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ON BOARD DIAGNOSTICS II (OBDII) EMISSIONS INSPECTION FAILURES COMPARED TO TRADITIONAL TAILPIPE EMISSIONS INSPECTION FAILURES

Fournier, Thomas J. *
Applus+ Technologies, Inc., U.S.A.

KEYWORDS -

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ABSTRACT -

During 2002, the implementation of vehicle On Board Diagnostics II (OBDII) as a means to determine emissions inspection failures for in-use vehicles occurred in some government mandated Inspection/Maintenance (I/M) programs within the United States of America (U.S.A.). In prior years, progress toward implementing OBDII-based I/M inspections involved controversy regarding the suitability of OBDII as a substitute for actual emissions tailpipe measurements. Much of this controversy resulted from early research conducted in laboratory environments on a limited number of vehicles and sponsored by government agencies. Now that actual OBDII-based inspection programs have been in place for more than a year, we are able to analyze real-world, statistically significant results. This paper utilizes millions of inspection results from in-use vehicles to compare OBDII and tailpipe emissions test outcomes.

My employer performs or manages the performance of vehicle inspection programs under contract to several governmental jurisdictions within the U.S.A. Therefore the process by which conclusions were reached for this paper involved management and/or oversight of vehicle inspection operations as well as collection, processing and analysis of millions of inspection records. Data analysis includes comparisons of initial inspection pass/fail rates, as well as post-repair retest pass/fail rates. Individual model years, as well as model year groupings are compared. Also OBDII inspection failure modes are presented using analysis of vehicle Diagnostic Trouble Codes.

Several interesting trends are revealed from the data analysis. These trends provide some insight into the performance differences between OBDII and tailpipe emissions testing applied to in-use vehicle I/M programs. Additionally, insight is gained regarding failure mechanism trends as viewed from the perspective of OBDII.

MAIN SECTION -

INTRODUCTION AND BACKGROUND

<u>Pollution Mitigation Success</u>

Since 1970 the aggregate emissions of air pollution in the United States of America has been reduced by 31%. The true significance of this reduction becomes apparent only when viewed in context. During the same period, the U.S.A. human population increased by 31%, the Gross Domestic Product increased by 114%, and Vehicle Miles Traveled increased by 127% (1). Despite these growth factors, air pollution was substantially reduced. The United States Environmental Protection Agency (EPA) credits a substantial portion of this air pollution reduction to Federal control of mobile sources. The statistics above underscore the importance of seeking improved efficiency regarding methods to control air pollution emissions so as to enable continued economic growth while simultaneously meeting our responsibility to the environment.

New Technology Inspection and Maintenance

In addition to mandating certification of vehicle design to tight emission standards, the EPA's control strategy has relied upon in-use vehicle Inspection and Maintenance (I/M) programs as a key part of the Federal air pollution control strategy. Historically the core element of I/M programs has been a tailpipe emissions testing. However, in keeping with the spirit of seeking improved efficiency in the control of air pollution, the U.S. Federal Clean Air Act Amendments of 1990 included provisions to standardize emissions related data and data retrieval for vehicle On Board Diagnostics II (OBDII) systems. This law eventually led to EPA rules enabling the use of OBDII testing using emissions related fault codes as a substitute for tailpipe emissions testing in I/M programs.

Concerns regarding the suitability of OBDII as an accurate and fair substitute for tailpipe emissions testing caused delay in the final implementation of OBDII for I/M purposes. A number of studies and/or pilot programs were conducted, including research by the EPA, State government agencies and universities. Finally, in 2002, the implementation of OBDII in several State government jurisdictions began in earnest as a means to pass or fail 1996 or newer model year motor vehicles during mandatory I/M inspections.

Early OBDII I/M Research

Prior to the rollout of OBDII as an I/M tool, early assessment of its benefits was primarily theoretic due to the lack of sufficient numbers of in-use vehicles equipped with OBDII technology. In 1995 representatives of the California Air Resources Board published a study of OBDII benefits based upon theoretic modeling (2). The study cited "higher identification rate for malfunctions" and increased "mechanic repair efficiency" as OBDII attributes. It concluded that using OBDII for I/M testing of newer model vehicles would produce a hydrocarbon (HC) emission benefit of 7.4% and a nitric oxides (NOx) emission benefit of 5.4% as compared to using the then-existing idle tailpipe emissions test with visual component check. The projected emissions benefit for carbon monoxide was less than 1%.

Five years later, the availability of 1996 and newer model year vehicles with actual road miles enabled EPA to conduct more real-world research into the suitability of OBDII as an I/M tool. An important element in EPA's effort to verify the suitability of OBDII was a comparative study conducted on 201 vehicles (3). Vehicles with the OBDII Malfunction Indicator Light (MIL) illuminated, indicating OBDII emissions related trouble codes, were tested for tailpipe emissions using both the initial certification Federal Test Procedures (FTP) and an I/M mass emissions test with a 240 second loaded transient drive cycle, known as the IM240 test. These same vehicles were then repaired using the OBDII trouble code information and retested. In regard to OBDII technology, the EPA study concluded, "…we believe that this technology has demonstrated an ability to identify vehicles with high emissions or defective components which is as good or better than available tailpipe testing at this time."

