	0.07%
Sierra 1500 2WD	1	0.04%	3	0.13%	2,281	99.82%	2,285	0.02%
Silverado / Suburban 4WD	1	0.65%	2	1.29%	152	98.06%	155	0.00%
Silverado 1500	33	0.01%	160	0.06%	270,715	99.93%	270,908	1.87%
Silverado 2500	1	0.04%	6	0.21%	2,795	99.75%	2,802	0.02%
Silverado 3500	1	0.26%	3	0.78%	383	98.97%	387	0.00%
Silverado LS	1	0.01%	14	0.10%	14,415	99.90%	14,430	0.10%
Sonic LT	1	0.00%	10	0.05%	20,748	99.95%	20,759	0.14%
SSR / Colorado / Trailblazer	11	0.05%	47	0.19%	24,125	99.76%	24,183	0.17%
Suburban LS	1	0.01%	5	0.05%	9,908	99.94%	9,914	0.07%
Suburban LTZ	2	0.02%	5	0.04%	12,090	99.94%	12,097	0.08%
Tahoe 2WD	55	0.05%	305	0.27%	111,953	99.68%	112,313	0.77%
Tahoe 4WD	16	0.05%	82	0.26%	31,316	99.69%	31,414	0.22%
Tahoe LS	3	0.02%	10	0.05%	18,945	99.93%	18,958	0.13%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Tahoe LT	1	0.00%	34	0.07%	46,435	99.92%	46,470	0.32%
Tahoe LTZ	1	0.01%	8	0.04%	19,398	99.95%	19,407	0.13%
Tahoe Police	3	0.04%	4	0.05%	7,756	99.91%	7,763	0.05%
Tracker 4WD	1	0.28%	3	0.83%	358	98.90%	362	0.00%
Trailblazer 2WD	2	0.02%	20	0.24%	8,149	99.73%	8,171	0.06%
Traverse FWD	1	0.02%	1	0.02%	4,668	99.96%	4,670	0.03%
Traverse LT/Traverse 1LT	5	0.02%	12	0.05%	22,510	99.92%	22,527	0.16%
Venture 2WD	1	0.02%	6	0.14%	4,396	99.84%	4,403	0.03%
CHRY								
	1	0.02%	2	0.04%	5,566	99.95%	5,569	0.04%
200 Limited	1	0.00%	18	0.08%	22,019	99.91%	22,038	0.15%
200 LX	2	0.03%	4	0.05%	7,976	99.92%	7,982	0.06%
200 Touring	3	0.03%	7	0.07%	9,778	99.90%	9,788	0.07%
200S	1	0.02%	4	0.09%	4,562	99.89%	4,567	0.03%
300 Limited	3	0.02%	14	0.07%	19,497	99.91%	19,514	0.13%
300 LX	1	0.02%	6	0.10%	5,929	99.88%	5,936	0.04%
300 Touring	2	0.01%	11	0.06%	18,509	99.93%	18,522	0.13%
300C	2	0.01%	7	0.05%	15,503	99.94%	15,512	0.11%
Pacifica FWD	2	0.02%	7	0.08%	8,329	99.89%	8,338	0.06%
PT Cruiser Classic LHD	2	0.02%	14	0.13%	10,630	99.85%	10,646	0.07%
PT Cruiser LHD	3	0.12%	6	0.25%	2,401	99.63%	2,410	0.02%
PT Cruiser Touring LHD	3	0.04%	6	0.08%	7,362	99.88%	7,371	0.05%
Sebring	2	0.04%	4	0.09%	4,683	99.87%	4,689	0.03%
Sebring GTC	3	0.66%	2	0.44%	447	98.89%	452	0.00%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Sebring JXi	1	0.21%	3	0.63%	472	99.16%	476	0.00%
Sebring LX	4	0.08%	14	0.28%	4,954	99.64%	4,972	0.03%
Sebring LXi	1	0.07%	9	0.61%	1,465	99.32%	1,475	0.01%
Sebring Touring	3	0.04%	9	0.12%	7,810	99.85%	7,822	0.05%
Town & Country	3	0.01%	13	0.06%	22,742	99.93%	22,758	0.16%
Town & Country FWD LHD	3	0.05%	5	0.08%	6,336	99.87%	6,344	0.04%
Town & Country FWD LWB & SWB	1	0.01%	6	0.09%	6,794	99.90%	6,801	0.05%
Town & Country Limited FWD	1	0.03%	10	0.25%	3,928	99.72%	3,939	0.03%
Town & Country LX FWD	2	0.09%	7	0.30%	2,336	99.62%	2,345	0.02%
Town & Country LXi FWD	1	0.06%	6	0.37%	1,610	99.57%	1,617	0.01%
Town & Country Touring FWD	2	0.04%	11	0.21%	5,241	99.75%	5,254	0.04%
DODG								
1500	2	0.01%	19	0.06%	30,296	99.93%	30,317	0.21%
	16	0.02%	68	0.08%	90,404	99.91%	90,488	0.62%
Avenger SE	5	0.02%	27	0.09%	30,266	99.89%	30,298	0.21%
Caravan / Grand Caravan ES FWD	1	0.36%	1	0.36%	279	99.29%	281	0.00%
Caravan / Grand Caravan SE	2	0.04%	7	0.14%	4,843	99.81%	4,852	0.03%
Caravan / Grand Caravan SXT FW	3	0.03%	18	0.16%	11,248	99.81%	11,269	0.08%
Caravan C/V FWD	4	0.03%	22	0.19%	11,498	99.77%	11,524	0.08%
Caravan Sport FWD	1	0.04%	7	0.25%	2,743	99.71%	2,751	0.02%
Challenger	4	0.02%	11	0.06%	19,084	99.92%	19,099	0.13%
Challenger SCAT Pack	1	0.04%	1	0.04%	2,538	99.92%	2,540	0.02%
Challenger SRT Hellcat	1	0.09%	1	0.09%	1,151	99.83%	1,153	0.01%
Challenger SXT	4	0.05%	4	0.05%	7,312	99.89%	7,320	0.05%

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

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Charger	4	0.02%	13	0.05%	25,488	99.93%	25,505	0.18%
Charger (RWD)	2	0.01%	16	0.08%	20,792	99.91%	20,810	0.14%
Charger R/T	2	0.01%	17	0.09%	18,965	99.90%	18,984	0.13%
Charger SE	1	0.01%	5	0.07%	6,768	99.91%	6,774	0.05%
Charger SXT	3	0.01%	14	0.06%	23,108	99.93%	23,125	0.16%
Dakota 2WD	5	0.05%	20	0.19%	10,511	99.76%	10,536	0.07%
Dakota SLT 2WD	1	0.01%	6	0.07%	8,548	99.92%	8,555	0.06%
Dakota Sport / Dakota R/T 2WD	1	0.13%	1	0.13%	793	99.75%	795	0.01%
Dakota Stampede 2WD	1	0.13%	4	0.51%	780	99.36%	785	0.01%
Dart SXT	3	0.02%	15	0.11%	13,254	99.86%	13,272	0.09%
Durango	2	0.01%	18	0.06%	30,945	99.94%	30,965	0.21%
Durango 2WD	1	0.02%	4	0.08%	4,763	99.90%	4,768	0.03%
Durango 4WD	2	0.07%	13	0.45%	2,881	99.48%	2,896	0.02%
Durango SLT 2WD	2	0.02%	9	0.09%	10,178	99.89%	10,189	0.07%
Grand Caravan	5	0.01%	17	0.05%	34,467	99.94%	34,489	0.24%
