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Effectiveness of OBD II Evaporative Emission Monitors - 30 Vehicle Study

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NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data that are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position, or regulatory action.

Note: This report is a revision of the August 2000 EPA technical report of the same title. The earlier report had the appearance of a draft report, and therefore this report has revised line spacing and page breaks. It also incorporates the results of a September 2000 FTP evaporative emission test conducted at the Ford Motor Company, Allen Park, Michigan testing laboratories. That result is discussed under “Ford Vehicle No. 192", in Section VII - Discussion, and also in the Appendix, under the section “Ford Vehicles 155 and 192.”

I. Summary:

From April 1999 through May 2000, EPA conducted a study to evaluate the effectiveness of onboard diagnostics (OBD II) evaporative emission monitors on a sample of in-use light duty vehicles and light duty trucks. The purpose of the study was to determine if OBD II technology is an effective and efficient means of identifying in-use vehicles with excess evaporative emissions. The results of this study have been routinely shared at quarterly I/M OBD workgroup meetings coordinated through the Mobile Sources Technical Review Subcommittee (MSTRS), authorized under the auspices of the Clean Air Act Advisory Committee.

Based on the results from a 30 vehicle test program conducted under contract with Automotive Testing Laboratories Inc. (ATL) in Mesa, Arizona, EPA has observed the following with respect to the effectiveness of OBD II evaporative emission monitors on 1996-2000 model year vehicles.

> 1) 22 of 25 OBD II evaporative emission monitors registered diagnostic trouble codes (DTCs) when failure conditions were induced. The 22 vehicles which registered DTCs showed no fault codes when the induced failure conditions were removed and the DTCs cleared. In general, these observations suggest OBD II evaporative emissions monitors work satisfactorily.
>
> Three of the vehicles with induced failures equal to or greater than 0.040 inch leaks did not illuminate the MIL or register diagnostic trouble codes. Two of the three vehicles were investigated in Ann Arbor using vehicles of identical make, model, and model year

and found to perform correctly. Results from the third vehicle are still being examined.

2) Five vehicles tested with small leaks (less than 0.020 in. diameter) were analyzed separately. Three of five vehicles calibrated to meet the 0.040 inch OBD leak standard but tested with a 0.020 inch leak produced a diagnostic trouble code and illuminated the malfunction indicator light (MIL). This suggests that some OBD systems are quite robust and have leak detection capability well below the minimum requirement.

3) Three vehicles with induced leaks produced Federal Test Procedure (FTP) evaporative emissions less than half the levels of the enhanced evaporative emission standards, suggesting that "maintenance" problems are being identified by OBD even though they result in emission levels below FTP standards.

4) Based on the effectiveness of OBD II evaporative emission monitors observed in this study and their advantages (non-intrusive, very time efficient) versus functional I/M evaporative emission pressure and purge tests, I/M OBD checks are a suitable alternative to functional I/M checks on 1996 and later model year vehicles which use evaporative emission monitors.

5) The induced failure results from vehicles built for compliance with Onboard Refueling Vapor Control (ORVR) standards averaged approximately half the running loss and half the hot soak plus diurnal levels compared to vehicles designed to meet only the enhanced evaporative standards.

6) This study suggests enhanced and ORVR evaporative emission control systems are durable and low emitting relative to the FTP enhanced evaporative emission standards.

7) Four vehicles showed post repair emission results which exceeded FTP emission standards. Reasons for this were investigated on three of the four vehicles and they are presented in the Discussion section of the report. The "high" emissions on the fourth vehicle were only slightly above standards on the diurnal loss test and because this test vehicle could not be retained for further testing, no explanation for the high emissions

will be provided in this study.

II. Background:

Due to its positive potential and EPA's awareness of difficulties with implementing effective I/M functional evaporative I/M emission tests, EPA has devoted considerable resources to understanding and assessing the viability of the OBD II system for detecting emission failures in in-use vehicles. An EPA draft technical report "Evaluation of OBD for Use In Detecting High Emitting Vehicles," by Gardetto and Trimble, dated August 2000, presents data and analysis to conclude that OBD II exhaust monitors function properly and are a technology that may be used to replace functional exhaust emission tests for 1996 and newer model year vehicles. [1] This 30 vehicle study presents EPA's findings regarding the effectiveness of OBD II evaporative emissions monitors in detecting emission problems on a sample of light duty vehicles and trucks. The report is based on results of a test program conducted for EPA under contract with Automotive Testing Laboratories Inc. in Mesa, Arizona from April 1999 to May 2000. [2]

This study did not examine the issue of OBD evaporative emission readiness under in-use driving conditions. This issue has been, and continues to be, addressed by EPA, in particular, by analysis of OBD pilot test results from the Wisconsin I/M program on a vehicle/model year specific basis. The incidence of OBD II vehicles with evaporative emission monitors which are not ready at the time of an I/M test is discussed in an EPA technical report, "Analyses of the OBD II Data from the Wisconsin I/M Lanes," by Trimble. [3]

III. Objectives of the ATL Study:

The ATL laboratory study had four objectives:

1) Verify the operation of the evaporative emission monitors in a cross section of in-use OBD II vehicles under laboratory test conditions.

2) Measure evaporative emissions from vehicles with evaporative emission DTCs by running the EPA Federal Test Procedure for vehicles designed to meet enhanced evaporative emission standards.

3) Measure evaporative emissions from vehicles which have been repaired to remove the DTCs on the same vehicles.

4) Based on the results of the first three objectives, determine whether OBD II is an adequate surrogate for the functional I/M "pressure" and "purge" tests which were originally recommended as part of the high enhanced I/M requirements.

IV. Test Protocol

Induced Failure Modes

Based on EPA's inspection of evaporative emission DTCs and their causes, it was suspected that the majority of evaporative emission failures in OBD vehicles can be attributed to loose gas caps, but EPA does not, at present, have a source of published data to verify this assertion. Rather, it is based on undocumented experience gained during recruitment of OBD II vehicles for test programs at the EPA National Vehicle Fuels and Emission Laboratory (NVFEL) and discussions with I/M and OBD experts from domestic vehicle manufacturers. Rather than recruit only loose gas cap vehicles as the primary source of "failed" vehicles, it was decided to procure rental vehicles and induce a variety of failure modes which could occur in the OBD II in-use fleet. Inducing failures was thought to be necessary given that evaporative emission failures are more age than mileage related, and we did not expect to find a variety of real world failure modes.

Table A-1 in the Appendix describes the test fleet, and Table A-2 describes the induced faults, the resulting DTCs, the drive cycles required to satisfy the readiness criteria for both "failure" and "repair" sequences, and a comment column for more detail on specific vehicle test issues. Although only one set of drive cycles are listed in Table A-2, both induced failure and post-repair sequences used the same drive cycles to satisfy readiness criteria and exercise the OBD system. The induced failures in the 30 vehicle sample included the following:

- Missing gas caps (3)
- Loosening gas caps (2)
- 0.040 inch diameter leaks in gas caps or vapor vent lines (11)
- Disabling canister fresh air inlet (1)
- Disconnecting purge lines (8)
- 0.020 inch leaks in gas caps (5)

Each vehicle received only one induced failure condition. These failure modes are not meant to represent the variety of real world failure modes, nor are they necessarily representative of the range of excess emissions which results from real failures. Rather, they were selected because they are reproducible, they are simple to repair, they are failure modes which a properly functioning evaporative emission control system should detect, and vehicles with these induced failures could be used to estimate the relation between the occurrence of an evaporative emissions DTC and mass measurements of evaporative emissions on the same vehicle.

<u>Induced Leak Size</u>

Under California and Federal OBD requirements, vehicles equipped with OBD II evaporative emission monitors for 1996-1999 model years are required to detect leaks of a hole size of 0.040 inches diameter or larger, and detect and identify a malfunctioning purge system. Beginning in the 2000 model year and phased-in nationwide through the 2002 model year, the 0.040 inch diameter leak check requirement becomes more stringent, requiring identification of a 0.020 inch diameter leak. Five vehicles were tested with 0.020 inch diameter leaks to examine the robustness of the current systems, and obtain estimates of the evaporative emissions from vehicles which might pass the current OBD II leak check but have leaks that may produce emissions above the current FTP standards.

Gas caps with 0.040 or 0.020 inch diameter leaks were supplied by Stant Manufacturing Corp. and were built with flow tested, precision machined, square edged orifices. Previous EPA attempts to produce such small leaks have shown that machining small orifices is not straightforward. Flow calibration was provided with the orifices used in the gas caps and therefore EPA is confident the 0.040 and 0.020 inch diameter leaks in the test gas caps are accurate.

The presence of induced failures of the evaporative emission systems were verified with functional “pressure” and “purge” tests. These tests were conducted by measuring pressure loss and purge system vacuum through the service port access on OBD evaporative emission vehicles. Vehicles not equipped with the service port received pre-OBD functional tests. These consisted of measuring pressure loss by pressurizing from the fill-pipe and monitoring the loss of pressure versus time. Purge system failures were verified by using a roto-meter to check for no purge flow. The “pressure” and “purge” tests conducted on vehicles without the service port were performed by experienced ATL laboratory technicians.

The qualification that the tests were performed by <u>experienced</u> ATL technicians is an important one because the U.S. vehicle manufacturers have been opposed to EPA’s pre-OBD intrusive functional purge test, and to a lesser degree, the functional pressure test applied at the fuel inlet. This study took care to avoid adversely influencing the evaporative emission results by carefully conducting functional evaporative checks on vehicles not equipped with a service port access.

<u>Test Procedures</u>

Following inspection for acceptable driveability, braking, and a leak free exhaust system, the OBD system was checked for readiness status and the presence of DTCs or an illuminated MIL.

Each vehicle’s OBD computer was reset to clear codes and show a “not ready” status prior to FTP testing with an induced failure. Vehicles were typically operated on chassis dynamometers to set a DTC and illuminate the MIL prior to the initial FTP exhaust and evaporative emission test. Exception to this practice occurred only when a chassis dynamometer was not available, at which time readiness criteria were satisfied by operating the vehicle over a local surface street route which approximated the speed time relation of the LA-4 driving schedule. (The LA-4, also known as the Urban Dynamometer Driving Schedule (UDDS) is the first 1372 seconds of the FTP speed/time driving schedule used for sampling exhaust emissions. Vehicle operated over the LA-4 typically satisfy enabling criteria and exercise the OBD evaporative emissions monitors.) Following the tests with the induced failures, each vehicle was repaired by the ATL technicians. The OBD system was again reset to clear the fault code and set the readiness status to a “not ready” state. The vehicle was then driven to satisfy readiness criteria and determine if the OBD system correctly showed no DTC code and no illuminated MIL.

The FTP evaporative emission test selected for this study was the three day diurnal procedure with running loss test. An abbreviated flowchart of the test procedure for the FTP evaporative test is presented in Figure A-1 in the Appendix. In general, tests were conducted in accordance with Title 40, Code of Federal Regulations (CFR) Part 86, Subpart B, revised July 1, 1998. [4] Gasoline meeting FTP fuel specifications was used for all exhaust and evaporative emission tests. Fuel tank temperature profiles used for the running loss test are the profiles submitted to EPA during the vehicle certification process.

Deviations from Subpart B test requirements included: 1) using external surface mounted fuel tank thermocouples (on vehicles with steel fuel tanks) as a surrogate for installing internal thermocouples, 2) draining the fuel tank by using the vehicle fuel pump instead of installing a fuel drain(s) at the lowest point in the fuel tank, and 3) permitting minor deviation from the requirement that measured and target liquid fuel temperature agreement be within 3 degrees F during the running loss test, 4) use of the EPA I/M Lookup Table for selecting the chassis dynamometer inertia and horsepower for the 1996-1998 vehicles. (Test parameters for the 1999 and 2000 model year vehicles were obtained from EPA new vehicle certification data.)

Use of external mounted thermocouples instead of installing internal thermocouples is a common EPA practice in in-use evaporative emission testing. Without this simplification, instrumenting the vehicle in strict accordance with the EPA certification requirements for locating thermocouples and fuel drains can require cutting access panels in the vehicle. ATL’s past practical experience in using surface mounted thermocouples is that this location does not compromise testing accuracy. Vehicles with plastic fuel tanks used thermocouples installed through the bottom of the fuel tank. Any fuel tank modification that compromised the integrity of the OEM tank was resolved by replacing the fuel tank before the vehicle was returned to the owner.

