Running Loss Testing with Implanted Leaks

Final Report

United States Environmental Protection Agency

Running Loss Testing with Implanted Leaks

Final Report

Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

Prepared for EPA by
SGS-ETC, Eastern Research Group, Inc.
EPA Contract No. EP-C-12-017
Work Assignment No. 1-08

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.

United States Environmental Protection Agency

EPA-420-R-14-009
March 2014

Running Loss Testing with Implanted Leaks

Final Report

EPA contract #: EP-C-12-017
Work Assignment 1-08

Prepared for:
U.S. Environmental Protection Agency

Prepared by:
SGS-ETC
Eastern Research Group

February 18, 2014

ERG Project No.: 0308.01.008.001

Running Loss Testing with Implanted Leaks

Final Report

EPA Contract No. EP-C-12-017
Work Assignment 1-08

Prepared for:

Constance Hart, Work Assignment Manager
Kent Helmer, Alternate Work Assignment Manager, Project Officer
U.S. Environmental Protection Agency
2000 Traverwood Dr.
Ann Arbor, MI 48105

Prepared by:

Michael Sabisch
Sandeep Kishan
Eastern Research Group, Inc.
3508 Far West Blvd., Suite 210
Austin, TX 78731

Jared Stewart
Gerard Glinsky
SGS Environmental Testing Corporation
2022 Helena Street
Aurora, CO 80011

February 18, 2014

Table of Contents

1.0 Objectives and Background 1
2.0 Study Equipment and Preparation 1
  2.1 Test Vehicles 1
  2.2 Laboratory and Test Equipment Overview 2
  2.3 Fuel Procurement and Preparation 3
  2.4 Vehicle Preparation 3
  2.5 Induced Leak Preparation 5
3.0 Test Program 5
  3.1 Testing Overview 5
  3.2 Data Collection Process 12
  3.3 Data Validation and Analysis 14
  3.4 Results 15
  3.5 Observations and Conclusions 27
4.0 References 29
5.0 Index of Appendices 30

Appendix A Fuel Analysis Results A-1
Appendix B Test-by-Test Results B-1
Appendix C Descriptions of Study Data C-1
Appendix D Issues Encountered and Solutions D-1
Appendix E Induced Leak Configurations E-1

List of Figures

Figure 1. FTP-75 Cycle 8
Figure 2. Hydrocarbon Sampling System 9
Figure 3. Urban Dynamometer Driving Schedule 10
Figure 4. New York City Cycle 11
Figure 5. Running Loss Tank Temperature Profiles 15
Figure 6. Running Loss Tank Temperature Profiles as a Percent of Temperature Gain 16
Figure 7. Running Loss Results versus Final Tank Temperature (No Leak) 16
Figure 8. Running Loss Results versus Final Tank Temperature (0.040” Tank Leak) 17
Figure 9. Running Loss Results versus Final Tank Temperature (0.040” Canister Leak) 17
Figure 10. Running Loss Results versus Final Tank Temperature (0.020” Tank Leak) 18
Figure 11. Running Loss Results versus Final Tank Temperature (0.020” Canister Leak) 18
Figure 12. Running Loss Results (10.0 psi RVP Fuel) 20
Figure 13. Running Loss Results (7.7 psi RVP Fuel) 21
Figure 14. Average Emission Rates for Running Loss Testing 21
Figure 15. Hot Soak Results (10.0 psi RVP Fuel) 23
Figure 16. Hot Soak Results (7.7 psi RVP Fuel) 23
Figure 17. Average Emission Rates for Hot Soak Testing 24
Figure 18. Unpressurized Static Test Results 25
Figure 19. Pressurized Static Test Results 26

List of Tables

Table 1. Test Vehicle Summary....2
Table 2. Test Vehicle Details....2
Table 3. Running Loss Testing Sequence....13
Table 4. Test Types by Sequence Test Number....13
Table 5. Total Running Loss Emissions (grams)....19
Table 6. Running Loss Emission Rates (grams/hour)....20
Table 7. Hot Soak Results....22
Table 8. Unpressurized Static Test Results....25
Table 9. Pressurized Static Test Results....26

Glossary of Terms and Acronyms

APTL	Ford's Allen Park Test Laboratory
CDPHE	Colorado Department of Public Health and the Environment
CFR	Code of Federal Regulations
CFV-CVS	Critical Flow Venturi—Constant Volume Sampler
CRADA	Cooperative Research and Development Agreement
CRC	Coordinating Research Council
ECU	Engine Control Unit
EPA	US Environmental Protection Agency
ERG	Eastern Research Group
FID	Flame Ionization Detector
FTP-72	Urban Dynamometer Driving Schedule of the Federal Test Procedure
FTP-75	City driving schedule of the Federal Test Procedure
FTTP	Fuel Tank Temperature Profile
HC	Hydrocarbon
LA-4	Urban Dynamometer Driving Schedule
LA-92	LA92 "Unified" Dynamometer Driving Schedule
MOVES	Motor Vehicle Emission Simulator
MWV	MeadWestvaco
NREL	National Renewable Energy Laboratory
OBDII	Second-Generation On-Board Diagnostics
OEM	Original Equipment Manufacturer
PZEV	Partial Zero-Emissions Vehicle
QAPP	Quality Assurance Project Plan
RVP	Reid Vapor Pressure
SGS-ETC	SGS- Environmental Testing Corporation
SHED	Sealed Housings for Evaporative Determination
UDDS	Urban Dynamometer Driving Schedule
VECI	Vehicle Emissions Control Information
VIN	Vehicle Identification Number
WC	Water Column

Executive Summary

This study, performed by Eastern Research Group (ERG) and subcontractor SGS-Environmental Testing Corporation (SGS-ETC), under contract to the US Environmental Protection Agency (EPA), was designed and conducted by EPA to characterize running loss emission rates on enhanced evaporative emissions control and partial zero-emissions vehicle (PZEV) technology vehicles. This work builds on prior evaporative emissions test programs performed to determine the prevalence and emission rates of diurnal and hot soak emissions in US vehicles[1].

Two leak sizes and locations were individually implanted for each vehicle; one in the fuel tank and one at the vapor canister. Each leak location was evaluated individually with two precision implanted orifice sizes. A no-leak condition was evaluated as a control. Additionally, two fuels were used to determine the effect of Reid Vapor Pressure (RVP) on each leak rate. Consequently, each vehicle was evaluated individually at five different implanted leak conditions and two different fuel RVPs.

The required laboratory testing for this program was supervised by subcontractor SGS-ETC and took place at Ford's Allen Park Test Laboratory (APTL) utilizing Ford technical staff and analytical assets. All test procedures followed the Code of Federal Regulation (CFR) procedures for the testing of light-duty passenger vehicles and light-duty trucks. Five vehicles participated in this study; all were supplied by EPA. All vehicles were modified to accommodate temperature sensors, fuel pressure measurement ports, fuel drains and fixtures for implanted leaks. Tests performed on each vehicle in each condition consisted of a combined procedure including a complete running loss procedure, hot soak, and unpressurized and pressurized static tests. Pressures, temperatures, and continuous on-board diagnostic (OBDII) purge data were recorded, when available. A total of 50 combined procedures were performed in this study.

Results from the study showed the following:

- Fuel RVP was shown to have an effect on running loss emissions from vehicles with induced leaks (higher RVP producing higher evaporative emission rates).
- Increases in the tank temperature profile were observed to exponentially increase running loss emissions for vehicles with induced leaks.
- Vehicles without induced leaks demonstrated comparable running loss emissions for all tank temperature profiles and both fuels, high RVP and low RVP.

- Leak size was a factor in the running loss and hot soak evaporative emission rates on all vehicles. Larger leak sizes were shown to produce higher levels of evaporative emissions.

- In general, leaks induced in the fuel tank vapor space typically produced higher running loss emissions than leaks of a similar size induced at the evaporative canister.

- Leak size produced a more significant effect than leak location for running loss and hot soak tests.