OBDII I/M Controversy

Despite EPA's positive conclusion, the study revealed that only 30% of the vehicles with the MIL illuminated actually failed the FTP emissions test, thereby exposing the OBDII test method to criticism as being prone to false failures. Worse yet, 22% of the vehicles with the MIL illuminated were found to be "Maintenance Not Required", meaning that no problem was found with the vehicle.

Because of these and other issues, the EPA received a number of negative comments when they published a Notice of Proposed Rulemaking on September 20, 2000 announcing intent to adopt OBDII as an alternate I/M test. In January of 2001 the EPA published a "Response to Comments" received in regard to the proposed OBDII rules (4). Some of the concerns or claims raised, as paraphrased from the EPA published Response to Comments, were:

- The EPA OBD-I/M pilot study was not rigorous enough partly due to inadequate sample size.
- The EPA needed to delay OBDII I/M implementation to study the issue of "OBD false failures".
- OBD is over-sensitive and could lead to motorist frustration due to the expected high number of failed vehicles and costly repairs.
- OBD is not an emissions test.

In their "Response to Comments" document the EPA defended OBDII indicating that:

- The pilot study sample size for OBDII was comparable to that used when IM240 was implemented as an I/M test method.
- The OBDII failures were not false failures because most of the MIL illuminated vehicles were ultimately demonstrated to have a faulty component and OBDII was, in fact, intended to find faulty components that would eventually lead to high emissions.
- On those OBDII vehicles where the MIL illuminated but no faulty components existed, the MIL would likely self-extinguished prior to an official I/M test because MIL illumination can be caused by a transient condition such as misfire and the aggressive procurement process for study vehicles likely inflated the number of such "Maintenance Not Required" vehicles.

Following the EPA's study, the California South Coast Air Quality Management District and EPA sponsored another OBDII study conducted by the University of California, Riverside (U of C) (5). The U of C study researched 77 OBDII equipped vehicles that had the MIL light illuminated by conducting comparative studies of emissions using FTP, IM240 and a steady state loaded test known as the California Acceleration Simulation Mode (ASM).

The U of C study “Summary and Conclusions” expressed no firm conclusion regarding the suitability of OBDII as an I/M tool. However, similar to the EPA study, the U of C study did yield data revealing that only 38% of the vehicles with the MIL illuminated actually failed the FTP test.

Study Goals

Despite the controversy outlined above, final EPA rules were made and OBDII was implemented as a substitute for tailpipe emissions testing on 1996 and newer vehicles during 2002 for several State jurisdictions within the U.S. The company that employs the author of this paper operates or manages I/M programs under government contract in five governmental jurisdictions within the U.S. This paper provides a study of OBDII inspection results in two such jurisdictions. In doing so it compiles the results of millions of OBDII inspections and therefore can be considered as both statistically significant and representative of the in-use fleet distribution; more so than the few hundred tests conducted by researchers prior to final rule making by the EPA. Emissions inspection pass/fail results for OBDII and non-OBDII vehicles as separate groups are compared. The study makes no attempt to correlate individual vehicle tests to FTP results. Instead, its goals are to use actual field I/M results in statistically significant quantities to:

- Assess whether OBDII test pass/fail rates are significantly different than traditional tailpipe emissions test pass/fail rates,
- Analyze repair effectiveness associated with OBDII failures in contrast to repair effectiveness associated with emissions tailpipe failures,
- Discover and communicate the most common modes of failure as found through OBDII Diagnostic Trouble Codes (DTC).

METHODS

Introduction

Due to regulatory requirements, the vehicle test procedures for non-OBDII vehicles were substantially different between the two governmental jurisdictions studied. Therefore, for purposes of this paper, each of the two jurisdictions is treated as an individual project, which we labeled “Project 1”, and “Project 2”. Data comparisons between OBDII and non-OBDII test results were limited to data within a given project.

Project 1 Methods

The Project 1 jurisdiction mandates a centralized vehicle inspection environment whereby motorists must take their vehicles to one of a limited number of test-only inspection facilities that are all operated by a single corporation under contract with the government. In the event that their vehicle fails, the motorist must seek repairs form a source different than the testing entity. The centralized contractor provides the test facilities, test equipment and personnel to conduct the inspection. The contractor has no business interest in the test results since they are forbidden to participate in vehicle repair.

Project 1 data encompassed inspection results for more than 1.40 million vehicle tests.