The FTP evaporative emission running loss test requires that the measured fuel tank temperature track the target temperature within 3 degrees F over the dynamometer driving portion of the running loss test (a series of four driving schedules in the order: one Urban Dynamometer Driving Schedule, two New York City Cycles, a second Urban Dynamometer Driving Schedule). In general, the measured fuel tank temperatures denoted as “Actual F” (induced failure test) or “Actual R” (post-repair test) in Table A-5 in the Appendix indicate close agreement with the vehicle manufacturer supplied fuel tank temperature profile. Manufacturer supplied fuel tank target temperatures and ATL measured temperatures for starting and ending segments of the running loss test are summarized in Table A-5 in the Appendix.

Exceptions to meeting the 3 degree tolerance were observed for vehicles 150, 154, 184, and 189. The deviations for these vehicles range from slightly over 3 degrees F to about 7 degrees F. These deviations from the target temperature profile, and the short time of the excursion, as a matter of engineering judgement are not thought to be important because their effect on running loss results is judged to be insignificant.

V. Test Fleet

Vehicle Selection

The test vehicle descriptive information is displayed in Table A-1 of the Appendix. These data include vehicle make, model, model year, mileage, engine family, evaporative emission family, whether the vehicle was designed to comply with enhanced evaporative emission standards or ORVR requirements, and chassis dynamometer test parameters.

The test fleet is characterized as follows:

> 8 vehicle manufacturers - Ford (7), GM (7), Honda (3), Isuzu (1), Mazda (2), Mitsubishi (1). Nissan (4), Toyota (5)
>
> 5 model years - 1996 (2), 1997 (1), 1998 (9), 1999 (16), 2000 (2)
>
> Mileage range - 5,259 to 116,730

20 light duty vehicles; 10 light duty trucks and SUVs

14 enhanced evap systems; 16 onboard refueling vapor recovery systems (ORVR)

29 rental vehicles; 1 privately owned vehicle

Inspection of the fleet shows the following: the sample is not sales weighted among manufacturers or car versus truck sales, most vehicles are low mileage, and Chrysler vehicles are not represented because they used an alternative Federal OBD certification provision in effect for 1996-1999 model year vehicles, and therefore did not use OBD evaporative emission monitors in their Federal certified vehicles. Because a sales weighted sample was not required for this study, flexibility was permitted in obtaining vehicles. Nevertheless, the sample described above represents the major vehicle manufactures and, where multiple vehicles were sampled from a manufacturer, the sample reflects an “approximate” sales ranking.

VI. Results

Complete evaporative emission results from the 30 vehicles are presented in Table A-3 in the Appendix. Note in Table A-3, that the letters E or R appended to the ATL identification number designate whether the vehicle is designed to comply with the enhanced evaporative emission standards, or the enhanced plus on-board refueling vapor recovery standards, respectively. These design standards classifications were determined by decoding the evaporative emission family name which is located on the underside of the vehicle’s hood.

DTC and MIL illumination status resulting from the induced failures were separated into two samples and summarized as follows:

DTC Response and MIL Illumination from Induced Failures on 25 Vehicles

(9 Purge system failures, 16 leaks $\geq$0.040 in. diameter)

DTC Set: 22 MIL Illuminated: Same 22

DTC Response and MIL Illumination from Induced Failures on 5 Vehicles

(5 gas caps with leaks of 0.020 in.)

DTC Set: 3   MIL Illuminated: Same 3

The five vehicles with induced leaks of 0.020 inches were not included in the 25 vehicle stratum in order to not “penalize” vehicles for finding leaks more stringent than their OBD design requirements.

An analysis of the purge failure results in Table A-3 shows that specific DTCs registered for similar induced failures were inconsistent among vehicle manufacturers for faults induced in the purge control systems of eight vehicles. Vehicle manufacturers’ proposals are under consideration which would lead to more standardization among DTCs.

Emission results are summarized below in the tables below, stratified as a function of evaporative emission control design - enhanced evap or ORVR designs, and divided between the induced failure results (Failures) and the post-repair results (Repairs). 11 vehicles were certified to the enhanced evap standard and 11 were designed to comply with ORVR requirements. Tables 1 and 2 divide the evaporative emission results into these strata because the design of ORVR systems (larger canisters, larger vapor lines, other unique components to control refueling loss) may also lead to lower evaporative emission loss. ORVR designs are manufacturer and vehicle design specific, and although their exact ability to produce inherently low evaporative emissions with the failure modes used in this study was not investigated, the data in Table 2 suggest lower evaporative emissions from ORVR control systems when compared to enhanced control systems (Table 1).

Table 1

Means (x) and Standard Deviations (s) 11 Enhanced Evaporative Emission Vehicles

	Failures	Repairs
Running Loss, g/mi	x = 7.86	x = 0.02
	s = 7.89	s = 0.01
1 hr Hot Soak Loss, g	x = 10.74	x = 0.13

	s = 16.12	s = 0.08
High 24 hr Diurnal Loss, g	x = 20.83	x = 0.95 (N=10)
	s = 17.77	s = 0.87

Table 2

Means (x) and Standard Deviations (s) for 11 ORVR Evaporative Emission Vehicles

	Failures	Repairs
Running Loss, g/mi	x = 4.51	x = 0.02
	s = 5.29	s = 0.01
1 hr Hot Soak Loss, g	x = 2.89	x = 0.14
	s = 3.20	s = 0.07
High 24 hr Diurnal Loss, g	x = 12.31	x = 0.87
	s = 12.00	s = 0.51

Not all vehicles had “fail” and “repair” pairs because not all of the vehicles registered DTCs, and not all vehicles had valid “repair” results. Therefore, Table 2 presents results from only 22 of the 30 vehicles. Repaired results which were not deemed to be valid are described in the Discussion section of this report.

21 of 22 after repair tests produced running loss emissions less than the enhanced running loss standard of 0.05 g/mi. Although the induced failures were simplistic and easy to rectify, the low running loss emissions after repairs show that this test sample of in-use vehicles is quite clean, i.e. below FTP standards.

20 of 21 after repair results showed hot soak plus diurnal (high 24 hour result) emissions less than the enhanced evaporative emission standard of 2.0 g. This also shows that this sample of

in-use vehicles is low emitting with respect to FTP evaporative emission standards.
The results summarized in Table 3 are the means of the combined repair effects (11 enhanced vehicles plus 11 ORVR vehicles) in Tables 1 and 2.

Table 3

Means (x) and Standard Deviations (s) of Repair Effects (Failure - Repair) for 22 Vehicles

Running Loss, g/mi	x = 6.17	s = 6.78
1 hr. Hot Soak Loss, g	x = 6.68	s = 12.04
High 24 hr Diurnal Loss, g	x = 14.18 (N=21)	s = 14.54

The repair effects for 22 evaporative emission repairs were substantial: 6.2 g/mi for the running loss test, 6.7 g for the hot soak test, and 14.2 g for the high 24 hr result for the diurnal loss test (21 vehicles). The range among the evaporative emission test results for the induced failures is large, as evidenced by values of the standard deviation which are equal to or greater than the mean. Emission results of the repaired vehicles did not exhibit the scatter observed by the "failed" vehicles.

Composite and bag by bag FTP exhaust emission results are summarized in Tables A-3 and A-4, respectively, in the Appendix.

Based on the results presented in Tables 1-3 above, and follow-up emission testing at ATL on one vehicle, and on two vehicles at the EPA NVFEL, EPA concludes that, in general, OBD II evaporative emission monitors accurately identify vehicles with evaporative emission problems, and the repair effects observed by comparing pre and post repair FTP emission levels are substantial. These findings satisfy the first three of four objectives of this study.

EPA believes the fourth objective, determining if using an OBD II scan tool to check MIL and DTC status is an acceptable I/M test for identifying in-use evaporative emission failures, has also been satisfied. This is based on the observations that 1) vehicles with illuminated MILs and evaporative emission DTCs have high emissions when compared against FTP evaporative emission standards, 2) the OBD scan for evaporative emissions is accurate and unintrusive, unlike pre-OBD II I/M functional evaporative emission “pressure” and “purge” checks, which are often impractical due to the inability to access the evaporative emission system, and/or risk of damage to the vehicle, and 3) using a scan tool in an I/M environment is very time efficient, requiring only about 30 seconds to conduct an entire OBD check once the scan tool is inserted in the data link connector, versus several minutes for functional tests.

VII. Discussion

OBD and I/M Gas Cap Tests

Reference [5] contains data that suggest the incidence of gas cap failures on 1998 model year OBD vehicles, determined using a functional leak test on the gas cap, is over 30 times the incidence of evaporative emission failures detected by the OBD monitor. Although this study did not quantify evaporative emissions from real world gas cap leaks, it would be desirable to collect such data in the future. Nevertheless, there appears to be an adequate benefit from conducting a stand alone functional gas cap test as part of the OBD check of the evaporative emission system. This is based on examining the emission results from the two vehicles with 0.020 in. diameter leaks in gas caps which were not identified by the OBD system. Even though the OBD systems in these two vehicles were not designed to find 0.020 in. leaks, EPA believes the mass emissions from leaking gas caps which are below the 0.020 in. threshold may still be significant over the in-use operation of the vehicle. Therefore, at present and until more data are available, EPA is recommending conducting a standard I/M gas cap check in conjunction with a scan of the OBD II system.

OBD II and I/M Pressure/Purge Tests

This study did not directly compare the effectiveness of OBD II evaporative emission monitors to the functional I/M pressure and purge tests proposed by EPA in the 1992 I/M rule. The reasons for this were twofold.

First, the failure criteria for functional I/M pressure and purge tests differ from the criteria used by OBD II vehicles, and therefore it would require a considerably larger sample than 30 vehicles to prove if there are differences between numbers of failures found by either method (identified independently by either method), and analyze the possible mass emissions reductions which could result from repairing vehicles identified by OBD II vs. functional testing. Pre-OBD II I/M pressure tests fail vehicles which lose more than six inches of water column pressure in two minutes starting from an initial pressure of six inches of water above ambient pressure. A vehicle fails the I/M purge test if the system flows less than 1.0 liters of a hydrocarbon and air mixture when measured at a point between the evaporative emission canister and the engine intake. The OBD II criteria require identifying vehicles with leaks in the vapor space of an equivalent hole size of at least 0.040 in. diameter (0.020 in. diameter leak identification is being phased-in nationwide for light duty vehicles starting with the 2000 model year). OBD II criteria for identifying defective purge systems require that a test be conducted to determine the presence of purge flow, such as an actual flow measurement, or indirect indicators of purge flow such as monitoring changes in air fuel ratio, to prove the canister is being purged. The OBD checks are performed whenever the vehicle is operated and enabling criteria have been satisfied. OBD II requirements for identifying malfunctioning evaporative emission systems were developed by the California Air Resources Board in the early 1990's independent of the EPA I/M 1992 functional pressure and purge tests.

More detailed discussions of the theoretical relationship between the OBD II 0.040 inch detection requirement and the pre-OBD functional pressure check, including estimating the merits of running a functional pressure test on OBD II vehicles with no MIL illuminated or no DTC, are contained in references [6] and [7]. Based largely on discussions among members of the MSTRS OBD workgroup, it is likely that the number of small leaks undetected by OBD II would be low, repairing such vehicles may be difficult, and conducting dual testing on OBD vehicles would be inconsistent with the data collected from this study.

Second, since the 1996 model year, and including some 1995 model year vehicles, vehicles have been designed to meet the enhanced evaporative emission standards. This standard resulted in the usage of less permeable and more durable materials, such as hard vapor lines between the fuel and tank and the canister which are not capable of being clamped without damage, and use of connectors which either could not be easily removed after vehicle assembly, or terminated in connections which prevented timely installation of hardware to conduct a pressure or purge test. Since the 1998 model year, manufacturers have produced vehicles designed to the FTP ORVR requirements. In general, vehicles without service ports can no longer receive a functional pressure test from the fillpipe location due to the presence of components to prevent liquid fuel spitback and vapor loss during refueling. Although the number of OBD II vehicles with evaporative emission monitors but without service ports is not easily documented, EPA estimates it constitutes a significant number of the OBD II vehicles equipped with evaporative emission monitors.