- The purge valve controls purge behavior, and it also produces changes in fuel system vapor vacuum. This relationship results in a strong correlation between commanded evaporative purge and measured fuel vapor vacuum.

- For vehicles with induced leaks, continuous hydrocarbon measurements during the running loss test demonstrated an increase in the emission rates when fuel system vapor vacuum was reduced to near zero (atmospheric) levels. This behavior was demonstrated when commanded evaporative purge was reduced, and also when purge was overwhelmed from vapor generation due to high fuel temperatures and high RVP fuels.

1.0 Objectives and Background

Recent studies of vehicles with high evaporative emissions in Denver, Colorado performed as part of a Cooperative Research and Development Agreement (CRADA) between the EPA and the Colorado Department of Public Health and the Environment (CDPHE) over three summers (2008-2010) provided information on the prevalence of evaporative emissions leaks and the emission rates of those leaks in the real world fleet[2]. These studies focused on hot soak and diurnal emissions. In addition, the E-77[1] test program recently performed by the Coordinating Research Council (CRC), the EPA and the Department of Energy's National Renewable Energy Laboratory (NREL) collected permeation emission rates of aging enhanced evaporative emission control and PZEV technology vehicles at various temperatures using different fuels during several evaporative test procedures, including the static permeation test, diurnal tests and the dynamic permeation test. Evaporative emission rates were also measured during these tests with 0.020" diameter leaks implanted at different locations on the test vehicles. A 0.020" leak diameter was selected because this is the smallest size detectable by vehicle OBDII systems.

This current running loss study builds on these prior evaporative emissions studies by simulating real-world evaporative emission leak rates during transient operation and static conditions. Laboratory testing was conducted to gather running loss emissions data as a function of induced leak size (0.020" and 0.040" diameter), leak location (fuel tank or canister) and fuel RVP (7 and 10 PSI) on enhanced evaporative emissions control and PZEV vehicles. The tank and canister locations were selected because these were the same leak locations that had been found to be most common in the Denver field studies and were also used previously in the E-77 test programs. The hot soak and static tests were conducted to tie the information back to the previous studies.

2.0 Study Equipment and Preparation

2.1 Test Vehicles

The EPA provided 5 vehicles to be tested in this study. The vehicles were chosen from available vehicles that had previously been used in prior EPA test programs. The five vehicles provided for the test program are listed in Table 1, and details regarding the selected vehicles and test parameters are listed in Table 2.

Table 1. Test Vehicle Summary

Vehicle Make and Model	Model Year	Approx. Odo	Emissions Standard	Canister Cap[1] (g)	Tank Vol (gal)	Canister/Tank Ratio[2]
Dodge Caravan	2007	117k	Tier 2 / Bin 5	177	20.00	8.85
Toyota Corolla	2009	121k	Tier 2 / Bin 5	115	13.25	8.68
Ford Focus PZEV	2010	29k	SULEV II PZEV	110	13.00	8.46
Honda Accord	2007	124k	Tier 2 / Bin 5	140	17.00	8.24
Chevrolet Silverado	2006	112k	Tier 2 / Bin 8	177	26.00	6.81

1 Canister Cap = canister working capacity, in grams
2 Canister working capacity (g) / Tank volume (gal)

Table 2. Test Vehicle Details

Vehicle	Model Year	Inertia Weight	Tank Capacity	Road Load A	Road Load B	Road Load C	Engine Family	Evap Family
Caravan	2007	4750	20.00	15.32	0.0948	0.02662	7CRXT03.8NEO	7CRXR0177GHA
Corolla	2009	3250	13.25	11.93	0.0068	0.02276	9TYXV01.8BEA	9TYXR0115P12
Focus	2010	3000	13.00	4.01	0.5575	0.01269	AFMXV02.0VZX	AFMXR0110GCX
Accord	2007	3500	17.00	9.76	0.2918	0.01602	7HNXV02.4KKC	7HNXR0140BBA
Silverado	2006	5500	26.00	1.44	1.2678	0.02258	6GMXT05.3379	6GMXR0176820

2.2 Laboratory and Test Equipment Overview

All testing was performed at Ford's APTL, which is equipped with two CFR 40 Part 86.1234-96 compliant point-source running loss test cells and two specially-equipped variable temperature (VT) sealed housings for evaporative determination (SHEDs) that were employed for hot soak and static pressurization tests. Ford APTL provides emissions certification testing for new vehicles manufactured to meet US EPA emissions standards.

Ford APTL provided all quality assurance and traceability requirements defined in CFR Title 40 Part 86, Subpart B and other test procedures performed during this study. The Ford APTL testing and control software automatically logged all calibrations. An SGS-ETC certified ISO 9001 lead quality auditor verified Ford's compliance with CFR regulations.

Equipment used in the study consisted of laboratory-grade electronic thermometers with thermocouples for measuring temperatures, pressure measurement devices and analytical systems containing sample conditioning, process gas analyzers, and a data acquisition and control system. The maintenance, calibration and verification of the measurement equipment used in this study conformed to requirements defined in the work plan and quality assurance project plan (QAPP) developed for this project.

All measurement devices used in this study met the requirements of 40 CFR 86 and were calibrated and verified for accuracy, precision and repeatability. Any changes to measurement equipment were performed in accordance with 40 CFR regulations and the standard operating procedures followed at Ford's APTL.

2.3 Fuel Procurement and Preparation

Two fuels were specified for use in this study, one with a target RVP of 7 PSI (target range of 6.5 to 7.5 psi) and one with a target RVP of 10 PSI (target range of 9.5 to 10.5 psi). SGS-ETC acquired these two seasonal blends with 10% ethanol (E10 fuel) from a local source for use in this study. EPA testing determined the low RVP fuel had a RVP of 7.67 psi. Although this was slightly higher than the target range, upon consultation with EPA it was deemed acceptable. SGS-ETC performed preliminary testing of the high RVP fuel using a Grabner Minivap VPS, model 210-000-00 RVP tester and determined the RVP of the "high RVP" fuel was 11.49 psi, significantly higher than the vapor pressure range specified for this study. To correct for this, the fuel was aged using an in-tank bubbler at the supplier's facility. SGS monitored the fuel's RVP throughout the aging process until a final RVP of approximately 10.3 psi was achieved (measured using the Grabner RVP tester). At that time, the aging was halted and the fuel was barreled and shipped to the Ford APTL. Subsequent testing by EPA determined the high RVP fuel had a RVP of 10.02 psi, well within the target range of the high RVP fuel. Both fuel blends contained between 9.0 and 11.0% ethanol. Once at APTL, the fuel was stored in sealed drums in the Ford APTL fuel room, which is climate controlled to minimize any fuel specification changes during the test program. Complete results of fuel analysis performed by EPA are provided in Appendix A.

2.4 Vehicle Preparation

The following steps were performed for each test vehicle in preparation for the running loss test program.

1) Log books were developed for recording and noting vehicle specifications and process chronology.

2) Test vehicles were checked to verify they were capable of safe operation on a dynamometer.

3) Test vehicles were examined for signs of potentially extraneous evaporative emissions, such as indications of collision, recent painting, tampering, new tires, interior vinyl treatments, and windshield replacement.

4) Vehicle information such as VIN, year, make, model, engine and evaporative families was documented, and photos were obtained of the vehicle, VIN plate and the vehicle emissions control information (VECI) label.

5) All OBDII diagnostic trouble codes and readiness monitor status were scanned.

6) Each vehicle's evaporative emissions control system was subjected to a static pressure test using a leak detection unit supplied by EPA. This instrument was a Snap-on EELD500 Smart Smoke Evap Elite pressure tester capable of detecting leaks with as small as a 0.010" diameter orifice.

7) A fuel drain was installed at the lowest point in each vehicle's fuel tank to facilitate draining fuels.