Light duty vehicles of model year 1996 and newer were tested using OBDII methods. In the relatively few instances where OBDII systems were non-functional, an alternate tailpipe test was performed. OBDII tested vehicles were either failed or passed on the basis of the OBDII test. Diagnostic Trouble Codes for failed OBDII vehicles were collected and are presented in summary form later in this paper.

For light duty vehicles older than model year 1996, the primary test procedure was the 2525 portion (i.e. 25mph @ 25% hp) of the Acceleration Simulation Mode (ASM) test procedure along with a simple idle emissions tailpipe test. The ASM is a steady state dynamometer-based test with emissions measurements taken in concentration form (e.g. percent Carbon Monoxide or parts per million Hydrocarbon). The loaded portion of the emissions test lasted anywhere from 15 seconds to 120 seconds depending upon the measured emissions values and their trend. This loaded portion time variation is the result of government specified fast pass and fast fail algorithms.

In Project 1, where light duty vehicles could not be dynamometer tested due to vehicle configuration or permanently engaged all-wheel-drive, a Two Speed Idle (TSI) test was conducted. The TSI test is conducted without load at both idle and 2500 rpm.

For both the ASM and the TSI tests the emissions analyzer measured only Carbon Monoxide (CO) and Hydrocarbons (HC). Nitric Oxide (NO) is not a required measurement in the I/M program for the Project 1 jurisdiction. The CO and HC measurements were made using non-dispersive infrared analyzers.

Project 2 Methods

In contrast to Project 1, the jurisdictional regulations of Project 2 mandate a decentralized inspection environment whereby inspections are conducted at hundreds of independent, private test and repair businesses. To ensure test standardization and adherence to proper procedures the government hired a single contractor to supply a number to products and services to the decentralized inspection network. Products and services supplied by the contractor included (in part) the following:

- All inspection equipment including emissions analyzers, dynamometers and OBDII readers,
- Centralized computer database, data processing and telecommunications services to all inspection facilities,
- Training and testing for all inspectors in the network,
- Covert auditing of inspection facilities using vehicles rigged to fail.
- Covert auditing of inspection facilities via the application of statistical techniques to the test results database (i.e. digital audits).

The independent businesses conducting inspections for the Project 2 jurisdiction are allowed to repair vehicles that they inspect. However, conflict of interest inherent in such a test-and-repair network is controlled using strict oversight by the contracting government agency coupled with the contractors monitoring data gathered through covert audits and digital audits.

Project 2 data encompassed inspection results for more than 1.26 million vehicle tests.

As with Project 1, light duty vehicles of model year 1996 and newer for Project 2 were tested using OBDII methods except for the relatively few instances where OBDII on the vehicle was non-functional. However, for Project 2 the results for the OBDII tested vehicles were used only to pass vehicles. In the event that an OBDII tested vehicle displayed emissions fault codes indicating a failure, the vehicle was retested using an emissions tailpipe test. Only a failed emissions tailpipe test resulted in a failed inspection result. None-the-less, fault codes for failed OBDII vehicles in Project 2 were collected and are presented in summary form later in this paper.

For light duty vehicles older than 1996, the Project 2 primary test procedure was a transient loaded drive cycle consisting of a single “hump” when viewed as a graph of speed verses time. The drive cycle lasted for 31 seconds and amounted to a short period of idle, followed by acceleration, a few seconds of cruise peaking out at 30 mph and finally a deceleration back to idle. For this transient drive cycle, dynamometer-based test the emissions measurements were taken in grams per mile using a low cost mass sampling device. By using a mass-based emissions measurement the results are more correlated to EPA’s preferred IM240 test method as compared to a simple concentration based measurement.

In Project 2, if a given light duty vehicle could not be dynamometer tested due to, for example, permanently engaged all-wheel-drive, a Two Speed Idle (TSI) test was conducted. The TSI test was conducted without load at both idle and 2500 rpm.

For both the transient loaded test and the TSI test in Project 2, the emissions analyzer measured CO, HC and NO. CO and HC were measured using a non-dispersive infrared system and NO was measured using an electrochemical cell.

<u>Summary of Methods</u>

For convenience Table 1 presents the main points differentiating Project 1 and Project 2 test methodology.

Table 1 - Project 1 and 2 Differences Summary

	PARAMETER	**PROJECT 1**	**PROJECT 2**
1.	I/M Program Type	Centralized Test Only	Decentralized Test and Repair
2.	Number of Tests Analyzed	1,406,444	1,264,016
3.	OBDII Test Application	Pass and Fail M.Y. ’96 & newer	Pass Only M.Y. ’96 & newer

		Light Duty Vehicles	Light Duty Vehicles
4.	Primary Non-OBDII Test	Loaded – Steady State 15s – 120s @ 25 mph Concentration-Based	Loaded – Transient 31 s with peak 30 mph Mass-Based
5.	Secondary Non-OBDII Test	Two Speed Idle	Two Speed Idle
6.	Non-OBDII Emissions Measurements	HC – Infrared CO – Infrared NO – Not Measured	HC – Infrared CO – Infrared NO – Chemical Cell
7.	Data Analysis Focus	Model year grouping failure rate comparisons, 1980 through 2003	Exclusively OBDII technology vehicles, Failure rates and Diagnostic Trouble Codes

RESULTS AND DISCUSSION

Project 1 Data

Project 1 data covered a wide range of vehicle ages from model year 1980 through model year 2003. Approximately 26% of the Project 1 vehicles were OBDII technology equipped while the remainder required emissions tailpipe testing. Therefore the Project 1 data was well suited to comparisons of test type results between OBDII methods and emissions tailpipe measurement methods.