From EPA observations and discussions with vehicle manufacturers, only OBD II vehicles which are equipped with the evaporative emission "service port" are capable of conducting a functional I/M pressure or purge test. In an I/M environment this would most safely and efficiently require a bi-directional scan tool which can also be used for directly reading the MIL status and DTCs. Therefore it appears that the service port is best used in the vehicle service industry to diagnose evaporative emission failures and confirm repairs.

Some I/M stakeholders have been concerned about not having the capability of testing an OBD vehicle which has a "not ready" status at the time of the I/M OBD check. In order to alleviate this concern, the MSTRS workgroup issued a consensus position stating it is acceptable to conduct an I/M leak check of the evaporative emission system on OBD II vehicles using the service port, or a method approved by vehicle manufacturers, if such functional tests are determined to be cost effective for the specific I/M program. [8] EPA will issue separate guidance on this and other implementation issues in the near future.

ATL Vehicles which had Difficulty Illuminating MILs and/or High Post-Repair Evaporative Emissions

Three vehicles, Nos. 150, 155, and 182, had difficulty illuminating MILs and registering DTCs after faults were induced in the evaporative emission control system. Three other vehicles, Nos. 153, 188, and 192, had high levels of running loss and/or hot soak plus diurnal emissions. This section summarizes the concerns with those vehicles, and where resolution of the issue(s) was reached, this is also presented. A more detailed discussion of these six vehicles, including references to relevant correspondence, is presented in the Appendix.

Vehicles with Difficulty Illuminating MILs - Two Mazda vehicles, Nos. 150 and 182 (1998 Mazda 626s), and Ford vehicle No. 155, (1999 Mercury Tracer) had difficulty illuminating MIL lights and setting DTCs during the period ATL had possession of the vehicles.

Vehicle Nos. 150 and 182 - The Mazda 626s had considerable difficulty illuminating MILs when a gas cap was removed (Vehicle 150), and when tested with a gas cap with a 0.040 inch leak (Vehicle 182). Vehicle 182 was specifically recruited to investigate the problems observed earlier with vehicle 150. When ATL again had difficulty setting the MIL light and producing a DTC, EPA asked for Mazda's assistance to determine why vehicle 182 was not responding to the induced failure condition.

After considerable investigation by Mazda and EPA technical staff, including two test programs in Ann Arbor, MI, it was determined that the Mazda vehicles did respond correctly when missing or leaking gas caps were installed and two similar Mazda 626s were driven on a chassis dynamometer and later driven on local road routes in the Ann Arbor area. However, during the investigation it was determined that Mazda had neglected to list a change in engine load enabling criterion. It appears that the 1998 Mazda 626 may be sensitive to an individual's driving behavior, and this affects the ability of the vehicle to exercise the evaporative emission monitor. Ultimately, it was unknown why ATL's experiences with the Mazda 626, in particular vehicle 182, were different from EPA's results in Ann Arbor.

Analysis of OBD data from the Wisconsin I/M program also verified that the 1998 Mazda 626 did not have an abnormal "not-ready" rate at the time the OBD system was examined as part of the Wisconsin IM240 test.

Vehicle No. 155 - ATL was not able to set a MIL light on a 1999 Mercury Tracer when a leaking gas cap was installed. After several attempts to set the MIL, EPA contacted Ford technical staff and requested their assistance. Ford suggested the vehicle be driven over their steady state driving cycle (unlike most OBD monitors which are designed to be run using cold start FTP driving cycles, Ford requested and received approval from EPA to use an evaporative emission monitor which functions when driven at steady state conditions) even though ATL did use steady state driving when attempting to illuminate the MIL and set a DTC. Ford also requested the tank be filled to 80% of capacity versus the standard 40% fuel fill for cold start FTP testing.

The suggestions by Ford did not exercise the monitor and the vehicle had to be returned to the rental agency because the initial phase of the 30 vehicle study ended. No resolution for the difficulty with this vehicle was reached and EPA is continuing to examine the OBD evaporative emission monitor on the 1999 Mercury Tracer and the Ford Escort.

Vehicles with High Post-Repair Evaporative Emissions

Three vehicles, Nos. 153, 188, and 192, had suspiciously high post-repair evaporative emissions relative to either the FTP running loss standard and/or the FTP hot soak plus diurnal loss standard. Given that the vehicles were relatively new and the “repairs” to the vehicles were very straightforward and were not likely to be the source of high evaporative emissions, considerable effort was expended in examining these three vehicles.

Honda Vehicle Nos. 153 and 188 - Vehicles 153 and 188 are 1999 Honda 2.3 liter Accords. A number of actions were taken by ATL to examine the reasons for the running loss, and high hot soak plus diurnal loss emissions for the post-repair test on vehicle 153. The first phase of the ATL contract period expired before the emissions results could be explained, and therefore vehicle 188 was recruited to further examine the results observed with vehicle 153.

When high evaporative emissions were again observed with vehicle 188 and ATL diagnostic investigations did not find a cause for the results, EPA requested technical assistance from Honda.

Honda staff made multiple visits to ATL to confirm the original post-repair results and also to examine in detail a number of differences between ATL’s and Honda’s equipment and procedures for instrumenting the fuel tank, and supplying heat to the fuel tank during the running loss test. Honda collected test results in Japan by replicating the systems and procedures used by ATL. Later, Honda returned to ATL and ran tests using procedures and equipment similar to those used for Certification testing of the Accord in Japan. When using a Honda-like system at ATL, running loss results were below FTP standards.

Honda concluded it was the combination of improper thermocouple placement in the fuel tank and an ATL heating system which produced localized and excessive heating of the fuel tank that lead to erroneously high evaporative emission results on vehicles 153 and 188.

EPA plans to investigate the test procedure issues in greater detail because both ATL and Honda claim to be following the requirements in the CFR related to thermocouple placement and heating system design and control.

Ford Vehicle No. 192 - Vehicle 192 is a 1998 3.8 liter Ford Windstar which produced hot soak plus diurnal emissions above the 2.0 gram standard. Because ATL diagnosis of the vehicle and test equipment did not produce an explanation for the high emission result, Ford technical staff were invited to offer their assistance. Ford had a number of concerns regarding the ATL test procedure and equipment, but no obvious engineering explanation was provided which would suggest ATL's results were erroneous.

Ford did not wish to visit ATL and more closely examine the vehicle, test equipment, and procedures, but they did offer to supply a Windstar fuel tank to ATL which was instrumented in a manner similar to a Certification test configuration. EPA decided not to conduct tests with the tank offered by Ford because it would have required access panels be cut in the floor of the vehicle to accommodate the protruding thermocouples and fuel drains which are typically used in testing of Certification prototype vehicles. The vehicle was then released to the rental agency because the second phase of the test program came to an end.

EPA asked if Ford would test a similar Windstar at their Allen Park, MI Certification facility, and in September 2000 Ford submitted FTP evaporative emission results of 0.80 g (hot soak loss plus highest 24 diurnal loss) and 0.003 g/mi (running loss). These results are well below the FTP evaporative emission standards and, at present, EPA has no plans to conduct follow-up testing to resolve the differences between results from ATL and Ford.

Although exact explanations for the high post-repair emissions were not provided for vehicles 153, 188, and 192 discussed above, explanations would likely be determined if more time and resources were devoted to studying them. Of equal or greater concern is the possible emissions sensitivity to differences in laboratories' running loss equipment and test procedures. These issues require more attention.

VIII. Conclusions

1) In general, OBD II evaporative emission monitors operated properly on a 30 vehicle sample of OBD II vehicles. This conclusion is based on the proper performance of the OBD system when evaporative emission failures were induced, the absence of codes or illuminated MILs when the failures were removed, and analysis of the FTP.

2) Based on the observations above, and given the impracticality of using functional I/M (pre-OBD) purge and fillpipe pressure checks on OBD vehicles, OBD II evaporative emissions checks are a suitable replacement for functional evaporative emission I/M tests.

3) Based on data from the Wisconsin I/M program that show over 30 times as many OBD vehicles fail the stand alone gas cap test as compared to setting an evaporative emission DTC, EPA recommends that gas cap testing continue for OBD I/M checks.

4) The emissions data show, in general, OBD II vehicles with evaporative emission DTCs and illuminated MILs exceed FTP evaporative emission standards, while vehicles without DTCs and illuminated MILs are below FTP evaporative emission standards. The repair effects associated with performing I/M evaporative tests using scan tools and OBD II technology, appears to be substantial.

IX. Recommendations

The following recommendations are based on this study:

1) It is desirable to conduct emission tests on a larger sample of OBD II vehicles, including vehicles designed to comply with the California Air Resources Board (CARB) 0.020 inch leak check requirements. Future test programs should include more real world evaporative emission failures and also include real world repairs.

2) Given the testing issues raised in analyses of the Mazda, Honda, and Ford vehicles, it would

be useful to conduct a study of the evaporative emission sensitivity to thermocouple location and fuel tank heating system design.

X. Acknowledgments

Completion of this study would not have been possible without the assistance of the vehicle manufacturers whose vehicles comprised the 30 vehicle sample: Ford, General Motors, Honda, Isuzu, Mazda, Mitsubishi, Nissan, and Toyota. These manufacturers provided timely assistance in locating fuel tank temperature profiles for the running loss test and also in addressing vehicle specific testing issues.

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Appendix

Selected Results from Individual Vehicles

Mazda Vehicles 150 and 182 - Vehicles 150 and 182 are 1998 Mazda 626s with identical engine and evaporative emissions families. In Table A-2, results from vehicle 150 with a missing gas cap show that three cold start LA-4s, two cold start FTPs, one cold start five minute 45 mph steady state, and one hot start 20 minute 60 mph steady state cycle were run in an attempt to set the evaporative emission monitor to “ready”, set a DTC, and illuminate a MIL. All cold starts were preceded by an overnight soak at 75 F. Following the last steady state cycle, the MIL was still not illuminated but a code 0455 (large leak) was recorded in the continuous memory of the OBD system. The vehicle was then FTP tested. Following installation of the gas cap, two cold start LA-4s, two cold start steady states, and one cold start FTP were run to set the evaporative emission monitor to “ready” and observe the MIL and DTC status. At the end of this sequence the evaporative emission monitor was still not ready but the vehicle was FTP tested in its “repaired” state.

Because vehicle 150 did not illuminate a MIL or produce a DTC, EPA contacted technical staff at Mazda and began to jointly investigate whether there was a design problem with the OBD evaporative emission monitor, or there were test protocol or vehicle instrumentation issues which might explain the apparent problems with the OBD system. Meetings were held among Mazda and EPA technical staff members, and a series of dynamometer and road tests were conducted in Ann Arbor, MI on two 1998 Mazda 626s identical to vehicle 150. EPA also analyzed data from the Wisconsin IM240 program to determine if 1998 Mazda 626s had high incidences of being “not ready” at the time of the I/M test. The results of these investigations and analyses are summarized in references [9], [10], and [11].

Reference [9] describes the results of a test program run on chassis dynamometers at the EPA NVFEL. One vehicle was instrumented to record a series of real time engine and evaporative emission control parameters. These parameters were recorded by using a custom powertrain control module (PCM) and Mazda’s auxiliary on-board data recording system. Discussions with Mazda and inspection of the identification numbers on the PCM confirmed the custom PCM was identical to the production unit with the exception of its ability to output parameters to an on-board data collection system. One vehicle was tested with a missing gas cap and the other vehicle was tested with a gas cap with a 0.040 in. diameter leak. Results from reference [9] show the OBD evaporative emission monitors performed properly by illuminating MILs and setting DTCs on the second cold LA-4 driven with each vehicle.