8) Two type J fuel tank thermocouples were installed in each fuel tank through the fuel sending unit, one thermocouple was extended into the liquid and one thermocouple was kept in the vapor space at a 40% fill. The vehicles were altered by removing material that made the top of the fuel sending unit easily accessible.

9) Tank pressure monitoring and an induced pressurization port were installed in the fuel sending unit.

10) As described in the following subsection, ports were fitted on the fuel tank, in the fuel sending unit, and the vapor collection canister inlet to accommodate the induced leak orifices. Lines were added to allow connection of the leaks, and the canister vent to the hydrocarbon measurement system.

11) The locations of the modifications to the vehicle's OEM configuration were photographed.

12) Pressure tests were performed on each vehicles fuel and evaporative emissions control system using the EPA-provided Snap-On leak detection unit.

13) Fluids and filters were checked and adjusted as necessary. To minimize issues with crankcase oil impacting emissions, oil was not added unless necessary, since new oil may impact evaporative testing results.

14) The appropriate vehicle road load coefficients for dynamometer testing were derived

15) The wiper fluid reservoir and system was drained and flushed to eliminate potential release of wiper fluid hydrocarbons into the SHED during static tests.

2.5 Induced Leak Preparation

Precision orifices were used for metering induced leaks. For each installation, the precision orifice was integrated into a “swage–type” compression fitting and was designed to be easily interchangeable and or blocked (sealed) when required. The vehicles were modified, as described in the following section, to accept the induced leak orifice fittings. Leak sizes were verified using the Snap-on EELD500 Smart Smoke Evap Elite pressure tester supplied by EPA before and after each test sequence.

3.0 Test Program

3.1 Testing Overview

Fuel samples were collected for RVP and ethanol content determinations. RVP samples were collected using a dip container. Hydrocarbon samples emitted from the vehicle during the running loss, hot soak SHED or static pressurization test sequence were collected and sampled per CFR Title 40 Part 86, Subpart B. Midway through the study, the program was expanded to include continuous measurement of hydrocarbon emissions during the running loss testing. Other data collected during this study consisted of vehicle and test setup information, weight, temperature and pressure measurements, and associated date and time for each of the measurements.

The test sequence was conducted for a no leak setup and for leaks located at the canister and at the fuel tank for two different leak sizes. The following 17 steps detail the test sequence performed.

No special procedures were performed to flush the system between switching fuels. The standard procedure of drain and fill, preparatory cycle, drain and fill, and canister load was deemed suitable for clearing the system of the previous test fuel.

There were initially plans to measure purge flow using a mass flow meter. However, due to concerns that this could interfere with proper purge behavior, purge mass flow was not measured during the study.

Step 1) Vehicle Prep, Modify / Restore & Documentation: SGS ETC prepared the vehicle for the test process and documented the condition and evaporative emission system component locations on individual test vehicles, photograph systems, scanned the OBDII system for diagnostic trouble codes and readiness status, leak checked the system with the Snap-On leak tester, created log books and established a data repository. The vehicle was prepared to accommodate induced leaks at the fuel tank and the canister. The vehicle received further modifications to facilitate canister loading, fuel draining and refueling, and HC emission sampling from the induced leak and canister vent. At the conclusion of this study, the vehicles were returned to EPA with modifications remaining in place and the leaks were capped.

Step 2) Road Load Dynamometer Determination: The vehicle load dynamometer characteristics were determined using the SAE J2264 "Chassis Dynamometer Simulation of Road Load Using Coastdown Techniques" procedure for each vehicle. This enabled proper loading of the vehicle on the chassis dynamometer system. Proper loading of the vehicle ensures that purge strategies, designed by the OEM, are used during vehicle operation on the chassis dynamometer.

Step 3) Prepare Canister for Test Process: Canister purging and loading was performed per 40 CFR 86.132-96 "Vehicle Preconditioning". Ford APTL controlled the humidity to 50 grains per pound of dry air in the canister purging and loading area and recorded the humidity on a daily basis. The nominal flow rate during canister purge was controlled to 0.8 cubic feet per minute (cfm). At the recommendation of MeadWestvaco (MWV), a leading supplier of original equipment manufacturer (OEM) activated charcoal product for capture of hydrocarbons in evaporative emissions canisters, purge was limited to 200 bed volumes, as opposed to the CFR-specified 300 bed volumes, to avoid disturbing the canister heel. The canister was loaded with a gas composition of 50% butane and 50% nitrogen to 1.5 times its working capacity at 15 grams per hour. The stabilization criteria contained in 40 CFR 86.132-96 was not applicable for this testing as these vehicles have an existing history with an unknown number of canister loads and subsequent purges.

Step 4) Insert Leak: Leaks were inserted after the baseline sequence on each fuel was completed and test data was reviewed for validity. The leaks were installed into fittings at the fuel tank and canister. Leaks were relatively easy to change and cap as required for each stage of the program. Specialty precision orifices were acquired for the study, and leak size was verified using the Snap-on leak detection device.

Step 5) Snap-On Leak Test 1: A pressure test was performed with the Snap-on leak detection device provided by EPA. This test was used to determine the baseline leak rate of the vehicle and estimate the cumulative diameter of all "leaks"; no vehicles exhibited leaks initially. The device was also used to measure and verify leak rates and diameters for installed leaks before testing.

Step 6) Drain and Refuel 1: To drain existing fuel and refuel the vehicle, an external pump was connected to the fuel tank drain quick connect located inside the vehicle, and the pump was run until vapors were observed in the clear Teflon tube coming from the tank. The pump system was turned off and adsorbent towels were placed under the quick connect. The pump system was disconnected at the quick connect and any liquid spills were contained on the adsorbent towel ensuring that no fuel spilled on the vehicle. The vehicle was then fueled to 40% of tank capacity with the fuel specified in the sequence and placed into soak.

Step 7) 6 to 24 Hour Soak: The vehicle was then placed in a temperature controlled room where the temperature was maintained at 74 °F +/– 2 °F for a time exceeding 6 hours but less than 24 hours.

Step 8) Preconditioning LA-4 cycle: The standard LA-4 drive cycle was used in this step to prepare the vehicle for subsequent procedures. Note: The LA-4 cycle is also called the U.S. FTP-72 (Federal Test Procedure) cycle or the Urban Dynamometer Driving Schedule (UDDS) *[CFR 40, 86, App.I]*

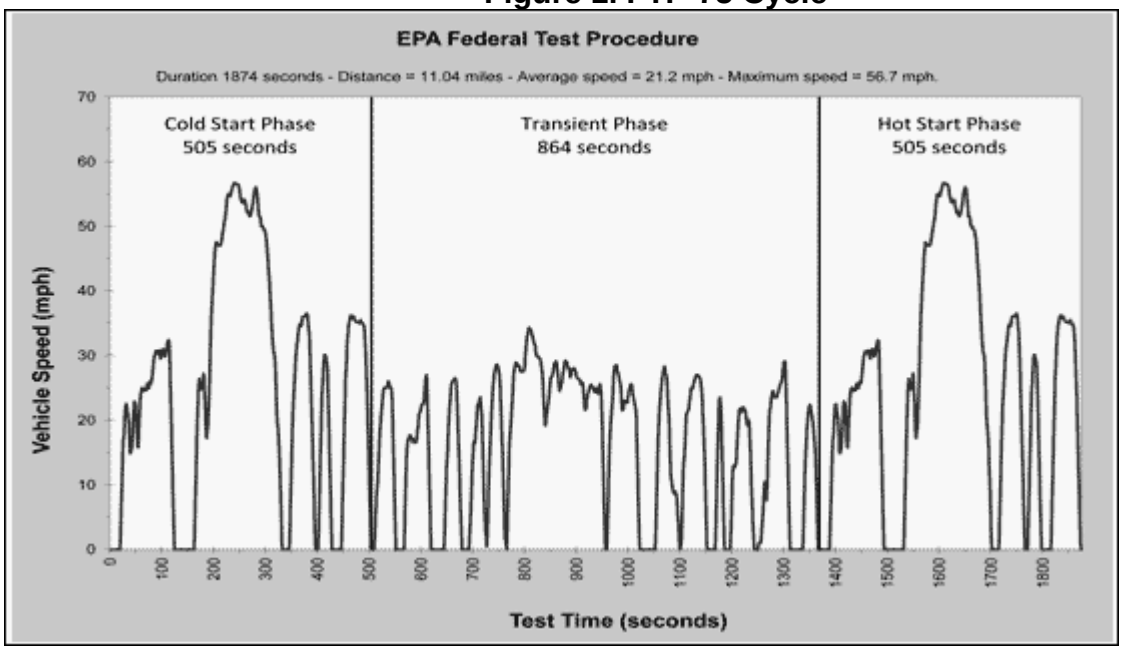
Step 9) Drain and Refuel 2: This procedure was identical to the "Drain and Refuel 1" procedure described in Step 6

Step 10) Canister Load with Butane: Within one hour of the fueling event, the evaporative emissions carbon canister on the vehicle was loaded with butane, at a rate of 40 grams per hour, until a 2 gram breakthrough occurred. This step was done in parallel to Step 11 below.