Grand Caravan ES FWD	1	0.25%	2	0.51%	390	99.24%	393	0.00%
Journey	4	0.01%	41	0.10%	40,786	99.89%	40,831	0.28%
Neon ES	1	0.07%	1	0.07%	1,455	99.86%	1,457	0.01%
Nitro SXT 2WD	1	0.02%	2	0.04%	5,193	99.94%	5,196	0.04%
ProMaster City	2	0.12%	1	0.06%	1,654	99.82%	1,657	0.01%
Ram Pickup	2	0.05%	4	0.10%	4,156	99.86%	4,162	0.03%
Ram Pickup 1500 2WD	37	0.03%	142	0.10%	139,376	99.87%	139,555	0.96%
Ram Pickup 1500 4WD	3	0.02%	18	0.11%	16,436	99.87%	16,457	0.11%
Ram Pickup 2500 4WD	1	0.25%	1	0.25%	401	99.50%	403	0.00%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Ram Pickup 2WD	22	0.06%	115	0.33%	34,753	99.61%	34,890	0.24%
Ram Pickup 4WD	1	0.02%	20	0.42%	4,758	99.56%	4,779	0.03%
RAM PK Light Duty 1500	2	0.01%	15	0.06%	24,506	99.93%	24,523	0.17%
Ram Van/Truck	1	0.19%	3	0.58%	517	99.23%	521	0.00%
Stratus SE	1	0.06%	7	0.44%	1,590	99.50%	1,598	0.01%
Stratus SXT	2	0.05%	12	0.31%	3,818	99.63%	3,832	0.03%
Viper	1	0.32%	1	0.32%	307	99.35%	309	0.00%
FORD								
	4	0.05%	5	0.07%	7,432	99.88%	7,441	0.05%
500 SEL FWD	1	0.02%	2	0.05%	4,399	99.93%	4,402	0.03%
Crown Victoria (Police)	5	0.07%	15	0.21%	7,066	99.72%	7,086	0.05%
Crown Victoria LX	1	0.02%	7	0.17%	4,035	99.80%	4,043	0.03%
Crown Victoria Police Intercep	1	0.03%	8	0.26%	3,116	99.71%	3,125	0.02%
E150 2WD	11	0.11%	51	0.51%	10,015	99.38%	10,077	0.07%
E150 Cargo/Regular Van	2	0.12%	2	0.12%	1,617	99.75%	1,621	0.01%
E250 2WD	5	0.21%	5	0.21%	2,359	99.58%	2,369	0.02%
E350 2WD	3	0.22%	14	1.03%	1,348	98.75%	1,365	0.01%
E350 Super Wagon	1	0.34%	3	1.02%	291	98.64%	295	0.00%
Edge	1	0.00%	23	0.03%	79,783	99.97%	79,807	0.55%
Edge Limited AWD	1	0.21%	1	0.21%	477	99.58%	479	0.00%
Escape	4	0.00%	59	0.05%	122,538	99.95%	122,601	0.85%
Escape XLS 2WD	3	0.02%	15	0.11%	14,190	99.87%	14,208	0.10%
Escape XLT 2WD	5	0.02%	26	0.09%	27,932	99.89%	27,963	0.19%
Excursion Limited 2WD	1	0.39%	1	0.39%	253	99.22%	255	0.00%

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Excursion XLT 2WD	1	0.48%	2	0.97%	204	98.55%	207	0.00%
Expedition	10	0.02%	42	0.07%	61,331	99.92%	61,383	0.42%
Expedition Eddie Bauer 2WD	13	0.03%	86	0.18%	46,534	99.79%	46,633	0.32%
Expedition Eddie Bauer 4WD	5	0.10%	6	0.12%	4,985	99.78%	4,996	0.03%
Expedition EL Eddie Bauer 2WD	1	0.04%	1	0.04%	2,358	99.92%	2,360	0.02%
Expedition XLS	1	0.09%	5	0.46%	1,070	99.44%	1,076	0.01%
Expedition XLT 2WD	14	0.04%	75	0.20%	37,376	99.76%	37,465	0.26%
Expedition XLT 4WD	2	0.05%	13	0.29%	4,398	99.66%	4,413	0.03%
Explorer	8	0.01%	77	0.07%	117,526	99.93%	117,611	0.81%
Explorer LTD 2WD	2	0.05%	5	0.13%	3,700	99.81%	3,707	0.03%
Explorer Sport	1	0.08%	3	0.23%	1,320	99.70%	1,324	0.01%
Explorer Sport 2WD	1	0.02%	22	0.36%	6,074	99.62%	6,097	0.04%
Explorer Sport Trac 2WD	11	0.06%	56	0.31%	17,888	99.63%	17,955	0.12%
Explorer XL	5	0.04%	22	0.17%	13,249	99.80%	13,276	0.09%
Explorer XL 4WD	1	0.04%	3	0.12%	2,411	99.83%	2,415	0.02%
Explorer XLS 2WD	1	0.01%	16	0.11%	14,660	99.88%	14,677	0.10%
Explorer XLT 2WD	9	0.03%	42	0.14%	29,327	99.83%	29,378	0.20%
Explorer XLT 4WD	1	0.01%	14	0.19%	7,532	99.80%	7,547	0.05%
F150	52	0.01%	379	0.08%	490,413	99.91%	490,844	3.39%
F150 2WD	53	0.04%	316	0.24%	129,725	99.72%	130,094	0.90%
F150 2WD Super Crew	45	0.04%	264	0.23%	115,197	99.73%	115,506	0.80%
F150 4WD	5	0.03%	39	0.23%	16,636	99.74%	16,680	0.12%
F150 4WD Super Crew	10	0.03%	86	0.23%	37,021	99.74%	37,117	0.26%
F150 Heritage	1	0.03%	9	0.23%	3,824	99.74%	3,834	0.03%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
F150 Heritage 2WD	4	0.13%	11	0.36%	3,063	99.51%	3,078	0.02%
F150 Regular Cab	3	0.09%	14	0.44%	3,194	99.47%	3,211	0.02%
F150 Regular Cab Flareside	3	0.09%	3	0.09%	3,158	99.81%	3,164	0.02%
F150 Regular Cab Styleside	1	0.01%	22	0.21%	10,634	99.78%	10,657	0.07%
F150 Super Cab 4WD	1	0.89%	1	0.89%	110	98.21%	112	0.00%
F150 Super Cab Flareside	5	0.06%	10	0.12%	8,616	99.83%	8,631	0.06%
F150 Super Cab Flareside 4WD	2	0.14%	1	0.07%	1,416	99.79%	1,419	0.01%
F150 Super Cab Styleside	6	0.02%	37	0.13%	28,627	99.85%	28,670	0.20%
F150 Super Cab Styleside 4WD	1	0.03%	6	0.18%	3,311	99.79%	3,318	0.02%
F150 Super Crew 2WD	17	0.03%	143	0.28%	50,027	99.68%	50,187	0.35%
F150 Super Crew 4WD	5	0.04%	27	0.24%	11,218	99.72%	11,250	0.08%
F250	1	0.04%	1	0.04%	2,327	99.91%	2,329	0.02%
F250 2WD	1	0.18%	4	0.73%	540	99.08%	545	0.00%
F250 Super Cab 4WD	2	0.56%	3	0.83%	355	98.61%	360	0.00%
Fiesta SE	1	0.01%	11	0.06%	19,953	99.94%	19,965	0.14%
Focus S	4	0.04%	33	0.34%	9,617	99.62%	9,654	0.07%
Focus SE	12	0.02%	49	0.06%	78,084	99.92%	78,145	0.54%
Focus SEL	1	0.01%	4	0.05%	7,656	99.93%	7,661	0.05%