Reference [10] describes a test program conducted at the EPA NVFEL which evaluated the ability of the evaporative emission monitor to detect a missing gas cap when the same vehicles used for the dynamometer study were driven over a series of road routes in the Ann Arbor area. This study showed that when the two vehicles were driven over a variety of road routes with several different drivers, MILs and DTCs were observed on 6 of 13 road trials. Reference [10] also describes the result of an analysis of data from the Wisconsin I/M test program. A check of the readiness status at the time of the Wisconsin I/M test on 152 Mazda 626s during the period August, 1998 through July, 1999 showed a “not ready” condition for only four vehicles. The analysis did not examine the reason for the not ready status, but even if the evaporative emission monitor was the reason for all four vehicles being “not ready”, this is not judged to be a significant concern. Based on the dynamometer and road test programs at the NVFEL, and an analysis of the Wisconsin data, EPA concluded the Mazda 626 OBD evaporative emission monitors operated acceptably.

Reference [11] is an engineering report submitted by Mazda describing the need for an additional enabling criterion. This report requests a “change in load < 4.0/sec” enabling criterion be added to their 1998 model year OBD application description. This criterion is based on the change in load fraction, expressed as a decimal from 0 to 1.0 during a period of 50 msec. The load fraction is based on the ratio of measured engine air flow divided by the air flow at a maximum load condition, and thus the numerator is dimensionless. The enabling criterion specifies that the rate of change in engine load must be less than a certain value. The enabling criterion added by Mazda implies that a driver should operate the vehicle in a “smooth manner” to obtain more frequent operation of the evaporative emission monitor.

During the period when the EPA was investigating the two Mazdas in Ann Arbor, ATL began testing a second Mazda 626. Vehicle 182 experienced difficulty in setting codes and illuminating MILs when tested with a 0.040 in. diameter leak in the gas cap, and also had high evaporative emissions in its “repaired” FTP test. The test history with vehicle 182 can be observed by examining the Fault, MIL, Code, Drive Cycle to Set Code, and Comments columns in Table A-2, and the emission results in Table A-3. Table A-3 uses the labels F1, R1, F2, and R2 to designate the first series of “failed” and “repaired” FTP tests, and the second series of “failed” and “repaired” tests, respectively. The identifier “Diag” refers to a diagnostic test which was performed to investigate reasons for the high evaporative emissions.

Note in Table A-2 that vehicles 182, 183, and 184 used several road driving cycles while attempting to illuminate MILs or produce DTCs. This occurred because ATL was installing a dynamometer in their laboratory and construction limited the access to and usage of their other dynamometers.

No MIL or DTC were present following two cold start LA-4s when vehicle 182 was driven on a road route with a 0.040 in. diameter leak in the gas cap. When the fault was removed and the FTP repeated, the running loss emissions were high. The cause for the high evaporative emissions was investigated and attributed to an inaccurate measurement of the fuel temperature which caused the fuel to be heated excessively, thereby generating high quantities of hydrocarbon vapor during the running loss test. The emission results in Table A-3 designated as “Diag” shows that correcting the over heating condition by using <u>internal</u> fuel tank thermocouples lowered the running loss emissions below the 0.05 g/mi standard.

Given that the previous emission tests, F1 and R1 were now suspect, the vehicle was rerun with a 0.040 gas cap leak. No MIL or DTCs were observed after the second cold start even though the evaporative emission monitor status was “ready.” A second FTP test was run with the leaking gas cap, and these are reported as F2 in Table A-3. A second FTP test was run with the fault removed and these results are reported as R2 in Table A-3. The gas cap was then removed and two cold LA-4s were run on the dynamometer. The MIL illuminated and DTC 0455 (large leak) was registered. One more attempt was made to illuminate a MIL and set a DTC with a 0.040 in. leak in the gas cap by running a series of cold start LA-4s, but after the third LA-4, no MIL was illuminated and no DTC was observed.

There are no obvious reasons for the apparent differences in MIL illumination and DTC response between the ATL and Ann Arbor investigations. EPA suspects the evaporative emission monitor in the 1998 Mazda 626 may not be easy to exercise during transient driving, although EPA reported more success in Ann Arbor in illuminating MILs and registering DTCs with induced faults. Neither of the Mazda vehicles tested at ATL were judged to have accurately identified a 0.040 inch leak, and therefore they constitute two or the three vehicles which did not illuminate MILs or register DTCs. Similarly, because they did not illuminate MILs, these vehicles did not qualify for inclusion in Tables 1- 3, which required that they illuminated MILs, set DTCs, and did not have questions concerning the validity of the evaporative emission results presented in Table A-3, particularly the post-repair tests.

<u>Vehicles with High Post-Repair Evaporative Emissions</u>
Two Honda vehicles, Nos. 153 and 188, had high evaporative emission results for the post repair FTP tests. Two Ford vehicles, Nos. 155 and 194, also had high evaporative emissions for the post repair FTP tests.

<u>Honda Vehicles 153 and 188</u> - Vehicle 153 is a 1999 Honda Accord LX with a 2.3 liter engine. This vehicle produced high evaporative emissions during the running loss, and subsequently in the hot soak and diurnal portions of the FTP. The fault induced in vehicle 153 was a disconnected purge line which was blocked at the end of the disconnection and also at the connection on the purge valve. Given the simplistic failure mode, there appears little likelihood that the vehicle was not restored to its original configuration for the "repaired" mode test. Unlike the problems described above for the Mazda vehicles, the OBD system had no difficulty in illuminating the MIL and setting a DTC.

A number of actions were taken by ATL to investigate the causes of the apparent high evaporative emissions first observed during the second bag of the first LA-4 cycle of the running loss driving schedule. They included checking for leaks, checking the adsorption efficiency of the canister by purging, loading, and weighing the canister, checking for adequate purge volume by installing a flowmeter, probing for sources of hydrocarbon vapor while driving a series of three LA-4s with the vehicle on a chassis dynamometer, probing for vapor sources when the vehicle was placed in the SHED after the series of LA-4s, and checking the performance of a two way control valve in the vapor control system. No cause for the high evaporative emissions was found and the vehicle had to be returned to the rental agency when the contract period expired at the end of September, 1999.

The contract work with ATL was begun again in October, 1999. Given the unexplained difficulties with vehicle 153, another 1999 Honda Accord, vehicle 188, was recruited for the study. 188 was identical to vehicle 153 but used a 0.040 in. diameter leak in the gas cap as the induced failure condition. Again, post-repair FTP results showed high levels of evaporative emissions starting with the fourth bag (2nd NYCC) during the running loss test. The hot soak and diurnal loss results were also high compared to the 2.0 g FTP evaporative emission standard.

A second set of tests with and without the induced fault were run, this time using thermocouples located in the fuel liquid, as opposed to the earlier test which attached thermocouples to the exterior fuel tank surface. These tests are identified as F2 and R2, respectively, in Table A-3. Although each FTP test sequence suggested lower running loss emissions (significantly lower for the repaired tests, 6.43 g/mi vs. 0.66 g/mi), the “repaired” test results still exceeded FTP standards. Analysis of the data showed hydrocarbon breakthrough occurred at the end of the sixth bag (second bag of the second LA-4) of the running loss driving schedule.

Honda conducted an extensive effort to find a cause for the high evaporative emissions reported during the post-repair FTP tests of vehicle 188. [12] Honda staff reviewed the second by second temperature versus time profile during the running loss tests of vehicle 188, and visited ATL to examine differences in test equipment between ATL and their certification test facility in Japan.

On April 4 and 5, Honda witnessed a running loss test that confirmed the previously reported high emissions. This series of tests used certification conditions for the dynamometer inertia and road load horsepower. These values were higher than the previous load settings, 3375 vs. 3250 pounds, and 7.8 vs. 5.2 horsepower. The running loss result, 0.38 g/mi was lower than earlier results, but still much higher than the 0.05 g/mi. standard. During the visit to ATL, Honda speculated that the location of the thermocouples in the fuel tank and the design and position of the ATL fuel tank heating system may have lead to localized tank heating and therefore higher evaporative emissions.

Honda conducted a baseline running loss test at their certification facility Japan on a similar Accord. This test produced a running loss result of 0.022 g/mi, well under the 0.05 g/mi standard. Next, they located thermocouples in positions similar to those used by ATL in their initial tests, and also duplicated the design of the ATL fuel tank heating system at their certification test facility in Japan. A running loss result of 0.031 g/mi was obtained following these modifications. Honda noted that their “simulated ATL system” did not control liquid or vapor temperature to within the CFR requirements, but given the higher vapor and liquid temperatures relative to the certification target profiles, Honda stated the evaporative emission control system was designed with a significant margin of safety.

Honda stated that the thermocouple positions used by ATL to monitor the interior fuel temperature were not in strict accordance with the CFR requirement for a “mid-volume” position at a 40% fill level of nominal tank capacity. [4]

A second series of FTP tests were conducted at ATL on May 15 and 16 using a tank heating system designed to approximate the system used for certification testing in Japan. These tests also used a Honda supplied fuel tank with internal thermocouples located at the positions used by Honda in their certification tests. The outlet area of the new air supply was slightly larger than the outlet area of the standard ATL system (approximately 187 in^2 vs. 157 in^2) and the modified system at ATL simulated the supply duct in Japan with respect to its location under the fuel tank. The outlet area of the modified system was restricted to achieve an adequate supply velocity. This was one of several design compromises which were made at ATL because the air flowrate was higher in Japan with similar duct sizes. Reference [12] includes photographs which show the original and modified systems at ATL and in Japan.

The net effect of the modifications to the ATL heating system and use of a fuel tank with different positions for the thermocouples was to produce FTP running loss below the FTP standard, 0.019 g/mi, and low hot soak emissions. Honda concluded it was the combination of improper thermocouple placement and a heating system which produced localized and excessive heating of the fuel tank which produced the erroneously high evaporative emission results on vehicles 153 and 188.

EPA desires to conduct follow-up testing on these vehicles to quantify the localized heating condition and the sensitivity to thermocouple placement on running losses, as the standard system used by ATL has been successfully used on many different vehicle/fuel tank combinations without adversely affecting a vehicle's evaporative emission results. It is important to note that both Honda's and ATL's running loss fuel tank equipment meet the CFR requirements.

<u>Ford Vehicles 155 and 192</u> - Vehicle 155 is a 1999 model year Mercury Tracer with 2.0 liter engine. The Ford OBD evaporative emission monitor operates under steady state conditions unlike most evaporative emission monitors which are designed to operate on cold LA-4 and/or cold start FTP driving cycles. A gas cap with a 0.040 in. leak was installed and combinations of LA-4s and steady state cycles were run to illuminate a MIL and set a DTC. A cold LA-4 followed by a cold steady state did not illuminate the MIL. The OBD system was reset, and a cold LA-4, cold start steady state, and hot start LA-4 sequence did not illuminate the MIL, although the evaporative emission monitor had completed its leak check. The FTP test was then run with the leaking gas cap followed by the post-repair FTP.

Ford engineering staff were notified of the test results. They requested the leaking gas cap be re-installed, the fuel tank filled to 80% capacity, and a cold LA-4, cold steady state, and second cold steady state driving cycle be run. The MIL was still not illuminated after this sequence of drive cycles, and the vehicle had to be returned to the rental agency because the initial portion of the ATL contract period had expired.

Vehicle 192 is a 1998 Ford Windstar with a 3.8 liter engine. The induced failure was a 0.040 in. diameter leak between the fuel tank and the canister. One cold start FTP and two cold start steady state tests illuminated a MIL and produced a DTC. The vehicle received its initial FTP, the fault was removed, and after readiness criteria were satisfied, the vehicle was retested on the FTP. Running loss and hot soak emissions were low, but the vehicle showed high diurnal emissions on each of the 24 hour portions of the three day diurnal test sequence. ATL technicians inspected the vehicle for leaks, and although the initial leak check of the vehicle did not indicate any leaks, inspection after the post-repair FTP emission test showed a possible leak at the sending unit seal. The seal was replaced and the vehicle FTP tested again. These results are identified as test R2 in Table A-3, and show the vehicle again exceeded the FTP hot soak plus diurnal standard. The vehicle was again checked for leaks but none were found and due to time constraints, the vehicle was returned to the rental agency.