Step 11) 12 to 36 Hour Soak: The vehicle was placed in a temperature-controlled room where the temperature was maintained at 74 °F +/– 2 °F for a time exceeding 12 hours but less than 36 hours.

Step 12) FTP-75 three phase cycle: The vehicle was then operated on the chassis dynamometer using the FTP-75 cycle, the driving cycle that is part of the certification process and graphically shown in Figure 1.

Figure 1. FTP-75 Cycle



Step 13) Running Loss Test: A running loss test was then performed employing the following steps and procedures:

1) Temperature stabilization. Immediately after the hot transient exhaust emission test (FTP-75), the vehicle was soaked in a temperature controlled area at 95 °F for a maximum of 6 hours until the fuel temperature stabilized. The fuel was allowed to be heated or cooled to stabilize fuel temperatures, but the fuel heating rate was not allowed to exceed 5 °F in any 1-hour interval during the soak period.

2) Fuel temperatures were held at 95 ±3 °F for at least one hour before beginning the running loss test.

3) None of the vehicles had a fuel temperature profile with an initial temperature lower than 95 °F. However, provisions were made that if a vehicle's fuel temperature profile had an initial temperature lower than 95 °F, then, as described

in §86.129–94(d)(7)(v) “Fuel Temperature Profile”, the fuel in the test vehicle would be stabilized to within 3 °F of that temperature for at least one hour before beginning the running loss test.

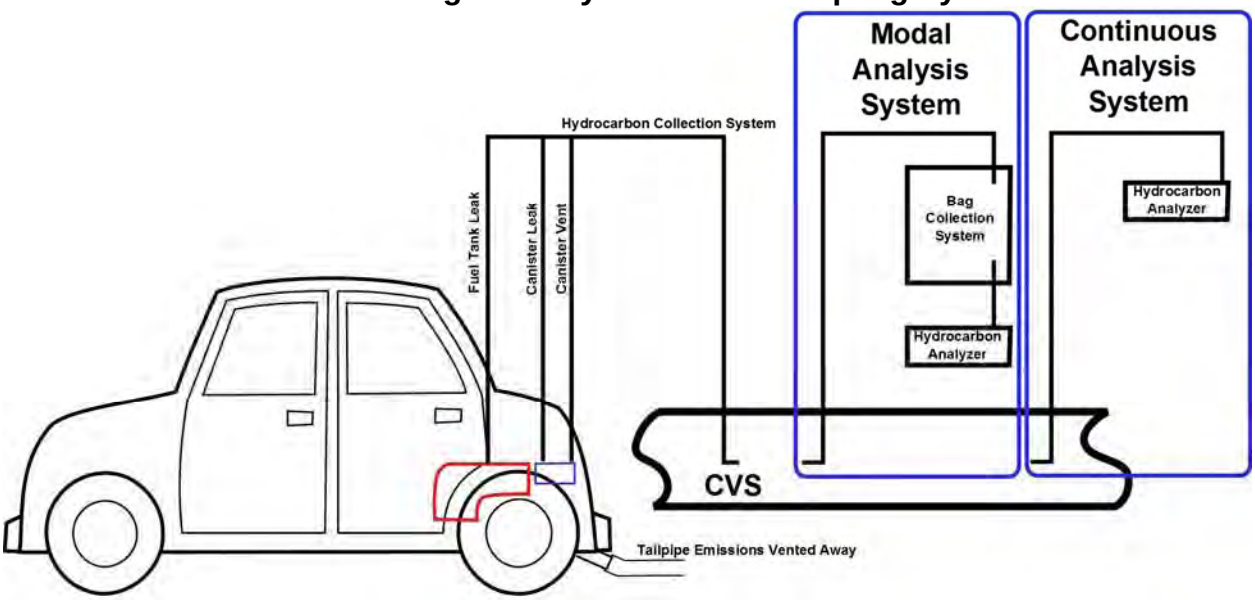
4) Running Loss Test. The running loss test was conducted using the point-source method described in §86.134–96(g)(2). For the running loss test, the vehicle was not tested in a SHED. Measurements were taken at point sources: canister vent, gas cap, and leak source, as shown in Figure 2.

5) The test vehicle, with the engine off, was moved onto the dynamometer. The vehicle engine compartment cover and any windows, doors, and luggage compartments were closed.

6) Fans were positioned as described in §86.135–90(b) “Dynamometer Procedure” and §86.107–96(d) “Sampling and Analytical Systems; Evaporative Emissions”.

7) The running loss vapor vent collection system was properly positioned at the fuel vapor vents and implanted leaks in the vehicle's fuel and evaporative emission systems. The sampling system configuration is shown in Figure 2.

Figure 2. Hydrocarbon Sampling System



8) The running loss vapor vent collection system was connected to a CFV-CVS bag collection system and also to a continuous FID analyzer.

9) The vehicle air conditioning system (if so equipped) was set to the "normal" air conditioning mode and adjusted to the minimum discharge air temperature and high fan speed. Vehicles equipped with automatic temperature controlled air conditioning systems were set to operate in "automatic" temperature and fan modes with the system set at 72 °F.

10) The temperature of the liquid fuel was monitored and recorded at least every 1 second with the temperature recording system specified in §86.107–96(e). The vapor temperature was monitored for reference only and was not used as a process variable for controlling tank temperature.

11) When the ambient temperature was 95±5 °F (35±3 °C) and the fuel tank temperature was 95±3 °F, the running loss test began.

12) The running loss test was conducted by operating the test vehicle through one Urban Dynamometer Driving Schedule (UDDS), a 2-minute idle, two New York City Cycles, another 2-minute idle, another UDDS, and then a final 2-minute idle (see §86.115). These are shown graphically in Figures 3 and 4. The transmission was operated according to the specifications of §86.128 during the driving cycles.