Focus SES	4	0.03%	8	0.06%	12,920	99.91%	12,932	0.09%
Focus Titanium	1	0.01%	6	0.07%	8,399	99.92%	8,406	0.06%
Focus ZTS	1	0.04%	2	0.09%	2,317	99.87%	2,320	0.02%
Focus ZX4	1	0.01%	5	0.05%	10,498	99.94%	10,504	0.07%
Freestar SE	1	0.06%	6	0.35%	1,722	99.60%	1,729	0.01%
Fusion Hybrid	3	0.09%	13	0.41%	3,162	99.50%	3,178	0.02%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Fusion S	3	0.02%	46	0.23%	19,937	99.75%	19,986	0.14%
Fusion SE	21	0.02%	160	0.16%	97,843	99.82%	98,024	0.68%
Fusion SEL	8	0.04%	105	0.51%	20,399	99.45%	20,512	0.14%
Fusion Sport	1	0.06%	2	0.12%	1,668	99.82%	1,671	0.01%
Fusion Titanium	1	0.01%	6	0.06%	10,334	99.93%	10,341	0.07%
Fusion Titanium HEV	1	0.07%	2	0.13%	1,510	99.80%	1,513	0.01%
LTD Crown Victoria	3	0.14%	6	0.29%	2,093	99.57%	2,102	0.01%
LTD Crown Victoria LX	1	0.05%	5	0.24%	2,079	99.71%	2,085	0.01%
Mustang	4	0.01%	56	0.10%	53,924	99.89%	53,984	0.37%
Mustang GT	5	0.01%	39	0.07%	54,885	99.92%	54,929	0.38%
Mustang V6	1	0.00%	11	0.04%	30,339	99.96%	30,351	0.21%
Ranger	4	0.05%	25	0.28%	8,784	99.67%	8,813	0.06%
Ranger 2WD	22	0.04%	158	0.27%	57,416	99.69%	57,596	0.40%
Ranger Regular Cab 2WD	4	0.04%	16	0.16%	9,862	99.80%	9,882	0.07%
Ranger Super Cab 2WD	6	0.05%	22	0.20%	10,919	99.74%	10,947	0.08%
Ranger Super Cab 4WD	1	0.10%	3	0.30%	989	99.60%	993	0.01%
Taurus LX	1	0.05%	5	0.24%	2,047	99.71%	2,053	0.01%
Taurus SE	3	0.01%	21	0.09%	23,000	99.90%	23,024	0.16%
Taurus SE Comfort	2	0.03%	1	0.01%	7,713	99.96%	7,716	0.05%
Taurus SEL	1	0.01%	11	0.07%	15,299	99.92%	15,311	0.11%
Thunderbird	1	0.03%	13	0.38%	3,448	99.60%	3,462	0.02%
Transit Connect	2	0.01%	18	0.10%	17,368	99.88%	17,388	0.12%
Windstar LX	1	0.04%	6	0.22%	2,758	99.75%	2,765	0.02%
GEO								

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Geo Prizm Lsi	1	0.15%	2	0.29%	681	99.56%	684	0.00%
Geo Tracker	1	0.42%	1	0.42%	235	99.16%	237	0.00%
GMC								
1500 2WD	13	0.03%	82	0.16%	49,837	99.81%	49,932	0.34%
1500 Suburban 2WD	4	0.03%	41	0.27%	15,045	99.70%	15,090	0.10%
1500 Suburban 4WD	1	0.03%	13	0.44%	2,927	99.52%	2,941	0.02%
1500 Suburban 4WD Luxury	4	0.12%	19	0.57%	3,335	99.32%	3,358	0.02%
2500 2WD	4	0.07%	5	0.08%	6,048	99.85%	6,057	0.04%
3500 2WD	1	0.03%	1	0.03%	2,939	99.93%	2,941	0.02%
Acadia SLE FWD	3	0.11%	1	0.04%	2,832	99.86%	2,836	0.02%
Acadia SLE1	1	0.02%	4	0.07%	6,148	99.92%	6,153	0.04%
Acadia SLE2	1	0.01%	1	0.01%	7,996	99.97%	7,998	0.06%
Acadia SLT1	2	0.01%	4	0.03%	14,601	99.96%	14,607	0.10%
Canyon / Envoy 2WD	2	0.03%	20	0.26%	7,668	99.71%	7,690	0.05%
Envoy 2WD	1	0.34%	1	0.34%	290	99.32%	292	0.00%
Envoy/Envoy XL SLE 2WD	4	0.03%	51	0.40%	12,796	99.57%	12,851	0.09%
Envoy/Envoy XL SLE 4WD	2	0.08%	9	0.35%	2,587	99.58%	2,598	0.02%
Full Size Truck 1500 4WD	1	0.06%	4	0.25%	1,590	99.69%	1,595	0.01%
Full Size Truck 4WD 1500	1	0.10%	8	0.82%	961	99.07%	970	0.01%
Jimmy/Envoy 2WD	3	0.09%	6	0.17%	3,437	99.74%	3,446	0.02%
Safari 2WD	1	0.04%	2	0.09%	2,237	99.87%	2,240	0.02%
Savanna 1500 2WD	1	0.04%	2	0.09%	2,234	99.87%	2,237	0.02%
Sierra / Yukon / 1500 4WD	1	0.02%	9	0.15%	6,045	99.83%	6,055	0.04%
Sierra 1500	9	0.01%	58	0.06%	102,697	99.93%	102,764	0.71%

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Sierra 1500 2WD	17	0.05%	101	0.29%	35,027	99.66%	35,145	0.24%
Sierra 1500 Pickup 2WD	2	0.02%	31	0.25%	12,228	99.73%	12,261	0.08%
Sierra 1500 Pickup 4WD	3	0.04%	11	0.15%	7,294	99.81%	7,308	0.05%
Sierra 2500 Pickup 2WD	3	0.28%	2	0.18%	1,083	99.54%	1,088	0.01%
Sierra Denali / Yukon 1500 4WD	1	0.01%	5	0.07%	6,914	99.91%	6,920	0.05%
Sonoma Pickup 2WD	2	0.05%	4	0.10%	4,142	99.86%	4,148	0.03%
Terrain SLE1	1	0.01%	6	0.04%	15,246	99.95%	15,253	0.11%
Terrain SLT1	2	0.03%	5	0.06%	7,863	99.91%	7,870	0.05%
Yukon 2WD	10	0.04%	78	0.28%	27,367	99.68%	27,455	0.19%
Yukon 4WD	2	0.03%	25	0.40%	6,272	99.57%	6,299	0.04%
Yukon Denali	2	0.01%	14	0.08%	18,404	99.91%	18,420	0.13%
Yukon SLE	1	0.02%	7	0.15%	4,693	99.83%	4,701	0.03%
Yukon SLT	2	0.01%	10	0.07%	14,173	99.92%	14,185	0.10%
Yukon XL	1	0.02%	3	0.06%	5,159	99.92%	5,163	0.04%
Yukon XL Denali	1	0.01%	4	0.03%	12,299	99.96%	12,304	0.08%
HOND								
	2	0.04%	1	0.02%	4,599	99.93%	4,602	0.03%
Accord	7	0.02%	39	0.10%	40,216	99.89%	40,262	0.28%
Accord Crosstour	1	0.01%	1	0.01%	9,353	99.98%	9,355	0.06%
Accord DX Value Pkg	1	0.04%	1	0.04%	2,352	99.92%	2,354	0.02%
Accord DX/DXVP	1	0.15%	2	0.30%	670	99.55%	673	0.00%
Accord EX	26	0.02%	101	0.09%	118,300	99.89%	118,427	0.82%
Accord EX L	1	0.01%	11	0.06%	17,061	99.93%	17,073	0.12%