I/M Failures by Model Year Grouping:

In Table 2 below, Project 1 data was divided into vehicle model year groupings and analyzed for pass/fail proportions.

Table 2 - Project 1 Pass/Fail Results Group by Model Year

Model Year	**Number Of Tests**	**%Fail Initial Test**	**%Fail First Retests**	**%Fail Subsequent Retests**
1996 & Newer	372,131	7.91	10.46	17.62
1990-1995	597,383	8.28	22.33	34.64
1985-1989	338,182	22.31	30.59	37.73
1980-1984	98,748	36.22	31.53	42.61
Total	1,406,444	-	-	-

The 1.4 million vehicle inspections presented above represent all inspection methods for the program mixed together and divided only according to model year groupings. The table reveals the differences between average pass/fail rates of the chosen model year groups. As could be expected we see a steady increase in failure rates with increased age. We also see an apparent increase in the difficulty to repair failures with age as evidenced by the increase in failure rates for post repair first retests and subsequent retests. Of particular note, however, are the results for 1996 and newer model years. The vast majority of these inspections (i.e. approximately 88%)

are OBDII inspections. Yet the 1996 and newer model year initial test failure rate of 7.91% is very close to the next older model year group (i.e. 1990 – 1995) which failed initial inspection at a rate of 8.28%. None of the vehicles in the 1990 – 1995 model year group were tested using OBDII. They all received some form of emissions tailpipe test.

These results would seem to contradict some of the controversial early predictions of excessively high failure rates for OBDII testing.

The results in Table 2 also seem to confirm EPA's expectation regarding repair effectiveness for OBDII tested vehicles. EPA's position has been that OBDII failures will be easier to diagnose and repair since the OBDII diagnostic trouble codes report the nature of the failure. In Table 2 the first retest failure rates in the OBDII dominated 1996 and newer group are nearly half of the retest failure rates in the emissions tailpipe tested group of 1990 –1995. That's good news for EPA, vehicle repairers and the motoring public.

But what happened to the expected high failure rates for OBDII testing? Do the initial failure rates above mean that OBDII testing is giving the same pass/fail results as the emissions tailpipe test? No. In the first four or five years of a vehicle's life we would expect the probability of failure to be considerably lower than the next four or five years. Therefore we would expect the 1996 and newer initial failure rates to be substantially lower than those for 1990 –1995 vehicles instead of being about equal.

Project 1 Failure Rates by Test Type:

To see if within the same model year group the results varied by test type we sorted only the 1996 and newer vehicles by test type and examined initial failure rates.

Table 3 - Project 1 New Vehicle Results by Test Type

Test Type (All 1996 & Newer)	**No. of Tests**	**% Fail Initial Test**
OBDII	326,685	8.49
ASM	17,413	4.31
TSI	19,462	3.27
Total	363,560	-

Within the 1996 and newer group the number of ASM or TSI tests were small (i.e. 17,413 and 19,462 respectively) as compared to more than 320,000 OBDII tests. Never the less, the ASM and TSI test count is more than sufficient to be statistically significant for purposes of this comparison. From table 3 we see that the OBDII test fails vehicles at a rate nearly twice that of ASM and approximately 2 ½ that of TSI.

<u>Project 2 Data</u>

The Project 2 portion of this study focused exclusively on OBDII technology vehicles (i.e. 1996 and newer). Failure rates and Diagnostic Trouble Codes (DTC) for more than 1.126 million OBDII equipped vehicles were analyzed.

Project 2 Vehicle Failure Rates by Test Type:

As with Project 1 data, a comparison of failure rates according to test type was made. Recall that in Project 2 the loaded test type was a transient drive cycle with mass-based emissions as compared to the steady state drive cycle and concentration-based emissions in the Project 1 loaded emissions test. Aside from this difference, both Project 2 and Project 1 preformed an OBDII initial test where possible on new technology vehicles and both performed a Two Speed Idle on vehicles that could not be tested with either an OBDII test or a loaded emissions test.

Table 4 - Project 2 New Vehicle Results by Test Type

Test Type (All 1996 & Newer)	**No. of Tests**	**% Fail Initial Test**
OBDII	1,126,108	8.69
Transient Loaded	103,894	5.42
TSI	34,014	1.33
Total	1,264,016	-

The Project 2 test results presented in Table 4 display a trend similar to the Project 1 results in Table 3. OBDII initial test failure rates are nearly the same between Project 2 and Project 1, (8.69% verses 8.49%).