EPA again contacted Ford technical staff and requested their assistance in determining why the vehicle exhibited high levels of evaporative emissions during the diurnal test. Ford requested a number of details concerning test equipment and test procedures used at ATL. Ford's concerns included the possibility that installation of the thermocouples through the bottom of the tank may have induced trace leaks, the position of the thermocouples in the fuel may have been incorrect, the diagnostic leak checks completed by ATL indicated inconsistent results, the fuel tank heating system did not closely duplicate the heating system used by Ford during certification testing of the 1998 Windstar, and the dynamometer inertia weight and 50 mph actual horsepower were low compared to the certification test parameters.

Ford's concerns are theoretically valid in that significant differences in instrumentation and test parameters may influence evaporative emission results, but EPA did not prove that these concerns, or combinations of them, were responsible for the high diurnal emissions measured on either of the post-repair FTPs.

The inertia and horsepower for the ATL tests on the 1998 Windstar were based on data from the EPA I/M Look-up Table. Certification vehicles, based on engine family groupings, do not accurately reflect the real world, "as built" fleet, which appear in I/M lanes. Real world vehicles are aggregated in the look-up table differently than the methodology certification vehicles (prototypes) use to represent multiple vehicles. For instance, a vehicle arriving for an I/M test which appears to be uniquely identified in terms of manufacturer, model year, model name, body style, number of cylinders, engine displacement, and transmission may have multiple combinations of inertia weight and horsepower in the EPA certification records. The look-up table is based on selecting the lowest inertia and/or dynamometer horsepower from EPA certification records when multiple values are listed. Therefore, the lower vehicle inertia selected at ATL, 3875 pounds versus 4250 pounds in the certification data, and the lower horsepower, 7.9 versus 10.0, are not unexpected. Ford staff expressed the view that, qualitatively, the lower dynamometer conditions would be expected to result in an incrementally smaller quantity of purge flow during tests at ATL. It is unknown how this affected the diurnal loss emissions at ATL.

Because no obvious reason for the high evaporative emissions could be determined, Ford offered to send ATL a Windstar fuel tank instrumented in a manner identical to a fuel tank used during the certification of the 1998 Windstar vehicle. It was determined that this would require that access panels be cut in the floor of the vehicle to accommodate the protruding thermocouples and fuel drains which are commonly present on certification vehicles. Given that this vehicle was procured from a rental agency, this was unacceptable unless EPA or Ford were to purchase the vehicle. Neither party wished to do this and the vehicle was returned to the rental agency without a determination of a reason(s) for the high diurnal emissions.

EPA asked if Ford would consider running an evaporative emission test on a similar vehicle at their Allen Park, Michigan certification test facility to demonstrate that, the ATL results notwithstanding, the 1998 Windstar meets CFR requirements for FTP evaporative emissions. EPA staff met with Ford and were given a tour of the test equipment and protocols which Ford used during the certification process for the 1998 Windstar. EPA asked, and Ford agreed, to test a similar Windstar at their Allen Park, MI Certification facility. [13]

In September 2000 Ford submitted FTP evaporative emission results of 0.80 g (hot soak loss plus highest 24 diurnal loss) and 0.003 g/mi (running loss). [14] These results are well below the FTP evaporative emission standards and, at present, EPA has no plans to conduct follow-up testing to resolve the reported emission differences between ATL and Ford.

Table A-1
Vehicle Descriptions

Veh No.	Model Yr	Make	Model	Disp liters	Odom miles	Engine Family	Evap Family	Tank Vol gal	Tank Material	Evap Std	Dyno Inertia lbs	Dyno Load Hp @ 50
140	99	Honda	Civic	2.0	7,576	XHNXV01.6CA3	XHNXR0099AAD	16.0	Metal	ORVR	2875	7.5
141	96	Ford	Explorer	4.0	116,730	TFM4.028GKFK	TFM1120AYMED	21.0	Metal	Enhanced	4500	11.8
142	99	Chevrolet	Tahoe	5.7	9,440	XGMXA05.7186	XGMXE0111911	30.0	Plastic	Enhanced	5625	16.0
143	98	Toyota	Camry	2.2	21,197	WTYXV02.2XBA	WTYXR0135AK1	18.5	Metal	ORVR	3500	7.3
144	99	Chevrolet	Monte Carlo	3.1	7,978	XGMXV03.4041	XGMXE0095904	16.6	Metal	Enhanced	3625	6.4
145	98	Nissan	Altima	2.4	35,574	WSNXV02.4A3A	WNSXR0110RCA	15.8	Plastic	ORVR	3000	11.3
146	99	Mitsubishi	Mirage	1.5	9,442	XMTXV01.5GFD	XMTXR0140A1A	12.4	Metal	ORVR	2750	6.4
147	97	Ford	Taurus	3.0	49,443	VFM3.0V8GKEK	VFM1115AYMEB	16.0	Metal	Enhanced	4000	3.8
148	99	Toyota	Pickup	2.4	78,042	XTYXT02.4BBH	XTYXE0095AE0	15.1	Metal	Enhanced	3125	13.2
149	99	Chevrolet	Cavalier	2.2	16,124	XGMXV02.2021	XGMXR0124912	15.0	Metal	ORVR	3000	7.0
150	98	Mazda	626 LX	2.0	21,378	WTKXV02.0VBA	WTKXR0125BFA	16.9	Metal	ORVR	3375	7.2
151	98	Chevrolet	Lumina	3.1	31,859	WGMXV03.1041	WGMXE0095904	16.6	Metal	Enhanced	3625	5.5
152	99	Ford	Ranger	3.0	5,259	XFMXT03.32DC	XFMXE0155FBE	19.5	Plastic	Enhanced	4250	14.3
153	99	Honda	Accord LX	2.3	12,950	XHNXV02.3PA3	XHNXR0130AAA	17.1	Metal	ORVR	2750	6.7
154	99	Nissan	Sentra	1.6	29,362	XNSXV01.6A1A	XNSXR0085RCA	13.3	Metal	ORVR	3000	6.3

155	99	Mercury	Tracer	2.0	12,782	XFMXV02.0VBA	XFMXR0080BAE	12.8	Metal	ORVR	4250	9.5
156	99	Toyota	Sienna	3.0	30,611	XTYXT03.0XBP	XTYXE0115AE1	21.0	Metal	Enhanced	3375	7.2
182	98	Mazda	626	2.0	32,854	WTKXV02.0VBA	WTKXR0125BFA	16.9	Metal	ORVR	3375	7.2
183	00	Nissan	Maxima	3.0	6,742	YNSZV03.0A6A	YNSXR0110RCC	19.5	Metal	ORVR	3500	7.9
184	99	Mercury	Gr.Marquis	4.6	25,678	XFMXV04.6VBE	XFMXR0115BAE	19.0	Metal	ORVR	4250	10.5
185	98	Chevrolet	S-10	4.3	14,745	WGMXT04.3183	WGMXE009504	18.5	Metal	Enhanced	4500	14.4
186	98	Ford	F-150	4.6	73,787	WFMXT04.6BAA	WFMXE0160BAE	24.5	Metal	Enhanced	4500	14.6
187	99	Infinity	QX4	3.3	27,453	XNSXT03.3A5B	XNSXE0110MBA	21.2	Metal	Enhanced	4500	17.9
188	99	Honda	Accord	2.3	11,636	XHNXV02.3PA3	XHNXR0130AAA	17.2	Metal	ORVR	3250	5.2
189	00	Toyota	Corolla	1.8	7,592	YTYXV01.8FFA	YTYXR0115AK1	13.2	Metal	ORVR	2750	6.2
190	99	Toyota	Tacoma	2.4	41,142	XTYXT02.4BBH	XTYXE0095AE0	15.2	Metal	Enhanced	3250	12.3
191	96	Isuzu	Rodeo	3.2	77,640	TSZ3.22JGKEK	TSZ1089AYME0	21.9	Metal	Enhanced	4250	16.4
192	98	Ford	Windstar	3.8	68,892	WFMXT03.8ABA	WFMXE0140BBE	20.0	Plastic	Enhanced	3875	7.9
193	98	Chevrolet	Malibu	3.1	29,871	WGMXV03.1041	WGMXR0124912	15.0	Metal	ORVR	3375	5.8
194	99	Pontiac	Grand Am	2.4	21,666	XGMXV02.4024	XGMXR0124912	15.0	Metal	ORVR	3250	5.7

Table A-2
Induced Failures, MIL and Diagnostic Trouble Code Status

Veh No.	Fault	MIL	Code	Drive Cycles	Comments
140	Removed the gas cap	On	P1456	LA-4 (1)	
140	Reinstall OEM Cap	Off	None		
141	Purge system inoperative	On	P1451	No drive cycle needed	True failure.
141	Replaced PCM	Off	None		
142	0.040 in. leak in gas cap	On	P0442	LA-4 (2)	
142	Reinstall OEM cap	Off	None		
143	0.040 in. leak in vent line	On	P0440	LA-4 (2.5)	
143	Removed 0.040 in. leak	Off	None		
144	Blocked purge line	On	P0440	LA-4 (2)	Removed purge line at throttle body, plug both ends.
144	Blockage removed	Off	None		
145	Vent solenoid line to atmosphere blocked	On	P0450, P1446	LA-4 (2)	
145	Blockage removed	Off	None		
146	0.040 in. leak in gas cap	On	P0442	LA-4 (2)	
146	Reinstall OEM cap	Off	None		
147	Purge and tank vent line disconnected at canister	On	P0455	LA-4 (1) SS (1)	Port disconnected from cansiter. Open to atmosphere. True failure.
147	Lines reconnected	Off	None		
148	0.040 in. leak in purge line to fuel tank.	On	P0446	LA-4 (2)	Leak in series between solenoid and fuel tank.
148	Remove leak	Off	None		

149	Disconnect purge line at throttle body	On	P0440	LA-4 (2)	Plugged at both ends.
149	Reinstall purge line	Off	None		
150	Remove gas cap	Off	None	LA-4 (6) FTP (2) SS(1)	
150	Remove gas cap	Off	None	SS (2)	Continuous code P0455, No MIL.
151	0.020 in. leak in gas cap	Off	None	LA-4 (3) FTP (1)	
151	Reinstall OEM cap	Off	None		
152	0.020 in. leak in gas cap	Off	None	LA-4 (1) Steady State (2)	
152	Reinstall OEM cap	Off	None		
153	Block purge line	On	P1457	LA-4 (2.5)	Line disconnected from purge valve, blocked at both ends.
153	Repair purge line	Off	None		
154	0.040 in. leak in purge line.	On	P1440	LA-4 (2)	Leak between canister and purge valve.
154	Remove leak	Off	None		
155	0.040 in. leak in gas cap	Off	None		All readiness monitors complete, no MIL.
155	Reinstall OEM cap	Off	None		
156	0.020 in.leak in gas cap	On	P0440	LA-4 (4)	MIL on after 4th LA-4.
156	Reinstall OEM cap	Off	None		
182	0.040 in.gas cap leak	Off	None	Road LA-4 (2)	EGR & evap monitors incomplete after 1st drive cycle, all monitors complete after 2nd. No MIL, no continous codes, all TIDs and CIDs pass.
182	Reinstall OEM cap	Off	None	Road LA-4 (2)	
182	0.040 in.gas cap leak	Off	None	LA-4 (2)	All monitors complete after 2nd LA-4.
182	Gas cap removed	On	P0455	LA-4 (2)	MIL on during 2nd LA-4.
182	2nd 0.040 in.gas cap leak	Off	None	LA-4 (3)	Vehicle had continuous code P0442 after 1st and 2nd drive trace. No cont. codes after 3rd drive trace, all readiness monitors complete, MIL off.