Figure 3. Urban Dynamometer Driving Schedule

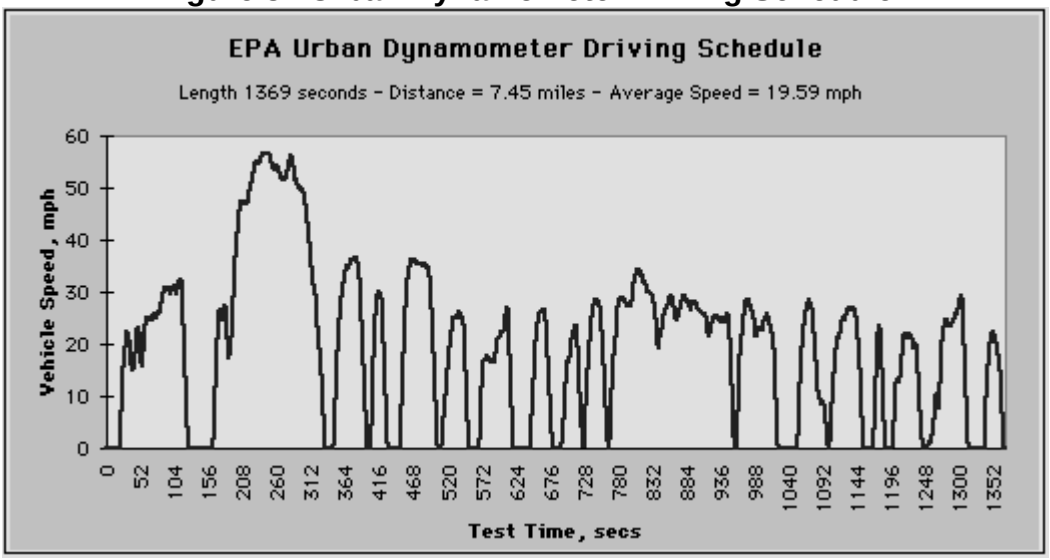
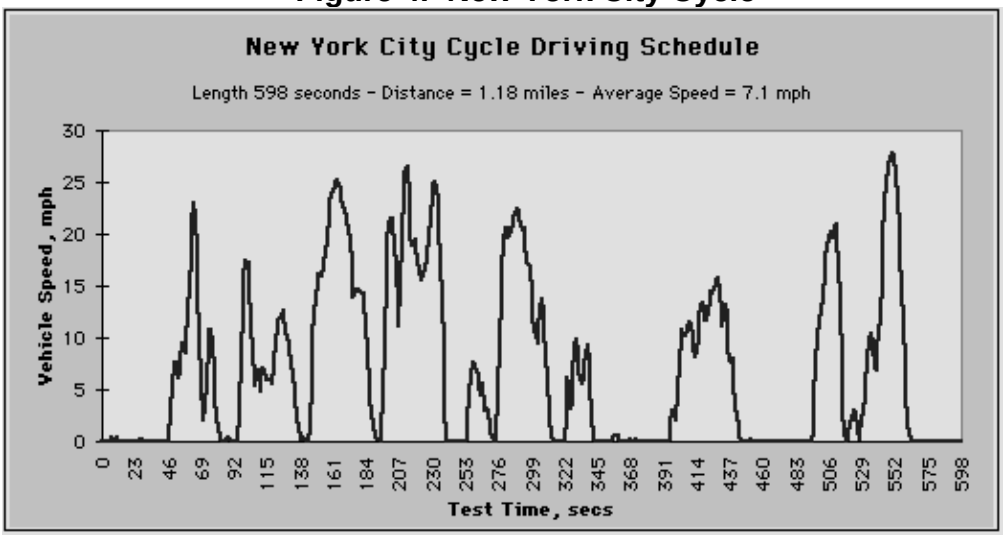


Figure 4. New York City Cycle



13) The ambient temperature was maintained at 95±5 °F (95±2 °F on average) during the running loss test.

14) Fuel temperatures were controlled according to the specifications of the temperature profile provided by the vehicle manufacturer.

15) The emissions collected in the sample bags were analyzed within 20 minutes of their respective sample collection phases, as described in §86.137–94(b)(15) "Dynamometer test run, gaseous and particulate emissions". The results of the analysis were used per §86.143 "Calculations: evaporative emissions" to calculate the mass of hydrocarbons emitted.

Step 14) Hot Soak Test: Following completion of the running loss test, the vehicle was administered a one-hour hot soak test in a SHED that was maintained and preheated to 95 °F in accordance with 40 CFR 86.138-96, "Hot soak test".

Step 15) Static Test Sequence: Immediately following the completion of the hot soak, the permeation and static pressure test sequence began and followed the steps listed below:

1) The SHED door was opened and the vehicle was removed from the SHED.

2) The fuel temperature was stabilized to 93 °F.

3) The vehicle was returned to the SHED.

4) The canister vent was plugged to allow pressure to build in the system.

5) The fuel tank pressurization system was connected.

6) The SHED door was closed and the temperature was maintained at 95 °F.

7) The enclosure temperature was stabilized to 95 °F; temperature stabilization was not allowed to exceed 10 minutes.

8) The SHED HC background was measured and the 15-minute permeation test was initiated. The SHED HC mass was read at the completion of the 15 minutes.

9) The fuel system was pressurized at 1" water column (WC) for 15 minutes for the tank pressurization leak rate determination. This immediately followed the permeation test. The final HC mass of the 15 minute permeation test was used as the initial mass for the pressurization leak rate determination. At the end of the 15 minute pressurization leak rate determination, the final HC mass was recorded. The 1" WC pressurization and 15 minute duration values were used based on preliminary testing and in order to avoid overwhelming the SHED analyzer.

Step 16) Snap-On Leak Test: A second leak rate pressure test was performed with the Snap-on pressure tester. If the measured leak rate had deviated from the initial leak test by +/- 10% then further examination would be necessary and further testing delayed. However, the leak rate was never found to deviate for tests that didn't have other problems (requiring retesting).

Step 17) OBDII Scan: The vehicle's OBDII system was scanned to assess vehicle condition. The test procedure continued, without intervention, as long as codes did not indicate a malfunction that would damage the vehicle or affect performance of the evaporative emission system (no such codes were detected).

3.2 Data Collection Process

Findings from the initial inspections of the vehicles and documentation of the modifications made to the vehicles were made available as soon as possible after a procedure was completed. This information was collected in electronic format and was usually available within one day of testing. A testing log for each vehicle was maintained and also provided electronically in Excel format.

The following file naming convention was utilized throughout the testing program:

[Sequence Number]_[Sequence Test]_[Date]_[Vehicle]_[Test Type]_[APTL Test Number]_[HC/OBD Data Set].[Extension]

The sequence number listed above designates the fuel and leak setup for a particular sequence of testing. The following table enumerates the sequence numbers and the setup used.

Table 3. Running Loss Testing Sequence

Sequence #	Fuel RVP (psi)	Leak Setup
1	10.0	No Leak
2	10.0	0.040" Tank Leak
3	10.0	0.040" Canister Leak
4	10.0	0.020" Tank Leak
5	10.0	0.020" Canister Leak
6	7.7	No Leak
7	7.7	0.040" Tank Leak
8	7.7	0.040" Canister Leak
9	7.7	0.020" Tank Leak
10	7.7	0.020" Canister Leak

The date stamp is compressed into a six-digit number, the first two digits represent the year, the following two digits represent the month, and the last two digits are the day.

Date Stamp:YYMMDD so 130115 becomes 1/15/2013

The following table documents the sequence test number and the abbreviated test type for each of the individual tests performed in a test sequence.

Table 4. Test Types by Sequence Test Number

Sequence Test #	Abbreviated Test Type	Associated Test
1	74	FTP-72 Preparatory Procedure
2	75	FTP-75 Preparatory Procedure
3	RL	Preheat and stabilization of fuel and running loss test
4	HS	Hot Soak test
5	ST	Static test (15 minute permeation test, and 15 minute pressurization test)

The following data has been collected from APTL and has been made available to EPA as a separate deliverable to this study:

- FTP 72 preparatory procedures report (pdf format)
- FTP 75 preparatory procedures report (pdf format)
- Running loss report (pdf format)
- Running loss data file (comma separated variable data file)
- Running loss continuous hydrocarbon measurement data file (collected during second half of program, comma separated variable data file)
- OBD2 live datastream datafile (comma separated variable data file available for some tests)
- Hot soak test data (hot soak results in an Excel spreadsheet)
- Static test data (complete static test results in an Excel spreadsheet)
- Static test data (text file which reports static test results at appropriate sampling intervals)
- Vehicle data (Excel spreadsheet with cumulative test data and results)

Additional information regarding each of these files, including field descriptions and data analysis steps used to obtain study results, are provided in Appendix C.