Accord EX L V6	2	0.02%	9	0.07%	13,137	99.92%	13,148	0.09%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Accord EX-L	2	0.01%	13	0.04%	32,171	99.95%	32,186	0.22%
Accord EX-L V6	2	0.01%	12	0.04%	33,414	99.96%	33,428	0.23%
Accord Hybrid Touring	1	0.08%	1	0.08%	1,238	99.84%	1,240	0.01%
Accord LX	10	0.01%	82	0.07%	119,582	99.92%	119,674	0.83%
Accord LX Premium	1	0.01%	6	0.07%	8,966	99.92%	8,973	0.06%
Accord LX-S	3	0.10%	2	0.06%	3,120	99.84%	3,125	0.02%
Accord LX-SE	2	0.05%	4	0.10%	4,165	99.86%	4,171	0.03%
Accord SE	6	0.02%	27	0.11%	24,373	99.86%	24,406	0.17%
Accord Sport	3	0.01%	15	0.05%	32,247	99.94%	32,265	0.22%
Accord Touring	1	0.02%	5	0.10%	5,166	99.88%	5,172	0.04%
Accord VP	2	0.05%	7	0.18%	3,928	99.77%	3,937	0.03%
Accrod EX-L	1	0.01%	6	0.04%	15,703	99.96%	15,710	0.11%
Civic	8	0.03%	31	0.13%	24,043	99.84%	24,082	0.17%
Civic DX-VP	4	0.06%	1	0.01%	6,876	99.93%	6,881	0.05%
Civic EX	20	0.02%	59	0.07%	87,608	99.91%	87,687	0.60%
Civic EX L	1	0.02%	2	0.05%	4,159	99.93%	4,162	0.03%
Civic EX-L	2	0.02%	3	0.03%	11,392	99.96%	11,397	0.08%
Civic Hybrid	3	0.03%	10	0.11%	9,407	99.86%	9,420	0.06%
Civic LX	25	0.01%	109	0.06%	173,179	99.92%	173,313	1.20%
CR-V	12	0.01%	88	0.05%	166,106	99.94%	166,206	1.15%
CR-V EX	2	0.03%	6	0.08%	7,350	99.89%	7,358	0.05%
CR-V EX 4WD	1	0.03%	6	0.15%	3,891	99.82%	3,898	0.03%
CR-V EX-L 2WD	1	0.01%	4	0.04%	9,417	99.95%	9,422	0.07%
CR-V LX	2	0.02%	17	0.13%	12,912	99.85%	12,931	0.09%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
CR-V LX 2WD	1	0.01%	13	0.11%	11,888	99.88%	11,902	0.08%
CR-V SE 4WD	1	0.05%	3	0.14%	2,111	99.81%	2,115	0.01%
Element	2	0.01%	12	0.07%	16,034	99.91%	16,048	0.11%
FIT HB LX	1	0.04%	1	0.04%	2,309	99.91%	2,311	0.02%
Fit Sport	1	0.01%	7	0.09%	8,178	99.90%	8,186	0.06%
Odyssey	16	0.01%	78	0.05%	152,997	99.94%	153,091	1.06%
Passport 2WD	1	0.06%	7	0.40%	1,733	99.54%	1,741	0.01%
Pilot	10	0.01%	86	0.07%	130,337	99.93%	130,433	0.90%
Prelude	2	0.09%	6	0.28%	2,163	99.63%	2,171	0.01%
Ridgeline	5	0.03%	7	0.05%	15,285	99.92%	15,297	0.11%
HUMM								
	3	0.06%	15	0.32%	4,656	99.61%	4,674	0.03%
H3 - SUV 4WD	6	0.15%	9	0.23%	3,957	99.62%	3,972	0.03%
HYUN								
Accent	2	0.00%	17	0.04%	44,683	99.96%	44,702	0.31%
Azera	1	0.01%	5	0.07%	7,587	99.92%	7,593	0.05%
Elantra	10	0.01%	69	0.07%	103,552	99.92%	103,631	0.71%
Elantra (XD)	6	0.03%	30	0.13%	22,331	99.84%	22,367	0.15%
Genesis / Equus	1	0.01%	11	0.06%	19,443	99.94%	19,455	0.13%
Santa Fe	2	0.00%	85	0.10%	81,005	99.89%	81,092	0.56%
Sonata	19	0.01%	171	0.12%	145,605	99.87%	145,795	1.01%
Tiburon	2	0.04%	13	0.27%	4,856	99.69%	4,871	0.03%
Tucson	2	0.01%	11	0.03%	32,659	99.96%	32,672	0.23%
Tuscon	3	0.04%	5	0.07%	6,999	99.89%	7,007	0.05%

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Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Veloster	2	0.01%	7	0.05%	14,847	99.94%	14,856	0.10%
XG350	1	0.06%	1	0.06%	1,574	99.87%	1,576	0.01%
INFI								
Cube	1	0.01%	8	0.06%	14,291	99.94%	14,300	0.10%
FX35 or FX45	2	0.02%	9	0.09%	10,090	99.89%	10,101	0.07%
FX35/FX50	1	0.02%	4	0.08%	5,070	99.90%	5,075	0.04%
G25/G37 Coupe	1	0.01%	21	0.12%	17,196	99.87%	17,218	0.12%
G35	5	0.02%	25	0.10%	24,095	99.88%	24,125	0.17%
G35 Coupe	1	0.01%	16	0.09%	17,785	99.90%	17,802	0.12%
G35 Sport	2	0.04%	5	0.10%	5,111	99.86%	5,118	0.04%
G37	1	0.01%	7	0.05%	14,556	99.95%	14,564	0.10%
M35/M45	1	0.01%	17	0.15%	11,409	99.84%	11,427	0.08%
Murano	1	0.01%	3	0.03%	10,828	99.96%	10,832	0.07%
Q50	1	0.00%	16	0.07%	21,505	99.92%	21,522	0.15%
QX50	1	0.02%	1	0.02%	4,876	99.96%	4,878	0.03%
QX70	1	0.03%	3	0.08%	3,981	99.90%	3,985	0.03%
ISU								
Rodeo 4WD	1	0.21%	2	0.41%	482	99.38%	485	0.00%
JAGU								
F-Type	1	0.04%	4	0.14%	2,758	99.82%	2,763	0.02%
S-Type	1	0.02%	9	0.21%	4,277	99.77%	4,287	0.03%
S-Type Sport	1	0.48%	1	0.48%	208	99.05%	210	0.00%
XJ8	1	0.21%	2	0.41%	484	99.38%	487	0.00%
XK8	1	0.15%	2	0.30%	655	99.54%	658	0.00%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
XK8 / XKR	1	0.09%	5	0.46%	1,086	99.45%	1,092	0.01%
JEEP								
Cherokee	4	0.01%	33	0.08%	43,560	99.92%	43,597	0.30%
Cherokee 2WD	3	0.05%	15	0.24%	6,259	99.71%	6,277	0.04%
Cherokee 4WD	1	0.02%	15	0.35%	4,320	99.63%	4,336	0.03%
Commander LHD 2WD	1	0.02%	2	0.04%	4,715	99.94%	4,718	0.03%
Compass	4	0.02%	25	0.11%	22,007	99.87%	22,036	0.15%
Grand Cherokee	6	0.01%	39	0.05%	79,042	99.94%	79,087	0.55%
Grand Cherokee 2WD	2	0.02%	9	0.10%	8,870	99.88%	8,881	0.06%
Grand Cherokee 4WD	1	0.02%	11	0.17%	6,622	99.82%	6,634	0.05%
Grand Cherokee Laredo 2WD	4	0.02%	25	0.14%	18,240	99.84%	18,269	0.13%
Grand Cherokee Laredo 4WD	3	0.04%	10	0.13%	7,696	99.83%	7,709	0.05%