183	0.040 in.leak in line between canister and fuel tank Leak removed from line	On	P0440	Road LA-4 (2)	MIL on during 2nd road LA-4.
183	Remove leak from line	Off	None	LA-4 (1)	All monitors complete after first dyno LA-4.
184	Gas cap removed	On	P0455	Road LA-4 (2) SS (3)	Steady state cycles performed on dyno.
184	Gas Cap Installed	Off	None	LA-4 (1) SS (1)	Steady state cycles performed on dyno.
185	0.040 in. leak in line between canister and fuel tank	Off	None	Road LA-4 (1)	All monitors completed during the first road LA-4 No MIL on, no codes.
185	Fault removed	Off	None	LA-4 (2) GM (1)	EGR monitor was reset during GM trace.
185	Reinstall 0.040 leak (metal)	On	P0442	LA-4 (2)	Steel adapter put in in place of plastic adapter. 2nd As-Received test performed.
186	Purge hose plugged	On	P0455	LA-4 (2) SS (4)	Continuous code P0455 after first drive trace. MIL on 5 minutes into the 4th steady state trace.
186	Remove plug from purge line	Off	None	FTP (1) SS (1)	Evap only incomplete monitor after FTP.
187	Loose gas cap	On	P0440	FTP (1) LA-4 (4)	All monitors complete, no MIL after 1st LA-4. Monitors cleared, cap loosened 1/2 in. Cold FTP trace driven. All monitors complete except evap after FTP trace. No continous codes. Three more LA-4 cycles driven. MIL on 18 minutes into the 3rd LA-4 trace. (1 FTP + 3 LA-4 cycles to set MIL on).
187	Tighten OEM cap	Off	None	FTP (2)	
188	0.040 in.gas cap leak	On	P1456	LA-4 (2)	Light on 15 minutes into the 2nd LA-4 drive cycle.
188	Install OEM cap	Off	None	FTP (1)	All monitors complete after 1st dyno FTP with no fault.
188	0.040 in.gas cap leak	On	P1456	FTP (2)	
188	OEM gas cap installed	Off	None	FTP (1)	All monitors complete.
189	0.020 in.gas cap leak	On	P0440	FTP (2)	
189	OEM gas cap installed	Off	None	FTP (1)	All monitors complete.

190	Purge line disconnected at canister	On	P0446	FTP (2)	Vehicle procured with MIL on and fault set.
190	Reconnect purge line	Off	None	FTP (1)	
191	Loose gas cap	On	P0440	FTP (2)	Evap monitor incomplete, no pending codes after first FTP.
191	Tighten gas cap	Off	None	FTP (1)	
192	0.040 in.leak between tank and canister.	On	P0442	FTP (1) SS (1)	
192	Remove fault	Off	None	FTP (1) SS (1)	
193	Blocked purge system	On	P0440	FTP (2)	
193	Reconnect purge	Off	None	FTP (3)	
194	0.020 in.leak in gas cap	On	P0440	FTP (3)	
194	Reinstall OEM cap	Off	None	FTP (2)	

Table A-3
Composite Emission Results

Veh No.	Failure/ Repair	Test No.	Composite Emissions, g/mi HC	CH4	CO	NOx	CO2	MPG	Running Loss Test No.	Grams	gr/mi	Hot Soak Test No.	Grams	SHED No.	3 Day Diurnal Loss Test No.	1st 24 Grams	2nd 24 Grams	3rd 24 Grams
140R	F	21060	0.03	0.03	0.6	0.04	273	32.4	21064	220.86	12.81	3057	3.91	15	3058	21.19	20.10	19.38
	R	21306	0.04	0.03	1.1	0.03	282	31.3	21256	0.28	0.02	3085	0.10	15	3087	0.51	0.38	0.41
141E	F	21173	0.15	0.11	1.1	0.28	441	20.1	21175	289.62	16.75	3078	2.72	15	3079	1.94	1.77	2.28
	R	21246	0.14	0.10	1.8	0.49	504	17.5	21248	0.57	0.03	3093	0.25	12	3094	2.89	2.28	2.10
142E	F	21571	0.10	0.09	1.7	0.26	618	14.3	21572	46.35	2.69	3097	8.62	15	3098	36.70	34.41	33.45
	R	21618	0.09	0.08	1.8	0.26	621	14.3	21620	0.31	0.02	3104	0.15	14	3105	0.57	0.43	0.40
143R	F	21253	0.14	0.13	1.5	0.24	344	25.6	21255	118.34	6.88	3095	3.62	14	3096	29.41	28.24	26.86
	R	21613	0.13	0.12	1.6	0.17	329	26.8	21615	0.17	0.01	3102	0.09	15	3103	0.29	0.22	0.20
144E	F	21589	0.12	0.11	1.3	0.10	411	21.5	21591	91.67	5.31	3099	54.88	14	3100	3.02	3.81	4.78
	R	21639	0.09	0.08	1.2	0.10	392	22.5	21641	0.24	0.01	3108	0.11	14	3109	0.50	0.42	0.40
145R	F	21677	0.08	0.07	1.3	0.20	355	24.9	21679	78.87	4.57	3112	0.72	15	3113	0.67	2.08	3.82
	R	21743	0.07	0.06	1.4	0.24	347	25.5	21745	0.24	0.01	3123	0.12	12	3124	0.76	0.79	0.80
146R	F	21663	0.15	0.13	1.7	0.19	297	29.7	21665	0.17	0.01	3110	0.07	15	3111	0.36	0.51	0.79
	R	21705	0.14	0.12	1.6	0.15	291	30.3	21707	0.18	0.01	3114	0.07	15	3115	0.32	0.40	0.58
147E	F	21791	0.16	0.14	1.4	0.24	423	20.9	21726	375.91	21.84	3119	23.66	15	3120	40.30	32.64	27.61
	R1	21857	0.25	0.22	2.5	0.43	453	19.4	21859	77.03	4.49	3143	8.28	12	3144	1.11	1.41	2.51
	R2	21970	0.20	0.18	1.8	0.29	420	21.0	21972	0.21	0.01	3177	0.07		Not Performed			
148E	F	21888	0.18	0.15	2.4	0.27	358	24.5	21890	1.55	0.09	3150	0.80	14	3151	3.66	4.22	5.30
	R	21993	0.18	0.15	2.1	0.30	363	24.2	21995	0.32	0.02	3183	0.13	11	3185	0.24	0.24	0.24
149R	F	21913	0.07	0.05	1.9	0.04	360	24.5	21914	111.79	6.52	3155	8.96	15	3156	4.17	5.91	6.32
	R	22006	0.09	0.08	1.4	0.04	351	25.1	22008	0.34	0.02	3189	0.30	14	3192	1.13	1.56	1.71

150R	F	21996	0.14	0.12	1.2	0.23	362	24.4	21999	95.01	5.53	3184	2.76	14	3186	0.62	0.56	0.69
	R	22137	0.13	0.12	0.9	0.20	349	25.4	22140	0.49	0.03	3230	0.18	11	3232	0.57	0.62	0.69
151E	F	22023	0.15	0.13	2.4	0.13	380	23.1	22026	18.43	1.07	3196	0.98	11	3199	3.59	3.65	6.11
	R	22081	0.14	0.11	2.0	0.15	383	23.0	22083	0.20	0.01	3215	0.06	14	3217	0.60	0.65	0.73
152E	F	22013	0.10	0.09	1.6	0.05	490	18.0	22015	0.34	0.02	3193	0.10	12	3204	0.40	0.42	0.43
	R	22132	0.09	0.09	1.5	0.03	491	18.0	22134	0.13	0.01	3228	0.05	12	3229	0.33	0.39	0.45
153R	F	22072	0.07	0.06	2.2	0.06	343	25.7	22074	212.01	12.29	3210	4.02	12	3214	2.10	3.83	6.03
	R	22166	0.04	0.04	1.6	0.05	350	25.2	22141	164.24	9.51	3231	2.98	11	3239	1.86	3.29	5.13
154R	F	22086	0.10	0.08	2.5	0.07	300	29.3	22088	3.50	0.20	3216	0.14	12	3218	0.84	0.71	1.12
	R	22177	0.10	0.08	2.2	0.08	298	29.5	22179	0.39	0.02	3241	0.12	12	3242	0.58	0.60	0.63
											0.18		0.02					0.49
155R	F	22155	0.06	0.05	0.5	0.09	303	29.2	22157	0.28	0.02	3234	0.09	12	3238	0.95	1.06	1.25
	R	22202	0.07	0.07	0.7	0.08	305	29.0	22204	0.31	0.02	3249	0.14	12	3250	1.46	1.70	2.18
156E	F	22121	0.21	0.18	1.4	0.22	434	20.4	22123	45.16	2.62	3223	6.83	14	3226	37.03	35.45	33.58
	R	22182	0.16	0.14	1.3	0.17	390	22.7	22186	0.39	0.02	3244	0.08	15	3247	0.37	0.25	0.34
182R	F1	22262	0.17	0.15	1.1	0.27	346	25.6	22264	128.00	7.42	3255	34.67	14	3256	1.68	2.45	4.76
	R1	22300	0.15	0.14	1.0	0.23	347	25.5	22302	86.43	5.02	3262	11.65	12	3263	1.35	1.64	2.31
	Diag	22456	0.14	0.13	1.2	0.24	353	25.0	22458	0.48	0.03	Not Perf			Not Performed			
	F2	22518	0.33	0.32	1.5	0.26	354	24.9	22520	46.40	2.69	3301	0.47	12	3301	0.46	0.48	0.65
	R2	22578	0.16	0.14	1.3	0.24	269	23.9	22557	0.44	0.03	3313	0.09	12	3314	0.65	0.75	1.15
183R	F	22368	0.10	0.09	1.1	0.22	412	21.5	22370	16.57	0.96	3277	0.67	11	3278	10.45	11.00	11.21
	R	22438	0.09	0.08	0.9	0.20	412	21.5	22440	0.26	0.02	3288	0.11	12	3289	0.78	0.80	0.74
184R	F	22398	0.33	0.25	6.1	0.06	462	18.8	22400	4.48	0.26	3281	0.55	11	3282	5.53	14.95	17.44
	R	22461	0.12	0.11	1.9	0.06	457	19.3	22463	1.11	0.06	3293	0.11	11	3294	0.52	0.48	0.49
185E	F1	22414	0.16	0.13	1.6	0.25	491	18.0	22416	9.29	0.54	3283	0.12	12	3284	0.55	0.53	0.58
	F2	22571	0.15	0.13	1.6	0.26	499	17.7	22548	8.08	0.47	3310	1.72	12	3311	3.70	0.45	0.53
	R	22469	0.14	0.12	1.6	0.29	480	18.4	22471	0.43	0.03	3295	0.05	12	3296	0.33	0.37	0.41
186E	F	22612	0.19	0.16	2.0	0.35	537	16.4	22614	262.43	15.14	3325	5.40	12	3326	1.63	2.45	4.91
	R	22679	0.18	0.15	1.8	0.37	542	16.3	22681	0.23	0.01	3343	0.04	11	3344	0.28	0.28	0.27

187E	F	22618	0.13	0.12	1.3	0.36	567	15.6	22620	272.47	15.75	3329	11.54	12	3357	45.30	41.66	40.95
	R	22712	0.13	0.12	1.3	0.39	586	15.1	22714	0.43	0.03	3355	0.12	12	3357	0.85	0.88	0.81
188R	F1	22609	0.11	0.18	0.7	0.01	287	30.8	22611	215.72	12.55	3324	21.41	11	3324	29.75	31.75	30.65
	R1	22663	0.06	0.05	1.9	0.04	339	26.0	22635	111.31	6.43	3333	5.34	12	3335	1.83	2.66	4.27
	F2	22694	0.07	0.06	1.5	0.04	335	26.4	22696	191.01	11.05	3348	16.21	12	3351	34.44	31.86	31.73
	R2			Not Performed					22728	11.33	0.66	3365	2.77	11	3366	1.14	1.64	2.89
	R3			Not Performed							0.02		0.14			Not Performed		
189R	F	22733	0.05	0.05	0.7	0.07	282	31.4	22735	42.22	2.44	3368	5.09	12	3370	27.79	25.33	24.62
	R	22763	0.06	0.05	0.5	0.08	285	31.1	22765	0.35	0.02	3388	0.13	12	3389	0.56	0.24	0.52
190E	F	22859	0.20	0.17	3.1	0.18	381	23.0	22831	101.89	0.92	3417	0.92	12	3419	10.08	11.69	13.30
	R	22921	0.13	0.11	1.8	0.16	370	23.8	22923	0.38	0.02	3442	0.14	12	3443	1.48	1.48	1.78
191E	F	22849	0.15	0.14	1.2	0.33	615	14.4	22851	84.87	4.90	3422	1.02	13	3424	35.58	32.46	30.44
	R	22873	0.15	0.13	1.3	0.33	612	14.5	22875	0.81	0.05	3430	0.28	12	3431	1.61	1.56	1.55
192E	F	22860	0.10	0.10	1.1	0.16	467	19.0	22862	4.16	0.24	3427	0.33	13	3428	17.54	16.73	16.82
	R1	22931	0.10	0.09	1.0	0.12	457	19.4	22933	0.63	0.04	3445	0.27	13	3445	2.38	1.94	1.79
	R2	22985	0.09	0.09	0.8	0.11	453	19.6	22969	0.68	0.04	3458	0.28	12	3458	2.78	2.68	3.15
193R	F	22940	0.14	0.12	1.6	0.12	380	23.2	22942	258.60	14.92	3446	7.63	12	3447	4.35	5.97	6.84
	R	23005	0.16	0.14	2.4	0.07	375	23.4	23007	0.45	0.03	3465	0.18	12	3466	1.60	1.53	1.44
194R	F	22959	0.14	0.13	0.9	0.24	370	23.9	22961	1.39	0.08	3455	0.42	11	3456	2.10	2.10	2.20
	R	23032	0.10	0.09	1.1	0.18	383	23.1	23034	0.41	0.02	3470	0.22	12	3471	1.48	1.50	1.60