3.3 Data Validation and Analysis

A quality check was performed on each test in order to verify the following:

- Proper progression of preparatory activities
- Trace conformance during running loss test
- Fuel temperature during running loss test
- Start of hot soak test within allotted time after completion of running loss test

The following calculation was performed to convert the total running loss mass emissions to an hourly mass emission rate format suitable for input into EPA's MOVES model.

$$m\left(\frac{g}{hr}\right) = \frac{m(g)}{4308\ s} \cdot \frac{3600\ s}{1\ hr}$$

Additional analysis was performed to determine the mass rate of emissions when continuous hydrocarbon measurement was included in testing. Issues that were discovered during the test program or during the data validation and analysis stage were documented and addressed as described in Appendix D.

3.4 Results

Running Loss Results

The final tank temperature of the running loss test was a significant factor in the quantity of emissions coming from leaky evaporative systems. Increases in tank temperature were observed to result in elevated emissions for both high and low RVP fuels. The following Figure 5 demonstrates the differences in tank temperature for the 5 vehicles participating in this study. Each vehicle has a different tank temperature profile. This complicates the process of analyzing the data for the effects of tank temperature on emissions. The subsequent graph, Figure 6, normalizes the tank temperature profiles by calculating the percent of temperature gain over the running loss cycle. While the five vehicles do not perfectly agree, the temperature profiles follow a similar trend. Figures 7 – 11 plot the running loss emissions versus the final tank temperature for each vehicle. These graphs demonstrate that vehicles with induced leaks exhibit an exponential increase in running loss emissions as final tank temperature increases.

Figure 5. Running Loss Tank Temperature Profiles

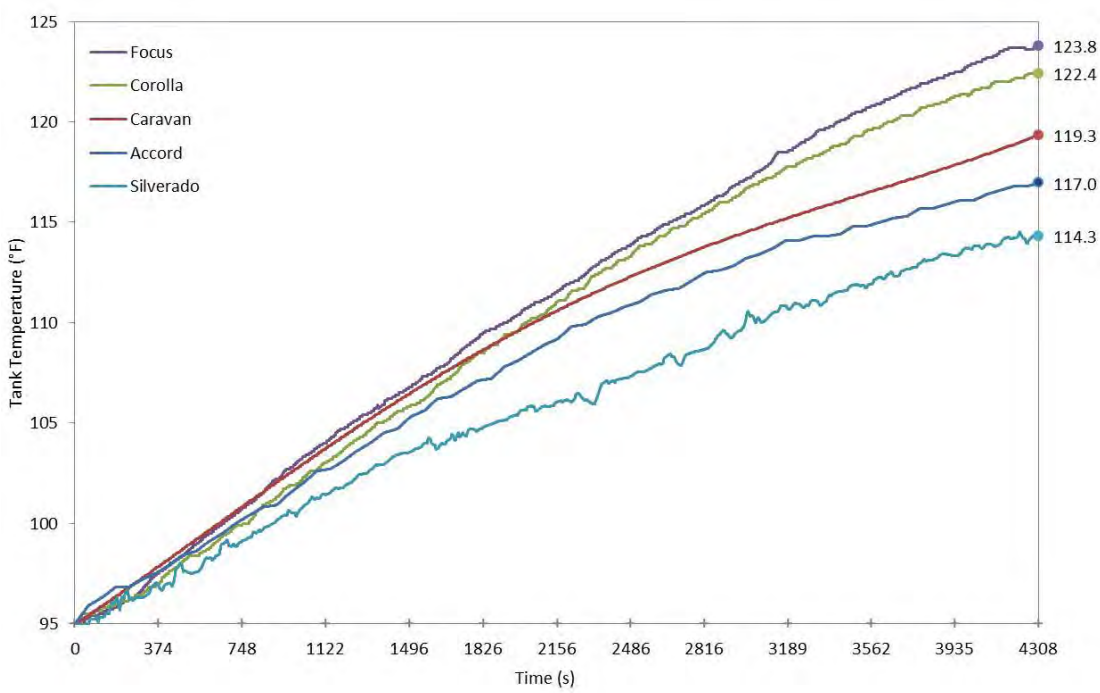


Figure 6. Running Loss Tank Temperature Profiles as a Percent of Temperature Gain

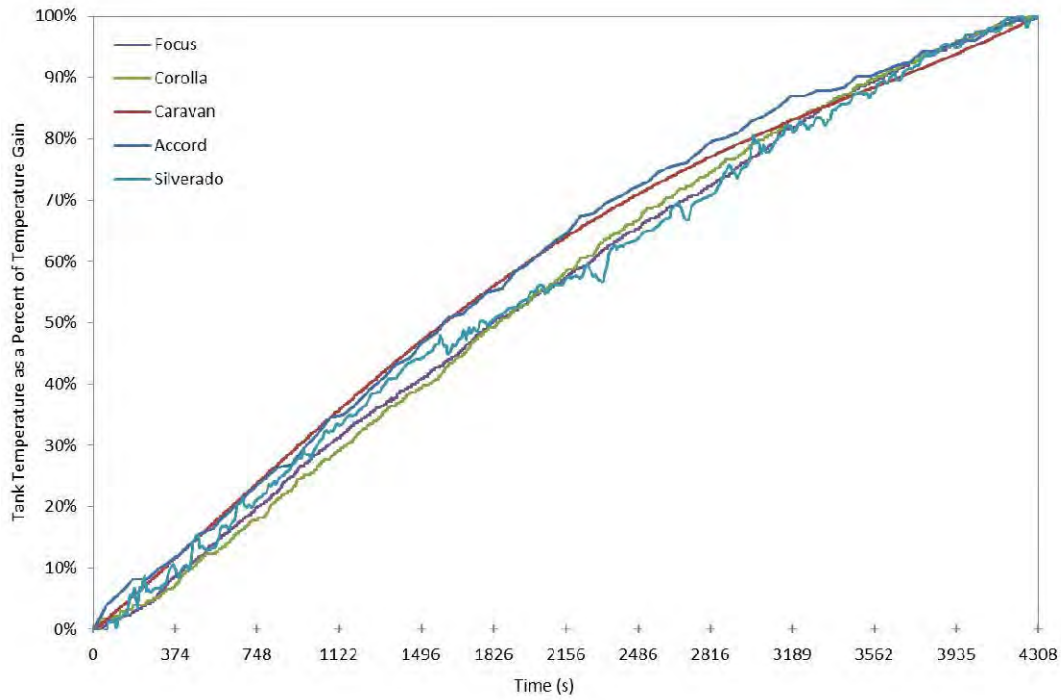


Figure 7. Running Loss Results versus Final Tank Temperature (No Leak)