The loaded emissions tailpipe test failure rates were also close. However, the transient loaded test failed about 1% more of its test population than did the ASM steady state loaded test, (5.42% verses 4.31%).

While low in both projects, the Two Speed Idle test failure rate in Project 1 was substantially higher than in Project 2, (3.27% verses 1.33%).

What can be gained from Table 4 is a reinforcement and confirmation of the conclusion drawn from Table 3. That being OBDII test procedures fail substantially more vehicles than do loaded or unloaded emissions tailpipe tests when compared over the same age group of vehicles. Also, the increase in failure rates associated with implementation of OBDII testing can be a factor of roughly 1 ½ to 6 ½ times the tailpipe test depending upon whether the comparison is against a more stringent transient loaded emissions tailpipe test or a two speed idle emissions test.

OBDII Failures by Vehicle Model Year:

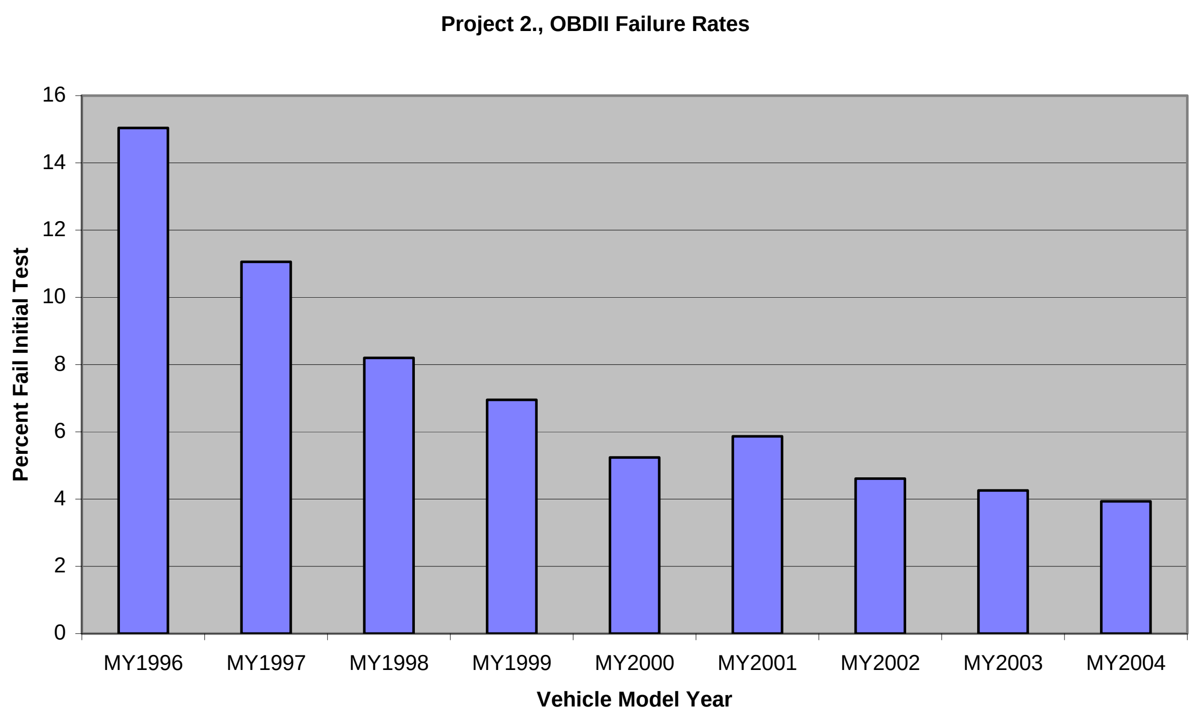
Given the large sample size of Project 2 OBDII tested vehicles (i.e.1.126 million), a fair representation of all 2003 and older model years was available for analysis. This enabled an accurate view of OBDII failure rates by model year. For completeness we've also included data from the relatively few 2004 model year vehicles that were in the database in December of 2003.

Table 5 – Project 2 OBDII Failure Rates by Vehicle Model Year

Model Year	Test Records in M.Y. Group	Initial Test Failure Rate
1996	196,307	15.04%
1997	188,662	11.06%
1998	176,848	8.20%
1999	196,161	6.95%
2000	183,065	5.24%
2001	101,430	5.87%
2002	64,106	4.61%
2003	19,173	4.26%
2004	356	3.93%
Total	1,126,108	

Table 5 shows the expected trend of failure rate increase with age. The trend is more readily seen when viewed in bar chart form.