Table A-4
FTP Exhaust Results: Bags 1-3

Veh No.	Test	Failure/ Repair	Bag 1 (g/mi) THC	NMHC	CO	NOx	CO2	MPG	Bag 2 (g/mi) THC	NMHC	CO	NOx	CO2	MPG	Bag 3 (g/mi) THC	NMHC	CO	NOx	CO2	MPG
140	20160	F	0.13	0.13	2.2	0.06	290	30.2	0.00	0.00	0.1	0.03	280	31.8	0.01	0.01	0.4	0.03	249	34.7
	21306	R	0.15	0.14	4.0	0.00	302	28.8	0.01	0.00	0.4	0.03	289	30.8	0.01	0.01	0.3	0.04	255	34.8
141	21173	F	0.47	0.41	4.9	0.47	463	18.9	0.06	0.02	0.0	0.17	459	19.4	0.08	0.05	0.4	0.35	391	22.7
	21246	R	0.44	0.38	6.6	1.03	523	16.6	0.05	0.02	0.0	0.16	526	16.9	0.10	0.06	1.3	0.72	447	19.8
142	21571	F	0.34	0.29	6.9	0.59	644	13.6	0.04	0.04	0.2	0.06	637	13.9	0.05	0.04	0.5	0.39	564	15.8
	21618	R	0.34	0.29	7.5	0.49	646	13.5	0.02	0.02	0.2	0.10	641	13.9	0.04	0.03	0.4	0.37	564	15.8
143	21253	F	0.55	0.52	5.7	0.67	373	23.2	0.02	0.01	0.1	0.12	355	25.1	0.06	0.04	0.8	0.14	303	29.2
	21613	R	0.54	0.50	6.3	0.56	358	24.0	0.02	0.01	0.3	0.05	334	26.6	0.05	0.03	0.6	0.11	298	29.8
144	21589	F	0.48	0.45	5.4	0.38	412	21.1	0.02	0.01	0.1	0.02	441	20.2	0.05	0.03	0.4	0.04	354	25.0
	21639	R	0.37	0.34	5.5	0.36	390	22.3	0.01	0.00	0.0	0.00	422	21.1	0.04	0.03	0.3	0.09	339	26.2
145	21677	F	0.30	0.27	4.5	0.43	401	21.7	0.02	0.02	0.3	0.08	342	26.0	0.03	0.02	0.6	0.26	346	25.7
	21743	R	0.26	0.24	4.2	0.46	406	21.5	0.02	0.01	0.7	0.13	340	26.1	0.03	0.02	0.6	0.29	315	28.1
146	21663	F	0.56	0.51	6.2	0.36	308	27.8	0.02	0.02	0.4	0.13	306	29.0	0.09	0.06	0.9	0.15	270	32.7
	21705	R	0.51	0.47	5.4	0.38	323	26.7	0.02	0.02	0.4	0.09	294	30.2	0.07	0.06	0.9	0.11	260	34.0
147	21797	F	0.51	0.46	5.9	0.61	427	20.3	0.03	0.02	0.0	0.08	452	19.7	0.14	0.12	0.5	0.25	364	24.4
	21857	R	0.85	0.77	9.0	0.65	456	18.8	0.05	0.03	0.6	0.29	483	18.4	0.20	0.17	1.1	0.50	395	22.4
148	21888	F	0.70	0.63	10.0	0.53	381	22.3	0.03	0.02	0.3	0.15	368	24.1	0.06	0.04	0.5	0.30	324	27.4
	21993	R	0.70	0.63	9.1	0.65	382	22.3	0.03	0.02	0.1	0.13	376	23.6	0.06	0.04	0.5	0.36	324	27.4
149	21913	F	0.41	0.37	7.7	0.20	396	21.7	0.02	0.01	0.1	0.00	370	24.0	0.00	0.00	0.9	0.01	316	28.1
	22006	R	0.31	0.27	5.4	0.17	368	23.6	0.00	0.00	0.2	0.00	362	24.5	0.10	0.08	0.9	0.01	318	27.8

150	21916	F	0.52	0.49	3.7	0.75	375	23.3	0.02	0.01	0.2	0.09	375	23.7	0.07	0.05	1.0	0.10	327	27.1
	22137	R	0.52	0.49	2.8	0.70	368	23.8	0.01	0.01	0.2	0.08	360	24.7	0.06	0.05	0.8	0.05	313	28.3
151	22023	F	0.55	0.49	9.4	0.46	380	22.4	0.01	0.00	0.1	0.03	408	21.8	0.12	0.09	1.7	0.06	327	26.9
	22081	R	0.51	0.45	7.6	0.53	387	22.2	0.01	0.00	0.0	0.02	409	21.7	0.10	0.08	1.6	0.12	330	26.7
152	22013	F	0.38	0.34	6.2	0.21	509	17.1	0.01	0.01	0.0	0.00	504	17.6	0.07	0.06	1.0	0.02	449	19.7
	22132	R	0.36	0.33	6.0	0.11	504	17.3	0.01	0.01	0.0	0.00	506	17.6	0.05	0.05	0.8	0.02	452	19.6
153	22072	F	0.28	0.25	5.8	0.21	368	23.5	0.01	0.00	1.3	0.02	352	25.1	0.02	0.01	1.1	0.02	306	28.9
	22166	R	0.27	0.25	6.2	0.20	374	23.2	0.00	0.00	0.5	0.01	359	24.7	0.00	0.00	0.4	0.03	314	28.3
154	22086	F	0.29	0.27	2.9	0.26	311	28.1	0.05	0.04	2.9	0.00	311	28.2	0.03	0.02	1.2	0.06	271	32.6
	22177	R	0.30	0.29	2.9	0.28	312	28.0	0.05	0.03	2.7	0.00	309	28.4	0.03	0.02	0.9	0.08	266	33.3
155	21155	F	0.21	0.19	2.3	0.29	327	26.8	0.02	0.02	0.1	0.02	309	28.7	0.01	0.01	0.1	0.09	273	32.5
	22202	R	0.28	0.26	2.7	0.26	330	26.6	0.01	0.01	0.1	0.03	312	28.4	0.02	0.02	0.1	0.05	274	32.4
156	22121	F	0.82	0.75	6.0	0.52	476	18.2	0.02	0.01	0.1	0.08	440	20.2	0.09	0.07	0.4	0.29	392	22.6
	22182	R	0.64	0.60	5.9	0.40	427	20.3	0.02	0.01	0.1	0.03	375	23.7	0.08	0.06	0.2	0.24	391	22.7
182	22262	F1	0.59	0.56	3.8	0.87	366	23.8	0.04	0.03	0.2	0.11	358	24.8	0.09	0.07	0.9	0.10	308	28.8
	22300	R1	0.60	0.03	3.4	0.79	366	23.8	0.01	0.01	0.2	0.09	355	25.0	0.08	0.02	0.7	0.07	315	28.1
	22518	F2	1.37	1.33	5.5	0.85	375	22.9	0.04	0.04	0.1	0.11	366	24.3	0.09	0.08	1.3	0.07	317	27.8
	22578	R2	0.58	0.55	4.3	0.79	367	23.7	0.02	0.02	0.2	0.09	403	22.1	0.08	0.06	1.1	0.07	312	28.3
183	22368	F	0.34	0.32	2.8	0.34	445	19.8	0.03	0.02	0.5	0.09	427	20.8	0.07	0.05	0.8	0.36	360	24.6
	22438	R	0.35	0.32	4.3	0.40	446	19.6	0.01	0.01	0.0	0.09	424	21.0	0.03	0.02	0.2	0.27	363	24.5
184	22398	F	0.94	0.72	14.0	0.23	473	17.9	0.21	0.15	5.7	0.00	479	18.2	0.08	0.07	1.0	0.04	420	21.1
	22463	R	0.48	0.42	6.9	0.29	463	18.7	0.02	0.02	0.5	0.00	477	18.6	0.05	0.04	0.7	0.01	414	21.4
185	22414	F1	0.62	0.57	6.8	0.86	508	17.1	0.02	0.01	0.2	0.06	502	17.7	0.06	0.03	0.4	0.15	459	19.3
	22571	F2	0.60	0.55	6.3	0.83	498	17.5	0.02	0.02	0.2	0.08	527	16.9	0.07	0.04	0.6	0.14	448	19.8
	22471	R	0.56	0.52	7.0	0.92	495	17.5	0.02	0.01	0.2	0.06	491	18.1	0.04	0.02	0.3	0.27	446	19.9

186	22612	F	0.76	0.70	9.4	0.76	552	15.6	0.03	0.02	0.1	0.17	572	15.5	0.05	0.02	0.2	0.37	460	19.3
	22679	R	0.72	0.66	8.4	0.89	549	15.8	0.02	0.01	0.0	0.16	567	15.7	0.06	0.04	0.3	0.38	490	18.1
187	22618	F	0.51	0.48	4.7	0.94	654	13.4	0.03	0.02	0.6	0.05	560	15.9	0.03	0.03	0.3	0.52	514	17.3
	22712	R	0.50	0.47	4.9	0.95	682	12.9	0.03	0.02	0.4	0.07	575	15.5	0.04	0.03	0.3	0.57	534	16.6
188	22609	F1	0.23	0.21	4.1	0.16	354	24.7	0.01	0.01	0.6	0.01	335	26.5	0.18	0.18	0.7	0.01	387	30.8
	22633	R	0.22	0.20	4.5	0.16	365	23.8	0.01	0.01	1.3	0.01	347	25.5	0.01	0.01	0.9	0.03	303	29.2
	22694	F2	0.27	0.25	4.5	0.16	355	24.5	0.02	0.02	1.0	0.01	346	25.6	0.01	0.01	0.3	0.03	299	29.7
189	22733	F	0.20	0.18	2.4	0.12	291	30.1	0.01	0.00	0.3	0.04	297	29.9	0.01	0.00	0.2	0.10	246	36.1
	22763	R	0.22	0.21	1.9	0.20	306	28.7	0.01	0.01	0.2	0.03	293	30.3	0.01	0.01	0.2	0.10	254	35.0
190	22859	F	0.76	0.68	13.2	0.30	393	21.4	0.05	0.03	0.5	0.12	398	22.3	0.06	0.04	0.5	0.19	339	26.1
	22921	R	0.53	0.48	8.2	0.27	384	22.3	0.02	0.01	0.1	0.13	384	23.2	0.03	0.02	0.2	0.15	333	26.7
191	22849	F	0.57	0.53	4.6	0.79	653	13.4	0.05	0.04	0.2	0.19	620	14.3	0.04	0.03	0.3	0.24	576	15.4
	22873	R	0.56	0.53	5.1	0.89	638	13.7	0.03	0.03	0.2	0.10	618	14.4	0.05	0.03	0.5	0.33	579	15.3
192	22860	F	0.41	0.38	3.7	0.51	474	18.5	0.01	0.01	0.1	0.03	492	18.1	0.07	0.06	1.2	0.13	415	21.3
	22931	R1	0.39	0.36	3.1	0.38	456	19.2	0.01	0.01	0.1	0.02	484	18.4	0.06	0.05	1.3	0.11	408	21.7
	22985	R2	0.36	0.34	3.0	0.38	467	18.8	0.01	0.01	0.0	0.01	475	18.7	0.05	0.04	0.7	0.11	400	22.2
193	22940	F	0.50	0.46	6.8	0.41	383	22.5	0.04	0.02	0.1	0.02	406	21.9	0.06	0.04	0.3	0.09	330	26.9
	23005	R	0.64	0.58	11.1	0.27	368	22.9	0.01	0.01	0.0	0.01	405	22.0	0.06	0.05	0.3	0.04	325	27.3
194	22959	F	0.61	0.58	4.2	0.27	398	21.9	0.01	0.01	0.1	0.23	390	22.8	0.01	0.00	0.1	0.24	312	28.5
	23032	R	0.39	0.36	4.1	0.27	391	22.3	0.00	0.00	0.3	0.14	408	21.8	0.05	0.05	0.3	0.19	328	27.0