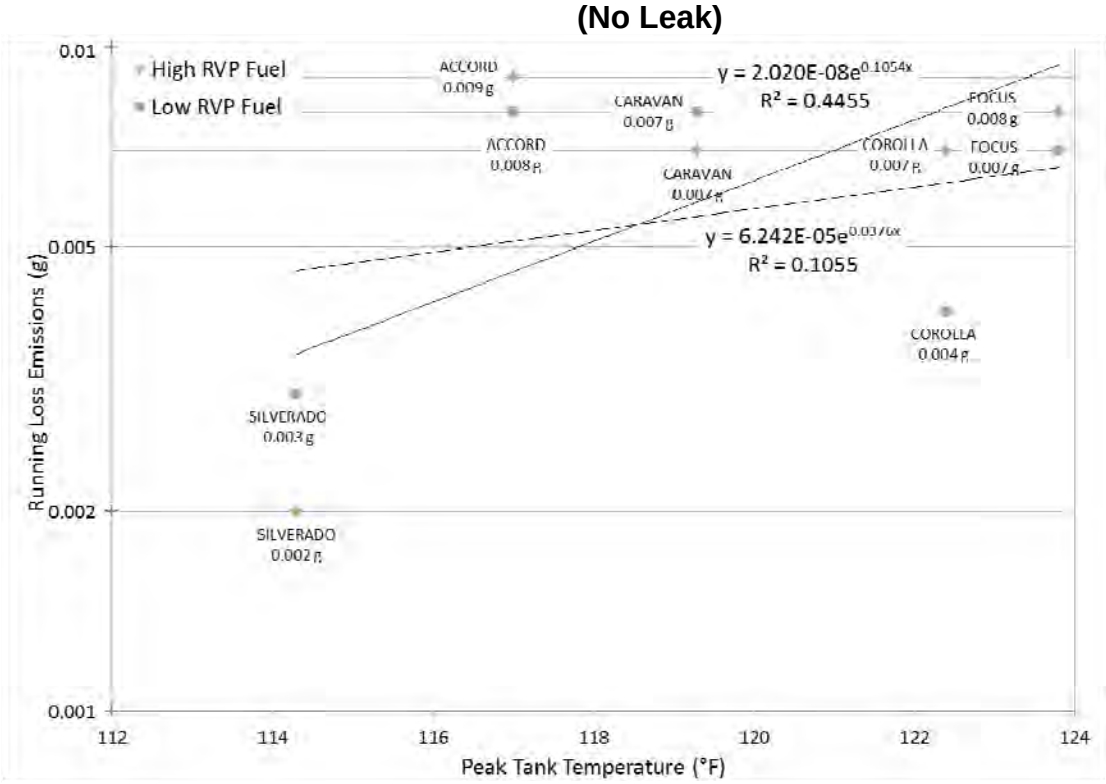


Figure 8. Running Loss Results versus Final Tank Temperature (0.040" Tank Leak)

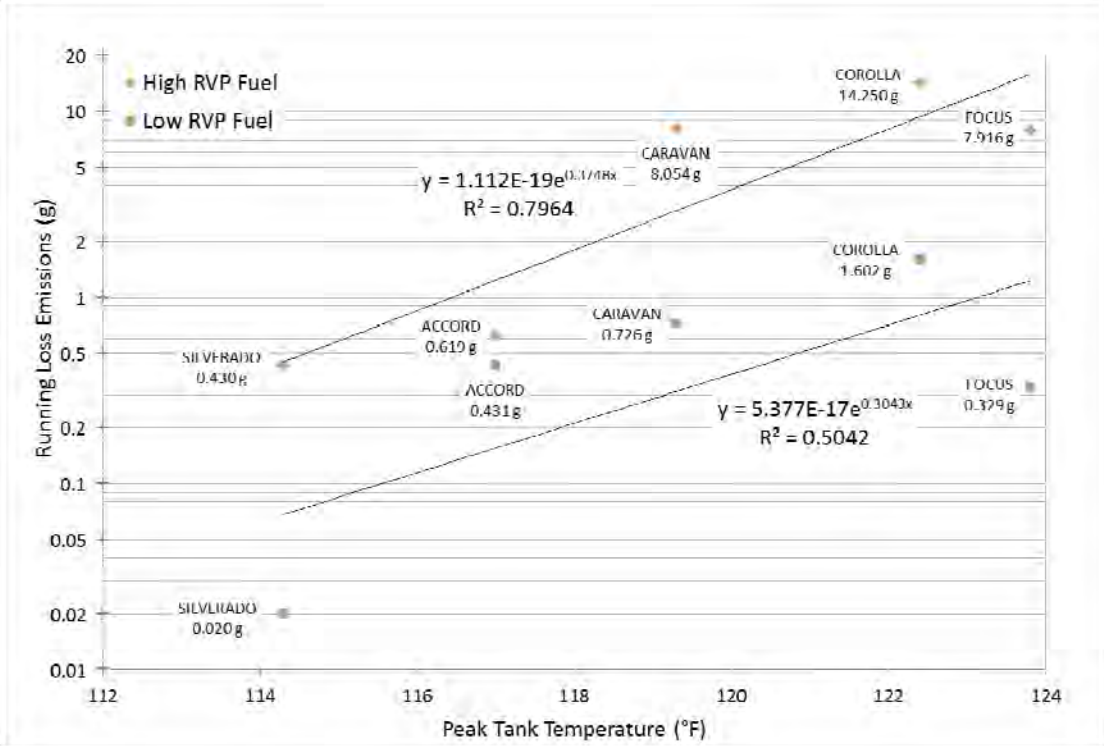


Figure 9. Running Loss Results versus Final Tank Temperature (0.040" Canister Leak)

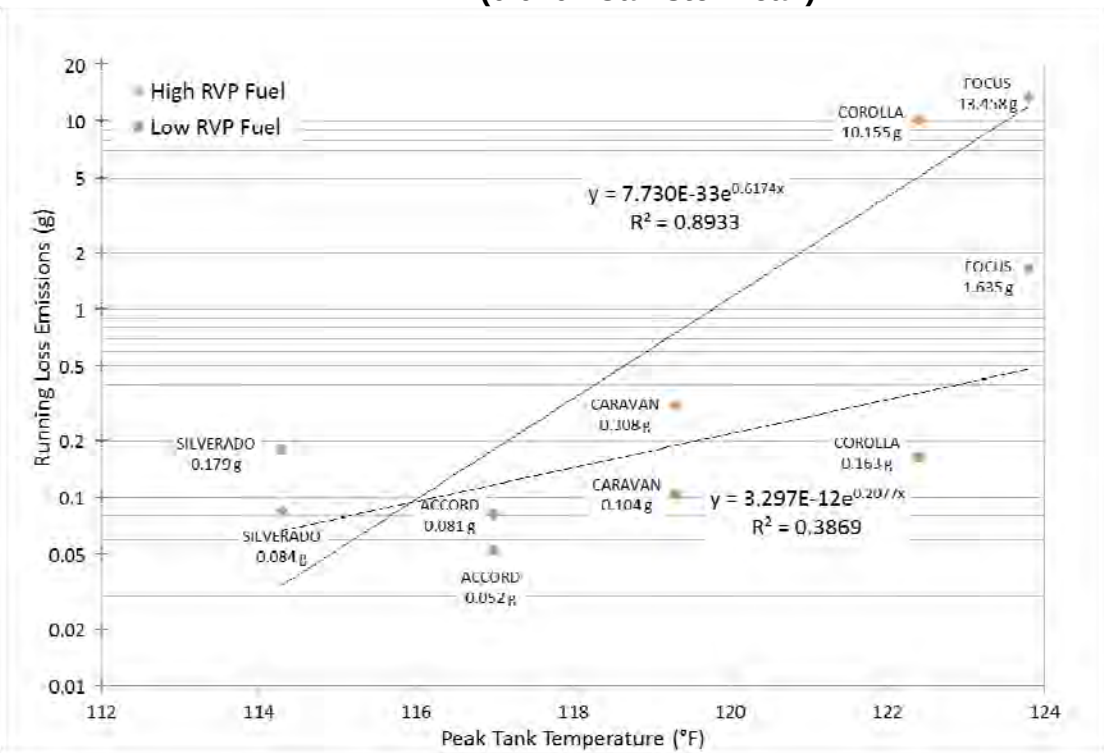


Figure 10. Running Loss Results versus Final Tank Temperature (0.020" Tank Leak)