Graph 1 – Project 2 OBDII Failure Rates by Model Year

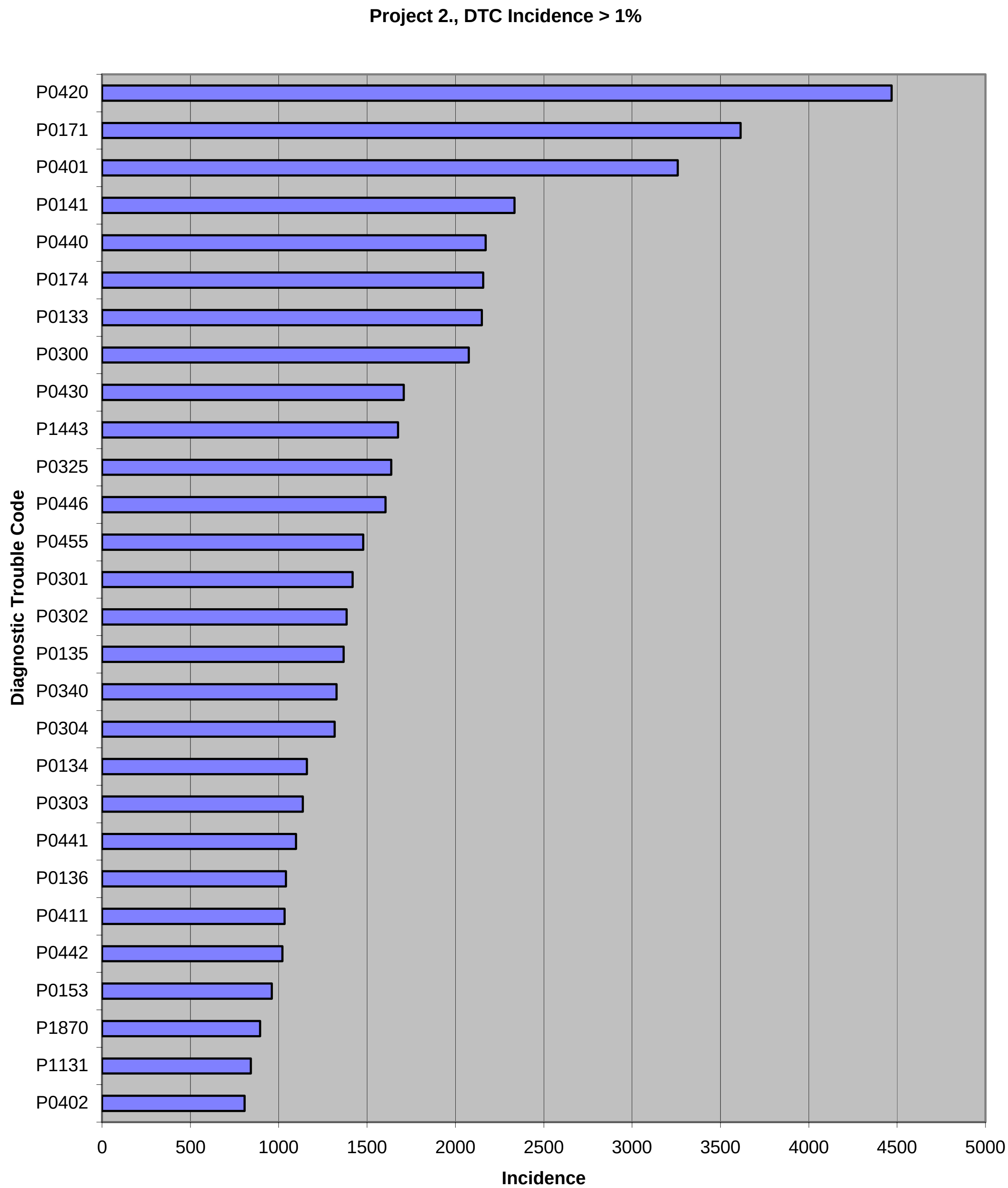


With the exception of a slight bump for MY2001, the relative increase in OBDII initial test failure rates shows an initially gradual but steady, nonlinear increase with vehicle age.

Diagnostic Trouble Code Analysis:

Thus far we have analyzed I/M initial test failure rates and repair retest failure rates by comparing OBDII results with emissions tailpipe results. We've also analyzed OBDII failure rates by model year. For the remainder of the paper we will look at the failure mechanisms for OBDII vehicles as reported by Diagnostic Trouble Codes (DTCs). We use the Project 2 data for this analysis. The universe of Project 2 data includes a total of 77,752 Diagnostic Trouble Codes read from vehicles undergoing I/M OBDII testing. Graph 2 provides a view of the incidence of OBDII DTCs. Only the DTCs that represent 1% or more of the total DTC count are shown.

Graph 2 – Project 2 Diagnostic Trouble Code Incidence



Graph 2 plots the totals for individual DTCs regardless of how many DTCs occurred on a given vehicle. In many cases there was more than one DTC on a given vehicle. Though not studied in any detail here, it may be informational for the reader to know that 19.3% of the vehicles failing OBDII showed two or more DTCs.