Table A-5
Liquid Fuel Temperature at Start or End of Running Loss Segment, Degrees F

Veh No	Fuel Profile	Failure/ Repair	Initial	Running Loss Segment Bag 1	Bag 2	2 min	Bag 3	Bag 4	2 min	Bag 5	Bag 6	2 min
140	Target		95.0	101.4	111.6	112.1	115.3	118.0	118.4	121.2	124.8	124.5
	Actual	F	95.5	99.6	112.7	114.1	115.6	117.8	118.4	122.1	125.6	124.4
	Actual	R	94.5	99.8	111.7	112.3	115.2	118.4	117.8	122.1	125.4	125.4
141	Target		95.0	99.0	109.5	110.9	117.3	122.2	123.0	125.8	128.9	129.4
	Actual	F	93.8	99.0	108.6	109.8	116.4	121.5	122.7	124.4	127.3	128.1
	Actual	R	95.1	99.8	109.0	109.0	116.8	123.6	124.8	125.8	127.0	127.9
142	Target		95.0	97.4	103.8	104.4	108.4	112.3	112.8	115.1	119.3	119.5
	Actual	F	94.7	95.9	101.4	102.5	105.9	109.8	110.5	113.3	118.2	118.8
	Actual	R	95.1	95.9	102.0	103.1	107.6	111.3	111.9	114.8	118.2	118.6
143	Target		95.0	97.3	104.3	104.7	108.7	112.2	112.7	114.8	116.8	117.0
	Actual	F	94.5	99.6	105.9	105.7	108.4	111.5	112.5	115.4	117.6	117.4
	Actual	R	94.9	98.6	104.7	105.3	108.8	112.1	111.5	114.6	117.2	117.2
144	Target		95.0	99.5	108.7	109.1	113.1	116.3	116.7	119.7	123.6	123.8
	Actual	F	95.7	102.0	109.0	109.0	113.7	116.2	116.6	121.7	124.4	125.0
	Actual	R	94.3	99.4	110.0	110.5	114.6	116.2	116.4	120.1	124.6	125.0
145	Target		95.0	102.8	111.1	111.7	114.6	116.4	116.6	118.3	120.6	120.6
	Actual	F	96.3	100.8	110.5	111.9	115.0	116.4	116.2	117.4	119.4	118.8
	Actual	R	94.9	98.2	109.6	110.2	115.4	118.4	118.9	119.1	120.5	120.9
146	Target		95.0	100.4	110.8	111.1	113.8	117.5	117.6	120.5	122.5	122.5
	Actual	F	94.7	101.0	106.4	107.2	111.5	114.6	115.0	119.3	122.3	121.9
	Actual	R	95.7	100.8	108.6	109.2	114.5	117.4	116.8	120.1	122.5	121.5
147	Target		95.0	101.7	114.5	115.7	122.3	128.1	127.9	130.5	134.2	133.6
	Actual	F	94.1	102.9	114.5	115.6	121.9	127.5	127.9	131.1	134.6	135.5
	Actual	R	95.0	105.1	113.9	114.6	122.5	127.9	128.1	131.4	135.4	134.6
148	Target		95.0	97.5	103.8	104.7	109.3	113.7	114.6	117.6	121.4	121.6
	Actual	F	94.3	99.6	103.5	104.3	109.2	113.7	114.3	116.8	120.9	121.1
	Actual	R	95.1	99.4	103.3	104.3	109.8	113.1	113.5	115.6	120.9	121.5
149	Target		95.0	98.9	106.3	106.9	110.6	114.6	115.2	117.6	120.5	121.4
	Actual	F	94.1	101.2	106.2	106.4	110.9	114.3	114.6	117.0	121.3	120.9
	Actual	R	94.1	100.6	107.4	109.4	111.3	113.7	117.2	116.8	121.3	119.5
150	Target		95.0	99.0	106.9	107.5	115.9	120.9	121.6	123.1	125.5	125.5
	Actual	F	95.1	102.0	108.4	109.0	112.3	117.8	119.1	126.8	126.0	124.2
	Actual	R	94.9	103.1	109.0	109.0	112.7	120.1	120.7	130.1	125.4	124.0

151	Target		95.0	99.5	108.7	109.1	113.1	116.3	116.7	119.7	123.6	123.8
	Actual	F	93.8	99.2	108.2	108.2	112.3	116.4	116.4	119.9	123.0	124.2
	Actual	R	94.3	99.6	108.0	108.6	113.5	115.8	116.0	119.9	124.6	122.9
152	Target		95.0	98.0	102.4	102.9	106.4	109.9	110.4	113.0	116.0	116.6
	Actual	F	94.7	97.1	103.1	103.7	106.3	112.1	110.9	112.7	116.2	117.0
	Actual	R	94.1	97.1	102.7	103.5	106.6	110.0	110.5	112.3	115.4	116.4
153	Target		95.0	99.5	110.7	112.6	116.5	120.0	120.4	122.9	126.6	127.1
	Actual	F	94.3	100.0	109.8	110.7	116.6	121.5	121.9	124.6	126.0	126.4
	Actual	R	96.9	101.2	110.4	111.3	117.4	121.3	122.1	124.6	126.2	126.0
154	Target		95.0	100.1	108.4	108.5	113.9	117.5	117.5	120.9	124.3	124.9
	Actual	F	93.9	105.3	112.3	112.3	113.5	118.0	117.8	121.3	123.8	124.0
	Actual	R	94.1	102.8	109.0	109.0	113.7	116.8	116.6	120.7	124.2	123.8
155	Target		95.0	103.2	113.5	115.2	117.6	119.8	121.2	124.4	128.3	128.3
	Actual	F	94.3	102.1	112.5	115.0	118.4	120.7	121.7	125.2	128.1	128.5
	Actual	R	95.3	102.3	112.3	113.9	116.6	120.7	121.5	122.7	128.1	127.9
156	Target		95.0	99.3	107.0	107.9	110.8	114.9	115.6	117.9	121.5	122.0
	Actual	F	94.5	98.2	106.6	107.0	109.8	114.5	114.6	118.8	121.9	121.7
		R	94.7	98.6	107.2	107.6	110.7	115.2	114.6	118.6	120.3	121.1
182	Target		95.0	99.0	106.9	107.5	115.9	120.9	121.6	123.1	125.5	125.5
	Actual	F1	94.3	100.6	107.6	107.6	114.1	119.3	121.3	123.4	125.8	127.0
	Actual	R2	94.5	102.0	107.4	107.6	114.6	119.7	120.7	123.6	126.0	125.6
	Actual	Diag	94.9	99.0	108.8	110.2	114.5	119.7	120.7	123.8	125.6	125.2
	Actual	F2	95.9	99.6	108.4	109.4	113.5	119.9	120.7	125.6	126.6	126.2
	Actual	R2										
183	Target		95.0	99.2	106.3	106.8	110.1	111.3	111.0	114.4	118.0	118.5
	Actual	F	94.5	98.6	107.0	107.0	111.5	112.9	112.9	115.6	118.0	118.4
	Actual	R	95.7	98.6	107.0	107.6	112.9	114.5	114.5	117.0	119.1	117.4
184	Target		95.0	99.1	107.7	108.7	113.3	117.8	118.4	122.0	125.3	124.9
	Actual	F	94.9	100.2	107.4	107.8	112.7	117.4	117.0	118.2	120.9	126.6
	Actual	R	93.8	101.8	107.8	108.2	113.3	116.0	117.4	121.3	126.0	126.0
185	Target		95.0	98.1	104.8	105.2	109.2	113.8	114.0	117.5	121.5	121.6
	Actual	F1	93.9	98.0	104.3	104.9	108.4	113.9	113.9	116.6	121.7	122.5
	Actual	F2	94.7	97.9	105.7	104.7	108.4	113.3	114.5	117.4	121.9	121.9
	Actual	R	94.3	97.7	105.1	104.9	108.6	113.7	114.5	116.8	121.5	122.5
186	Target		95.0	98.9	107.2	107.7	111.8	115.8	116.4	119.3	122.5	122.9
	Actual	F	96.5	100.6	106.8	107.2	111.3	114.6	115.0	117.8	120.5	121.5
	Actual	R	95.3	99.0	106.6	107.4	111.1	115.2	115.6	118.8	121.7	123.0
187	Target		95.0	97.4	105.3	105.6	110.3	113.1	113.3	116.7	119.9	120.0
	Actual	F	95.5	99.0	104.5	106.1	110.9	113.0	114.8	117.2	119.7	120.5
	Actual	R	95.1	98.4	103.1	104.1	109.8	113.7	114.3	116.6	119.7	120.9

188	Target		95.0	99.5	110.7	112.6	116.5	120.0	120.4	122.9	126.6	127.1
	Actual	F	96.1	100.0	111.1	111.9	116.4	120.9	120.1	122.7	127.1	126.6
	Actual	R	95.9	100.4	110.7	110.7	116.2	119.7	119.7	123.4	127.7	127.7
	Actual	F	95.3	99.4	109.8	111.3	117.4	120.1	119.9	121.3	126.0	127.0
	Actual	R	95.7	99.4	110.2	111.9	118.0	120.5	120.7	121.7	126.4	126.8
189	Target		95.0	98.5	104.9	105.0	108.3	111.4	111.5	114.5	118.2	118.2
	Actual	F	95.9	98.6	105.1	105.7	109.2	111.7	117.7	113.7	118.9	118.9
	Actual	R	95.9	99.4	105.7	105.7	109.0	111.9	111.1	115.0	117.6	117.6
190	Target		95.0	97.5	103.8	104.7	109.3	113.7	114.6	117.6	121.4	121.6
	Actual	F	94.1	96.7	102.0	103.9	108.4	113.1	113.7	116.0	119.9	120.3
	Actual	R	94.5	97.5	104.1	104.9	109.6	113.7	113.9	116.8	120.7	120.9
191	Target		95.0	100.3	109.4	110.4	114.6	118.4	119.4	120.6	123.5	123.5
	Actual	F	93.9	97.5	107.4	107.8	113.1	116.8	118.0	120.7	122.9	122.5
	Actual	R	93.6	98.8	108.8	108.8	114.1	118.0	118.8	122.1	125.8	125.6
192	Target		95.0	97.6	104.2	104.8	108.8	112.7	112.4	115.2	119.0	119.2
	Actual	F	93.6	96.1	104.3	105.9	110.4	113.1	113.3	115.2	118.8	119.9
	Actual	R1	94.1	99.0	105.1	105.7	109.4	112.1	112.1	114.6	119.9	120.3
	Actual	R2	94.3	97.3	105.7	106.4	110.7	113.1	114.1	115.8	118.9	119.1
193	Target		95.0	99.9	110.7	111.0	114.8	118.5	119.2	123.1	126.7	126.7
	Actual	F	94.1	99.2	110.2	111.7	116.4	120.1	120.9	124.0	125.8	126.2
	Actual	R	94.1	99.0	109.6	110.2	115.2	119.9	120.7	122.1	126.2	127.0
194	Target		95.0	99.6	109.1	109.3	113.1	117.9	118.4	121.5	124.8	124.8
	Actual	F										
	Actual	R	95.1	98.8	109.0	110.0	115.6	117.6	118.2	120.7	127.3	127.7

Figure A-1
FTP Evaporative Emission Test Procedure