Grand Cherokee Limited 4WD	1	0.02%	7	0.15%	4,715	99.83%	4,723	0.03%
Liberty Limited 4WD	1	0.03%	7	0.22%	3,130	99.75%	3,138	0.02%
Liberty Renegade 2WD	1	0.08%	1	0.08%	1,302	99.85%	1,304	0.01%
Liberty Sport 2WD	3	0.02%	17	0.14%	12,264	99.84%	12,284	0.08%
Liberty Sport 4WD	4	0.08%	4	0.08%	5,167	99.85%	5,175	0.04%
Patriot	5	0.02%	31	0.09%	33,200	99.89%	33,236	0.23%
Renegade	1	0.01%	15	0.12%	12,289	99.87%	12,305	0.08%
Wrangler	6	0.01%	65	0.07%	93,784	99.92%	93,855	0.65%
Wrangler Rubicon / Unlimited R	2	0.08%	1	0.04%	2,506	99.88%	2,509	0.02%
Wrangler Rubicon 4WD	2	0.07%	10	0.36%	2,755	99.57%	2,767	0.02%
Wrangler Sahara/Unlimited Saha	1	0.03%	1	0.03%	3,537	99.94%	3,539	0.02%
Wrangler Sport 4WD	2	0.04%	10	0.19%	5,208	99.77%	5,220	0.04%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Wrangler X / Wrangler Willys	3	0.07%	9	0.21%	4,178	99.71%	4,190	0.03%
KIA								
Forte	4	0.01%	14	0.05%	27,645	99.93%	27,663	0.19%
Forte / Forte Koup	1	0.00%	13	0.06%	21,506	99.93%	21,520	0.15%
Optima	2	0.02%	10	0.08%	11,765	99.90%	11,777	0.08%
Optima / Optima Hybrid	5	0.01%	48	0.07%	70,606	99.92%	70,659	0.49%
Rio	3	0.01%	18	0.07%	26,714	99.92%	26,735	0.18%
Sedona	1	0.01%	2	0.02%	10,747	99.97%	10,750	0.07%
Sedona 2WD	2	0.07%	6	0.21%	2,799	99.71%	2,807	0.02%
Sedona VQ	2	0.04%	6	0.11%	5,425	99.85%	5,433	0.04%
Sorento 2WD	2	0.01%	15	0.10%	15,750	99.89%	15,767	0.11%
Soul	7	0.01%	40	0.05%	80,289	99.94%	80,336	0.55%
Spectra	6	0.02%	16	0.06%	25,409	99.91%	25,431	0.18%
Sportage	2	0.01%	11	0.07%	14,776	99.91%	14,789	0.10%
Sportage 2WD	1	0.01%	5	0.05%	9,122	99.93%	9,128	0.06%
LEXS								
ES 350	3	0.00%	15	0.02%	61,992	99.97%	62,010	0.43%
ES300	6	0.03%	37	0.17%	21,213	99.80%	21,256	0.15%
ES330	1	0.01%	19	0.12%	16,117	99.88%	16,137	0.11%
ES350	5	0.02%	26	0.09%	28,636	99.89%	28,667	0.20%
GS 350	1	0.00%	24	0.11%	21,029	99.88%	21,054	0.15%
GS300/GS450	2	0.04%	6	0.11%	5,539	99.86%	5,547	0.04%
GS350	1	0.02%	7	0.12%	5,789	99.86%	5,797	0.04%
GX 460	1	0.00%	13	0.05%	27,275	99.95%	27,289	0.19%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
GX470	4	0.03%	20	0.15%	13,545	99.82%	13,569	0.09%
IS 250	1	0.00%	36	0.13%	27,496	99.87%	27,533	0.19%
IS 250C	1	0.03%	4	0.11%	3,801	99.87%	3,806	0.03%
IS 350	1	0.02%	10	0.16%	6,209	99.82%	6,220	0.04%
IS250	5	0.03%	18	0.10%	18,140	99.87%	18,163	0.13%
IS300	1	0.02%	2	0.04%	4,900	99.94%	4,903	0.03%
LS 460	5	0.04%	3	0.02%	12,559	99.94%	12,567	0.09%
LS400	1	0.01%	6	0.09%	6,889	99.90%	6,896	0.05%
LX 570	1	0.02%	1	0.02%	5,381	99.96%	5,383	0.04%
LX470	1	0.02%	7	0.15%	4,627	99.83%	4,635	0.03%
NX 200t	3	0.02%	11	0.06%	17,547	99.92%	17,561	0.12%
RX 350	6	0.01%	52	0.05%	103,904	99.94%	103,962	0.72%
RX 450h	1	0.02%	9	0.14%	6,541	99.85%	6,551	0.05%
RX300	3	0.02%	24	0.15%	16,170	99.83%	16,197	0.11%
RX330	8	0.04%	25	0.12%	20,302	99.84%	20,335	0.14%
RX350	3	0.01%	39	0.15%	25,762	99.84%	25,804	0.18%
RX400h	1	0.02%	9	0.19%	4,755	99.79%	4,765	0.03%
SC430	1	0.01%	9	0.12%	7,484	99.87%	7,494	0.05%
LINC								
Aviator	7	0.17%	29	0.70%	4,128	99.14%	4,164	0.03%
LS	1	0.02%	11	0.24%	4,626	99.74%	4,638	0.03%
Mark LT 2WD SuperCrew	4	0.16%	7	0.27%	2,547	99.57%	2,558	0.02%
MKX	2	0.01%	4	0.02%	16,028	99.96%	16,034	0.11%
MKZ	6	0.03%	19	0.10%	18,118	99.86%	18,143	0.13%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Navigator	2	0.02%	7	0.06%	12,108	99.93%	12,117	0.08%
Navigator 2WD	8	0.04%	75	0.41%	18,042	99.54%	18,125	0.13%
Navigator 4WD	2	0.05%	8	0.21%	3,841	99.74%	3,851	0.03%
Town Car Cartier	4	0.13%	15	0.50%	2,982	99.37%	3,001	0.02%
Town Car Executive	8	0.13%	36	0.58%	6,191	99.29%	6,235	0.04%
Town Car Signature	3	0.03%	38	0.34%	11,024	99.63%	11,065	0.08%
Town Car Signature Limited	4	0.06%	8	0.12%	6,490	99.82%	6,502	0.04%
Town Car Ultimate	1	0.09%	4	0.36%	1,094	99.55%	1,099	0.01%
Zephyr	2	0.08%	1	0.04%	2,655	99.89%	2,658	0.02%
LNDR								
Range Rover	10	0.02%	64	0.11%	58,860	99.87%	58,934	0.41%
MASE								
	2	0.25%	3	0.37%	799	99.38%	804	0.01%
MAZD								
3	6	0.02%	37	0.13%	27,666	99.84%	27,709	0.19%
5	2	0.05%	5	0.12%	4,049	99.83%	4,056	0.03%
6	11	0.07%	80	0.50%	15,869	99.43%	15,960	0.11%
	2	0.02%	18	0.19%	9,475	99.79%	9,495	0.07%
B-Series Super Cab 2WD	1	0.05%	4	0.21%	1,917	99.74%	1,922	0.01%
CX-7	7	0.05%	73	0.50%	14,621	99.46%	14,701	0.10%
Mazda 2	1	0.02%	18	0.43%	4,180	99.55%	4,199	0.03%
Mazda 3	9	0.02%	54	0.15%	36,104	99.83%	36,167	0.25%
Mazda 3 Touring	1	0.01%	3	0.04%	7,853	99.95%	7,857	0.05%
Mazda 6	1	0.01%	39	0.41%	9,556	99.58%	9,596	0.07%