As seen from Graph 2, no single DTC accounts for the majority of the OBDII emissions failures. In fact, the highest incidence DTC (i.e. PO420) accounted for only 5.7% of the failures and the top three highest DTCs (i.e. P0420, P0171 and P0401) accounted for only 14.6% of the DTCs in total. However, a simple analysis of trouble codes strictly by code number can be somewhat deceptive because several different fault codes can describe nearly identical failure mechanisms.

The broad meaning of OBDII Diagnostic Trouble Codes can be gleaned from the names assigned to the codes by the SAE in their Recommended Practice J2012 (6). [Note: SAE J2012 Recommended Practice, as revised in April 2002, is equivalent to ISO/DSI 15031-6:April 30, 2002.] Table 6 below presents SAE's descriptive names for the DTCs that appear in Graph 2. It also shows the incidence count for each trouble code.

Table 6 – Project 2 Diagnostic Trouble Code Incidence

	Diagnostic Trouble Code	**Incidence Of Occurrence**	**Description**
1	P0420	4468	Catalyst System Efficiency Below Threshold, Bank 1
2	P0171	3614	System Too Lean, Bank 1
3	P0401	3258	Exhaust Gas Recirculation Flow Insufficient Detected
4	P0141	2335	O2 Sensor Heater Circuit, Bank 1 Sensor 2
5	P0440	2172	Evaporative Emissions System
6	P0174	2157	System Too Lean, Bank 2
7	P0133	2149	O2 Sensor Circuit Slow Response, Bank 1 Sensor 1
8	P0300	2075	Random/Multiple Cylinder Misfire Detected
9	P0430	1707	Catalyst System Efficiency Below Threshold, Bank 2
10	P1443	1676	*Manufacturer Controlled Auxiliary Emissions Controls
11	P0325	1637	Knock Sensor 1 Circuit, Bank 1 or Single Sensor
12	P0446	1605	Evaporative Emission System Vent Control Circuit
13	P0455	1479	Evaporative Emission System Leak Detected (large leak)
14	P0301	1418	Cylinder 1 Misfire Detected
15	P0302	1385	Cylinder 2 Misfire Detected
16	P0135	1367	O2 Sensor Heater Circuit, Bank 1 Sensor 1
17	P0340	1327	Camshaft Position Sensor "A" Circuit, Bank 1 or Single Sensor
18	P0304	1316	Cylinder 4 Misfire Detected
19	P0134	1159	O2 Sensor Circuit No Activity Detected, Bank 1 Sensor 1
20	P0303	1137	Cylinder 3 Misfire Detected
21	P0441	1098	Evaporative Emission System Incorrect Purge Flow
22	P0136	1041	O2 Sensor Circuit, Bank 1 Sensor 2
23	P0411	1034	Secondary Air Injection System Incorrect Flow Detected
24	P0442	1021	Evaporative Emission System Leak Detected (small leak)
25	P0153	961	O2 Sensor Circuit Slow Response, Bank 1 Sensor 1
26	P1870	895	*Manufacturer Controlled Transmission
27	P1131	842	*Manufacturer Controlled Fuel and Air Metering

28	P0402	807	Exhaust Gas Recirculation Flow Excessive Detected

* Manufacturer controlled code indicates the precise meaning/assignment of the code is not controlled by the ISO/SAE