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Mazda 6 Sport	1	0.02%	1	0.02%	4,737	99.96%	4,739	0.03%
MPV	1	0.02%	9	0.19%	4,798	99.79%	4,808	0.03%
MX5 Miata	1	0.03%	27	0.89%	2,998	99.07%	3,026	0.02%
MX-5 Miata	4	0.05%	12	0.16%	7,533	99.79%	7,549	0.05%
Protege	5	0.07%	31	0.41%	7,521	99.52%	7,557	0.05%
RX-8	1	0.04%	11	0.41%	2,656	99.55%	2,668	0.02%
Tribute DX 2WD	1	0.04%	2	0.07%	2,854	99.89%	2,857	0.02%
Tribute LX 2WD	2	0.04%	6	0.12%	5,163	99.85%	5,171	0.04%
MERC								
Grand Marquis GS	3	0.02%	28	0.22%	12,751	99.76%	12,782	0.09%
Grand Marquis LS	10	0.05%	51	0.25%	20,085	99.70%	20,146	0.14%
Montego Luxury	1	0.12%	3	0.35%	847	99.53%	851	0.01%
Mountaineer 2WD	3	0.06%	4	0.09%	4,631	99.85%	4,638	0.03%
Sable GS	1	0.04%	4	0.16%	2,546	99.80%	2,551	0.02%
MERZ								
	4	0.01%	26	0.08%	30,956	99.90%	30,986	0.21%
C230	6	0.06%	29	0.29%	10,028	99.65%	10,063	0.07%
C250	1	0.00%	10	0.04%	22,499	99.95%	22,510	0.16%
C280	5	0.22%	6	0.26%	2,289	99.52%	2,300	0.02%
C300	5	0.02%	29	0.12%	23,737	99.86%	23,771	0.16%
CLA250	2	0.02%	4	0.03%	12,085	99.95%	12,091	0.08%
CLK320	2	0.08%	1	0.04%	2,524	99.88%	2,527	0.02%
E300	1	0.04%	1	0.04%	2,819	99.93%	2,821	0.02%
E320	1	0.04%	4	0.15%	2,719	99.82%	2,724	0.02%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
E320W	3	0.04%	5	0.07%	7,136	99.89%	7,144	0.05%
E350	6	0.01%	38	0.08%	48,131	99.91%	48,175	0.33%
E400	1	0.05%	3	0.15%	2,047	99.80%	2,051	0.01%
G63 AMG	1	0.10%	2	0.19%	1,045	99.71%	1,048	0.01%
GL450	1	0.01%	11	0.08%	14,590	99.92%	14,602	0.10%
GL550	2	0.05%	3	0.08%	3,848	99.87%	3,853	0.03%
GLC300	1	0.01%	6	0.07%	8,116	99.91%	8,123	0.06%
GLE350	1	0.01%	4	0.04%	9,713	99.95%	9,718	0.07%
GLK350	1	0.01%	15	0.08%	18,026	99.91%	18,042	0.12%
ML350	1	0.00%	13	0.04%	31,876	99.96%	31,890	0.22%
R350	1	0.05%	2	0.09%	2,124	99.86%	2,127	0.01%
S430V	2	0.06%	4	0.12%	3,281	99.82%	3,287	0.02%
S500	2	0.18%	1	0.09%	1,112	99.73%	1,115	0.01%
S550	3	0.02%	7	0.04%	19,012	99.95%	19,022	0.13%
SL500R	1	0.03%	7	0.22%	3,134	99.75%	3,142	0.02%
SL550	1	0.02%	7	0.16%	4,500	99.82%	4,508	0.03%
SLK230	1	0.05%	6	0.33%	1,839	99.62%	1,846	0.01%
MITS								
Eclipse	2	0.28%	3	0.41%	718	99.31%	723	0.00%
Eclipse GS	1	0.02%	8	0.19%	4,141	99.78%	4,150	0.03%
Eclipse GS Spyder	1	0.13%	4	0.53%	748	99.34%	753	0.01%
Eclipse GT	5	0.31%	5	0.31%	1,593	99.38%	1,603	0.01%
Eclipse GT Premium	1	0.27%	2	0.53%	373	99.20%	376	0.00%
Eclipse Spyder GT Premium	1	0.46%	1	0.46%	217	99.09%	219	0.00%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Galant	2	0.54%	3	0.81%	367	98.66%	372	0.00%
Galant ES / GTZ / LS	2	0.05%	11	0.26%	4,173	99.69%	4,186	0.03%
Galant ES / SE/ GTS	1	0.03%	10	0.26%	3,898	99.72%	3,909	0.03%
Galant ES/SE	2	0.07%	21	0.76%	2,752	99.17%	2,775	0.02%
Galant FE	5	0.18%	25	0.88%	2,812	98.94%	2,842	0.02%
Lancer ES	3	0.02%	11	0.08%	14,344	99.90%	14,358	0.10%
Lancer GT	1	0.09%	1	0.09%	1,131	99.82%	1,133	0.01%
Lancer OZ-Rally	1	0.10%	2	0.20%	976	99.69%	979	0.01%
Mirage DE	1	0.03%	8	0.24%	3,353	99.73%	3,362	0.02%
Mirage ES	4	0.13%	5	0.16%	3,157	99.72%	3,166	0.02%
Montero Limited	1	0.07%	3	0.20%	1,531	99.74%	1,535	0.01%
Montero Sport 2WD	2	0.04%	5	0.10%	4,916	99.86%	4,923	0.03%
Outlander LS FWD	1	0.08%	8	0.64%	1,239	99.28%	1,248	0.01%
Outlander SE FWD	1	0.02%	11	0.21%	5,181	99.77%	5,193	0.04%
Outlander Sport SE FWD	2	0.04%	2	0.04%	4,683	99.91%	4,687	0.03%
NISS								
	9	0.05%	5	0.03%	19,196	99.93%	19,210	0.13%
350Z	1	0.01%	18	0.15%	11,870	99.84%	11,889	0.08%
Altima	35	0.01%	329	0.09%	371,529	99.90%	371,893	2.57%
Armada/Titan	3	0.02%	14	0.07%	18,666	99.91%	18,683	0.13%
Cube	1	0.02%	5	0.12%	4,141	99.86%	4,147	0.03%
Frontier	7	0.01%	48	0.07%	73,595	99.93%	73,650	0.51%
Juke	2	0.01%	9	0.04%	24,056	99.95%	24,067	0.17%
Maxima	9	0.01%	71	0.08%	86,077	99.91%	86,157	0.59%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Murano	8	0.01%	50	0.06%	85,237	99.93%	85,295	0.59%
NV200	1	0.02%	8	0.19%	4,263	99.79%	4,272	0.03%
Pathfinder	6	0.01%	53	0.06%	84,027	99.93%	84,086	0.58%
Pathfinder Armada	4	0.02%	13	0.07%	18,690	99.91%	18,707	0.13%
Pickup Crew Cab	2	0.02%	9	0.10%	9,408	99.88%	9,419	0.06%
Pickup King Cab	4	0.03%	15	0.11%	14,004	99.86%	14,023	0.10%
Quest	5	0.03%	17	0.10%	17,339	99.87%	17,361	0.12%
Rogue	7	0.00%	59	0.04%	140,543	99.95%	140,609	0.97%
Rogue Select	1	0.01%	6	0.04%	13,663	99.95%	13,670	0.09%
Sentra	19	0.01%	107	0.07%	156,192	99.92%	156,318	1.08%
Titan	8	0.02%	22	0.06%	37,419	99.92%	37,449	0.26%
Truck Regular Bed	2	0.03%	10	0.17%	5,748	99.79%	5,760	0.04%
Versa	13	0.02%	58	0.07%	77,302	99.91%	77,373	0.53%
Versa Note	4	0.02%	10	0.06%	17,926	99.92%	17,940	0.12%
Xterra	7	0.02%	37	0.10%	38,740	99.89%	38,784	0.27%
OLDS								
Delta 88	1	0.17%	1	0.17%	574	99.65%	576	0.00%
OTHR								
	15	0.03%	50	0.11%	45,356	99.86%	45,421	0.31%
Accent	1	0.05%	2	0.10%	2,087	99.86%	2,090	0.01%
Accord EX	2	0.16%	2	0.16%	1,256	99.68%	1,260	0.01%
Altima	1	0.01%	6	0.06%	10,879	99.94%	10,886	0.08%
Avenger SXT	1	0.44%	1	0.44%	225	99.12%	227	0.00%
Camry	1	0.01%	11	0.07%	16,216	99.93%	16,228	0.11%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Caravan C/V FWD	1	0.17%	1	0.17%	585	99.66%	587	0.00%
Caravan SE / Grand Caravan SE	1	0.88%	1	0.88%	112	98.25%	114	0.00%
Charger SE	1	0.14%	1	0.14%	698	99.71%	700	0.00%
Cooper S	1	0.04%	2	0.07%	2,664	99.89%	2,667	0.02%
Corolla	1	0.01%	10	0.09%	10,989	99.90%	11,000	0.08%
CX-7	1	0.55%	1	0.55%	179	98.90%	181	0.00%
Escape	1	0.01%	5	0.05%	9,168	99.93%	9,174	0.06%
Explorer	1	0.01%	7	0.07%	10,073	99.92%	10,081	0.07%
F150	4	0.02%	13	0.06%	22,514	99.92%	22,531	0.16%
F150 2WD	1	0.29%	1	0.29%	342	99.42%	344	0.00%
Jetta	1	0.04%	3	0.11%	2,696	99.85%	2,700	0.02%
Journey	1	0.04%	6	0.21%	2,792	99.75%	2,799	0.02%
Mini Cooper S	1	0.03%	4	0.11%	3,586	99.86%	3,591	0.02%
Mirage ES	1	0.31%	1	0.31%	317	99.37%	319	0.00%
NX 200t	2	0.06%	2	0.06%	3,144	99.87%	3,148	0.02%
Odyssey	3	0.03%	8	0.07%	11,078	99.90%	11,089	0.08%
Passat	1	0.04%	9	0.40%	2,247	99.56%	2,257	0.02%
Pilot	1	0.02%	4	0.07%	5,409	99.91%	5,414	0.04%
Range Rover	1	0.03%	7	0.19%	3,688	99.78%	3,696	0.03%
Ranger	1	0.85%	2	1.71%	114	97.44%	117	0.00%
RAV4 XLE	1	0.03%	5	0.14%	3,640	99.84%	3,646	0.03%
Rogue	1	0.01%	8	0.07%	10,776	99.92%	10,785	0.07%
Santa Fe	1	0.02%	5	0.08%	6,222	99.90%	6,228	0.04%
Sentra	1	0.02%	8	0.13%	6,370	99.86%	6,379	0.04%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Sienna	1	0.03%	2	0.07%	3,040	99.90%	3,043	0.02%
Sienna LE	2	0.04%	6	0.12%	5,161	99.85%	5,169	0.04%
Silverado 1500	1	0.01%	12	0.07%	17,234	99.92%	17,247	0.12%
Sonata	3	0.06%	5	0.10%	4,909	99.84%	4,917	0.03%
Tahoe 2WD	1	0.49%	1	0.49%	201	99.01%	203	0.00%
Wrangler	5	0.07%	8	0.12%	6,813	99.81%	6,826	0.05%
PLYM								
Neon LX	1	0.22%	1	0.22%	458	99.57%	460	0.00%
PONT								
Aztek 2WD	1	0.08%	7	0.59%	1,181	99.33%	1,189	0.01%
Bonneville SE	1	0.07%	5	0.35%	1,415	99.58%	1,421	0.01%
G5 Sport	1	0.39%	2	0.78%	255	98.84%	258	0.00%
G6 GT	2	0.03%	9	0.13%	7,017	99.84%	7,028	0.05%
G6 SE1	2	0.02%	23	0.20%	11,253	99.78%	11,278	0.08%
Grand Am GT	1	0.08%	1	0.08%	1,323	99.85%	1,325	0.01%
Grand Am GT1	1	0.21%	2	0.42%	470	99.37%	473	0.00%
Grand Am SE	3	0.10%	4	0.14%	2,909	99.76%	2,916	0.02%
Grand Prix GT	3	0.06%	13	0.26%	4,968	99.68%	4,984	0.03%
Grand Prix SE1	3	0.31%	10	1.04%	945	98.64%	958	0.01%
Grand Prix Sedan	1	0.03%	6	0.17%	3,441	99.80%	3,448	0.02%
Sunfire	3	0.09%	6	0.18%	3,294	99.73%	3,303	0.02%
Torrent FWD	3	0.09%	2	0.06%	3,291	99.85%	3,296	0.02%
Vibe	1	0.01%	12	0.14%	8,535	99.85%	8,548	0.06%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
PORS								
911	1	0.01%	23	0.15%	15,249	99.84%	15,273	0.11%
	3	0.43%	24	3.60%	667	96.11%	694	0.00%
986 Boxster	1	0.03%	19	0.58%	3,299	99.40%	3,319	0.02%
Cayenne	11	0.08%	76	0.56%	13,493	99.36%	13,580	0.09%
Cayman / Boxster	2	0.07%	8	0.28%	2,814	99.65%	2,824	0.02%
Panamera	1	0.02%	15	0.23%	6,490	99.75%	6,506	0.04%
RAM								
	1	0.01%	9	0.08%	11,486	99.91%	11,496	0.08%
SAA								
9/3/2020	1	0.02%	6	0.14%	4,440	99.84%	4,447	0.03%
SCIO								
	6	0.02%	54	0.18%	29,603	99.80%	29,663	0.20%
Scion tC	1	0.00%	11	0.05%	20,590	99.94%	20,602	0.14%
STRN								
Astra XE	1	0.31%	2	0.62%	322	99.08%	325	0.00%
ION Level 2	4	0.05%	27	0.35%	7,637	99.60%	7,668	0.05%
Relay 2WD	1	0.23%	1	0.24%	424	99.53%	426	0.00%
SC1 / SL	4	0.94%	10	2.42%	413	96.72%	427	0.00%
SC1 Auto	1	0.38%	1	0.38%	261	99.24%	263	0.00%
SC2 / SL1 / SW1	7	0.49%	25	1.80%	1,389	97.75%	1,421	0.01%
SL2 / SW2	4	0.24%	38	2.37%	1,603	97.45%	1,645	0.01%
Vue FWD	10	0.08%	72	0.60%	11,940	99.32%	12,022	0.08%

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Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
SUBA								
B9 Tribecca	1	0.06%	5	0.33%	1,538	99.61%	1,544	0.01%
BRZ	2	0.06%	12	0.38%	3,132	99.55%	3,146	0.02%
Crosstrek	1	0.01%	2	0.02%	10,951	99.97%	10,954	0.08%
Forester	2	0.01%	34	0.09%	36,464	99.90%	36,500	0.25%
Impreza	5	0.03%	17	0.11%	15,490	99.86%	15,512	0.11%
Legacy/Outback	1	0.01%	13	0.19%	6,846	99.80%	6,860	0.05%
Outback	1	0.00%	15	0.05%	27,618	99.94%	27,634	0.19%
SUZI								
Forenza / Reno	2	0.06%	4	0.12%	3,364	99.82%	3,370	0.02%
Grand Vitara	1	0.13%	10	1.37%	732	98.52%	743	0.01%