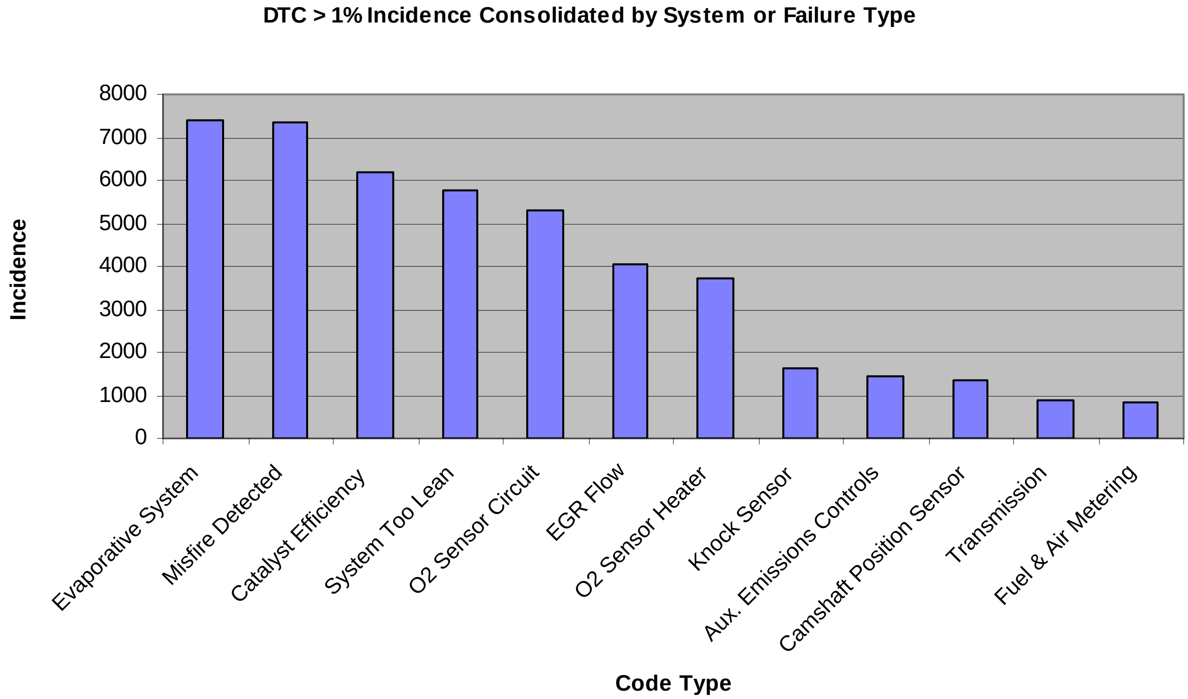
From Table 6 notice several of the trouble code descriptions are identical except for the bank or cylinder number that they refer to. Also, some are similar in that they refer to the same system but distinguish between failure magnitudes such as large or small leak size; or between particular component failures within a given system. It is informational to consolidate trouble codes into broader system or failure types by ignoring parameters such as bank number, sensor number, and cylinder number or leak size. We do so in Table 7 below.

Table 7 – Diagnostic Trouble Codes Consolidated by System or Failure Type

	Diagnostic Trouble Code	**Incidence Of Occurrence**	**Description**
1	P0440 or P0441 or P0442 or P0446 or P0455	7375	Evaporative System
2	P0300 or P0301 or P0302 or P0303 or P0304	7331	Misfire Detected
3	P0420 or P0430	6175	Catalyst Efficiency
4	P0171 or P0174	5771	System Too Lean
5	P0133 or P0134 or P0136 or P0153	5310	O2 Sensor Circuit
6	P0401 or P0402	4065	EGR Flow
7	P0141 or P0135	3702	O2 Sensor Heater
8	P1443	1676	Aux. Emissions Controls
9	P0325	1637	Knock Sensor
10	P0340	1327	Camshaft Position Sensor
11	P0411	1034	Secondary Air Inj. Flow
12	P1870	895	Transmission
13	P1131	842	Fuel & Air Metering

Table 7 provides a somewhat different sense of the major failures as compared to Table 6. From Table 7 we see that evaporative system related trouble codes lead with 9.5% of the failures, followed very closely by misfire related trouble codes with 9.4% of the failures. Catalyst efficiency is next with 7.9%. These top three groups then represent 26.8% of all failures.

Graph 3 - Diagnostic Trouble Codes Consolidated by System or Failure Type



Graph 3 provides a more visual representation of the data in Table 7. We see that, in general the consolidated trouble code groupings dominate the chart. In fact, the first seven trouble code grouping bars account for 51.1% of all failures.

SUMMARY AND CONCLUSIONS

This study has analyzed in total more than 2.6 million vehicle emissions Inspection/Maintenance results from two different government jurisdictions encompassing a variety of test methods including: OBDII as well as transient loaded, steady state loaded and two speed idle emissions tailpipe methods. The study analyzed initial test failure rates and repair retest failure rates by comparing OBDII results with emissions tailpipe results and also analyzed OBDII failure rates by model year. Finally, failure mechanisms for OBDII vehicles were analyzed as reported by Diagnostic Trouble Codes (DTCs). The conclusions of the study can be summarized as follows:

1. Implementing OBDII as a substitute for tailpipe emissions testing has not resulted in excessive failure rates.
2. OBDII test techniques applied to I/M inspections do fail vehicles at a somewhat higher rate than do emissions tailpipe test techniques.

3. Within the group of 1996 and newer model year vehicles, OBDII failed vehicles at a rate of approximately: 1 ½ times that of a transient loaded emissions tailpipe test and 2 times that of a steady state loaded emissions tailpipe test.
4. The repair efficiency associated with OBDII failed vehicles is substantially better than the repair efficiency of emissions tailpipe failed vehicles as evidenced by lower post repair retest failure rates.
5. The initial test failure rates for OBDII tested vehicles increases nonlinearly with age.
6. No single diagnostic trouble code accounts for more than 5.7% of the total OBDII failures.
7. Grouping diagnostic codes by general system or failure type reveals that approximately 51% of all OBDII failures fit within seven failure categories, namely: Evaporative System, Misfire, Catalyst Efficiency, System Too Lean, O2 Sensor Circuit, EGR Flow, and O2 Sensor Heater.

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