Grand Vitara 2WD	2	0.08%	19	0.77%	2,483	99.16%	2,504	0.02%
Grand Vitara XL7 2WD	1	0.07%	3	0.21%	1,447	99.72%	1,451	0.01%
TOYT								
4dr Wagon 2WD	2	0.04%	3	0.06%	4,994	99.90%	4,999	0.03%
4Runner	1	0.00%	33	0.06%	56,201	99.94%	56,235	0.39%
4Runner 2WD	3	0.02%	28	0.18%	15,859	99.80%	15,890	0.11%
4Runner Limited	1	0.01%	7	0.05%	13,525	99.94%	13,533	0.09%
4Runner SR5	13	0.02%	49	0.09%	56,172	99.89%	56,234	0.39%
Avalon	6	0.01%	68	0.09%	79,113	99.91%	79,187	0.55%
Camry	68	0.01%	411	0.08%	522,147	99.91%	522,626	3.61%
Camry Hybrid	1	0.01%	7	0.04%	18,698	99.96%	18,706	0.13%
Celica	3	0.05%	7	0.12%	5,971	99.83%	5,981	0.04%
Corolla	32	0.01%	208	0.06%	320,413	99.93%	320,653	2.21%

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Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Corolla/Matrix	10	0.01%	73	0.10%	73,127	99.89%	73,210	0.51%
Echo	1	0.03%	3	0.08%	3,792	99.89%	3,796	0.03%
FJ Cruiser	1	0.01%	17	0.09%	18,722	99.90%	18,740	0.13%
Highlander	6	0.01%	47	0.06%	77,920	99.93%	77,973	0.54%
Highlander LE	1	0.01%	10	0.08%	12,489	99.91%	12,500	0.09%
Land Cruiser	3	0.04%	8	0.12%	6,759	99.84%	6,770	0.05%
Matrix	2	0.02%	8	0.07%	11,416	99.91%	11,426	0.08%
Prius	4	0.02%	14	0.06%	21,819	99.92%	21,837	0.15%
Prius Hybrid	4	0.01%	31	0.07%	43,829	99.92%	43,864	0.30%
Prius V Hybrid	1	0.01%	9	0.13%	7,116	99.86%	7,126	0.05%
RAV4	9	0.02%	35	0.06%	58,462	99.92%	58,506	0.40%
RAV4 Ltd	1	0.01%	7	0.05%	14,373	99.94%	14,381	0.10%
RAV4 XLE	3	0.01%	17	0.04%	41,433	99.95%	41,453	0.29%
Scion tC	1	0.08%	1	0.08%	1,316	99.85%	1,318	0.01%
Sequoia / Highlander	3	0.03%	10	0.10%	10,075	99.87%	10,088	0.07%
Sequoia Limited	1	0.01%	18	0.13%	13,726	99.86%	13,745	0.09%
Sequoia Platinum	1	0.02%	2	0.03%	5,976	99.95%	5,979	0.04%
Sequoia SR5	2	0.01%	16	0.10%	16,494	99.89%	16,512	0.11%
Sienna	1	0.01%	3	0.02%	12,459	99.97%	12,463	0.09%
Sienna CE	1	0.03%	8	0.21%	3,764	99.76%	3,773	0.03%
Sienna LE	5	0.01%	62	0.10%	62,524	99.89%	62,591	0.43%
Sienna Ltd	1	0.00%	10	0.04%	25,935	99.96%	25,946	0.18%
Sienna XLE	4	0.03%	21	0.15%	13,803	99.82%	13,828	0.10%
Solara	5	0.02%	27	0.13%	20,486	99.84%	20,518	0.14%

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

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	Count	Percent	Count	Percent	Count	Percent	Count	Percent
T100 Regular Cab 2WD	1	0.46%	1	0.46%	216	99.08%	218	0.00%
T100 XTRACAB 2WD	1	0.06%	4	0.26%	1,564	99.68%	1,569	0.01%
Tacoma	3	0.01%	31	0.06%	56,334	99.94%	56,368	0.39%
Tacoma Deluxe	5	0.02%	33	0.11%	29,677	99.87%	29,715	0.21%
Tacoma DLX	3	0.01%	44	0.09%	48,055	99.90%	48,102	0.33%
Tacoma SR/SR5/TRD	1	0.02%	2	0.04%	5,498	99.95%	5,501	0.04%
Tacoma SR5	1	0.04%	9	0.34%	2,622	99.62%	2,632	0.02%
Tacoma XTRACAB 2WD	1	0.02%	13	0.26%	4,987	99.72%	5,001	0.03%
Tundra	1	0.00%	18	0.09%	20,084	99.91%	20,103	0.14%
Tundra SR/SR5	2	0.00%	17	0.04%	40,613	99.95%	40,632	0.28%
Tundra Limited	3	0.03%	8	0.08%	10,480	99.90%	10,491	0.07%
Tundra Platinum	1	0.01%	5	0.04%	11,990	99.95%	11,996	0.08%
Tundra SR5	5	0.00%	70	0.07%	105,214	99.93%	105,289	0.73%
Yaris	4	0.01%	14	0.05%	27,516	99.93%	27,534	0.19%
VOLK								
CC	1	0.01%	4	0.04%	9,466	99.95%	9,471	0.07%
Golf / GTI / Jetta Wagon	1	0.03%	7	0.23%	3,063	99.74%	3,071	0.02%
Golf/Golf R/GTI/Jetta/Jetta Sp	1	0.01%	4	0.03%	11,779	99.96%	11,784	0.08%
Golf/GTI/Jetta/Jetta Sportwage	2	0.01%	23	0.07%	33,841	99.93%	33,866	0.23%
Golf/Jetta/Jetta Sportwagen	1	0.02%	8	0.14%	5,811	99.85%	5,820	0.04%
Jetta	9	0.03%	52	0.17%	30,740	99.80%	30,801	0.21%
Jetta/Golf/GTI	4	0.25%	25	1.62%	1,541	98.15%	1,570	0.01%
Jetta/Rabbit/GTI	7	0.03%	25	0.10%	24,289	99.87%	24,321	0.17%
New Beetle	2	0.02%	24	0.25%	9,423	99.72%	9,449	0.07%

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

Make/Model	DLC is Damaged, Inaccessible, or Cannot be Found		Vehicle will not Communicate with Analyzer		Vehicle Successfully Communicates with Analyzer		Total Count of Tests by Make	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
New Beetle Convertible	6	0.14%	19	0.44%	4,330	99.43%	4,355	0.03%
Passat	7	0.01%	53	0.11%	46,931	99.87%	46,991	0.32%
Tiguan	2	0.01%	22	0.12%	17,627	99.86%	17,651	0.12%
Touareg	1	0.02%	7	0.16%	4,411	99.82%	4,419	0.03%
VOLV								
S40 / V50	1	0.02%	3	0.05%	6,164	99.94%	6,168	0.04%
S60	1	0.01%	10	0.05%	18,405	99.94%	18,416	0.13%
S70 / V70	2	0.13%	7	0.46%	1,516	99.41%	1,525	0.01%
XC60	1	0.01%	4	0.03%	14,033	99.96%	14,038	0.10%
XC90	1	0.01%	11	0.06%	18,199	99.93%	18,211	0.13%
Grand Total	**2,788**	**0.02%**	**15,956**	**0.11%**	**14,475,838**	**99.87%**	**14,494,582**	**100.00%**