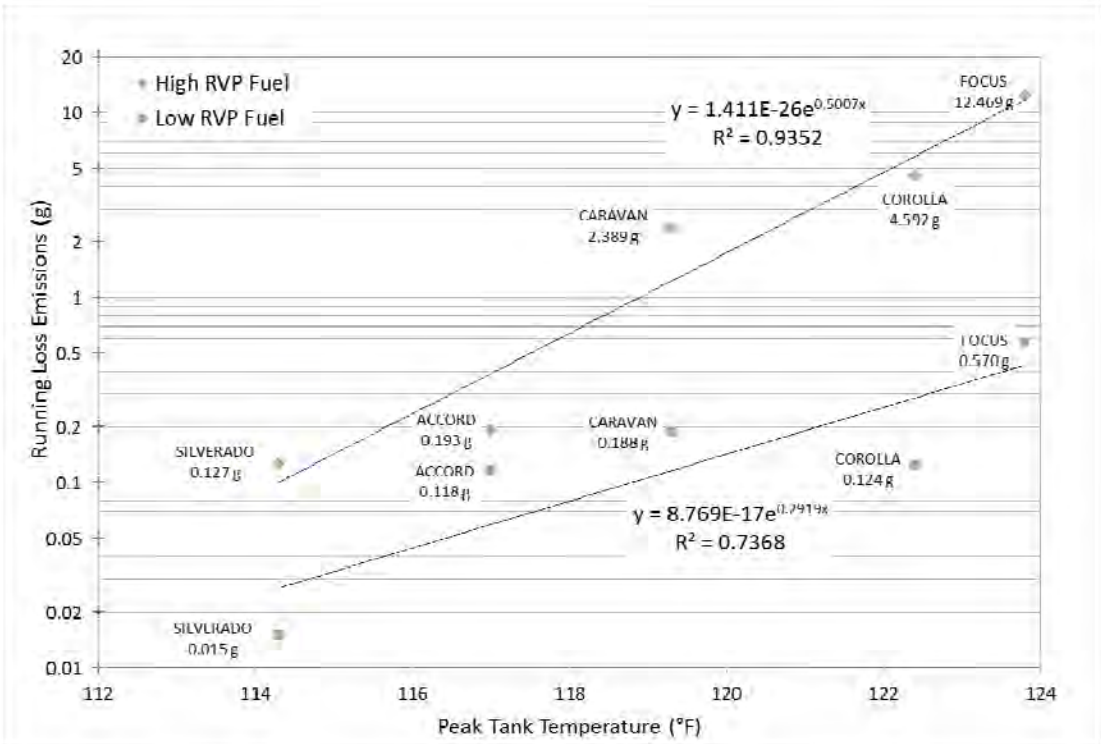
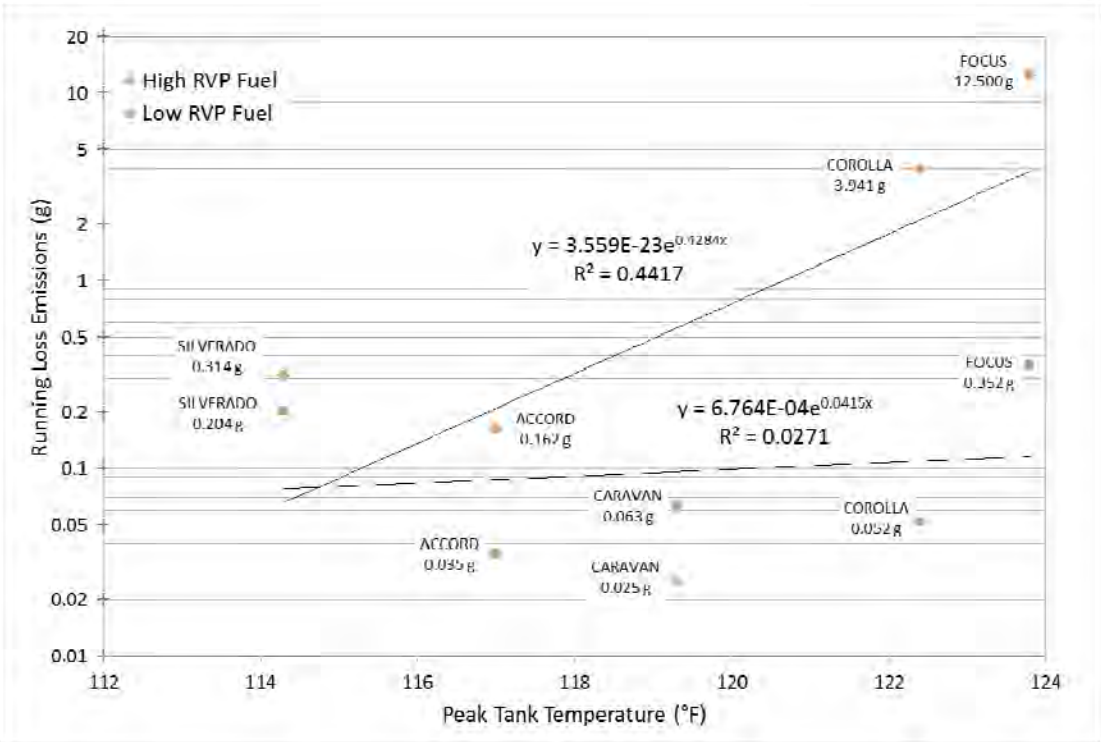


Figure 11. Running Loss Results versus Final Tank Temperature (0.020" Canister Leak)



The following tables and figures characterize the total emissions measured through each vehicle's series of running loss tests, which were composed of three phases; one Urban Dynamometer Driving Schedule (UDDS) followed by a 2-minute idle, two New York City Cycles followed by another 2-minute idle, and finally a final UDDS followed by a 2-minute idle (see §86.115). The total running loss emissions (in grams) for each test sequence of each of the five vehicles are listed in Table 5. These results are then provided as hourly emission rates in Table 6. The Table 6 hourly emission rates for each vehicle were calculated using the equation shown in Section 3.3. The "Average" emission rates listed at the bottom of Table 6 were calculated as the overall average emission rates for all 5 vehicles, i.e.,

$$Average\ Emission\ Rate\ \left(\frac{g}{hr}\right) = \frac{\sum_{Vehicle\ 1}^{Vehicle\ 5} Emission\ Rates\ (\frac{g}{hr})}{5}$$

Figures 12 and 13 show total gram emissions for each phase and test sequence, with the peak temperature of the tank temperature profile listed for each vehicle, and Figure 14 shows the overall average emission rates for all vehicles combined. Plots of continuous results from running loss testing are available in Appendix C.

Table 5. Total Running Loss Emissions (grams)

		No Leak	**0.040" Tank Leak**	**0.040" Canister Leak**	**0.020" Tank Leak**	**0.020" Canister Leak**
ACCORD (g)	High RVP	0.009	0.619	0.081	0.193	0.162
	Low RVP	0.008	0.431	0.052	0.118	0.035
CARAVAN (g)	High RVP	0.007	8.054	0.308	2.389	0.025
	Low RVP	0.008	0.726	0.104	0.188	0.063
COROLLA (g)	High RVP	0.007	14.250	10.155	4.592	3.941
	Low RVP	0.004	1.602	0.163	0.124	0.052
FOCUS (g)	High RVP	0.008	7.916	13.458	12.469	12.500
	Low RVP	0.007	0.329	1.635	0.570	0.352
SILVERADO (g)	High RVP	0.002	0.430	0.084	0.127	0.314
	Low RVP	0.003	0.020	0.179	0.015	0.204

Table 6. Running Loss Emission Rates (grams/hour)

		No Leak	0.040" Tank Leak	0.040" Canister Leak	0.020" Tank Leak	0.020" Canister Leak
ACCORD (g/hr)	High RVP	0.008	0.517	0.068	0.161	0.135
	Low RVP	0.007	0.360	0.043	0.099	0.029
CARAVAN (g/hr)	High RVP	0.006	6.730	0.257	1.996	0.021
	Low RVP	0.007	0.607	0.087	0.157	0.053
COROLLA (g/hr)	High RVP	0.006	11.908	8.486	3.837	3.293
	Low RVP	0.003	1.339	0.136	0.104	0.043
FOCUS (g/hr)	High RVP	0.007	6.615	11.246	10.420	10.446
	Low RVP	0.006	0.275	1.366	0.476	0.294
SILVERADO (g/hr)	High RVP	0.002	0.359	0.070	0.106	0.262
	Low RVP	0.003	0.017	0.150	0.013	0.170
AVERAGE (g/hr)	High RVP	0.006	5.226	4.026	3.304	2.832
	Low RVP	0.005	0.519	0.356	0.170	0.118

Figure 12. Running Loss Results (10.0 psi RVP Fuel)

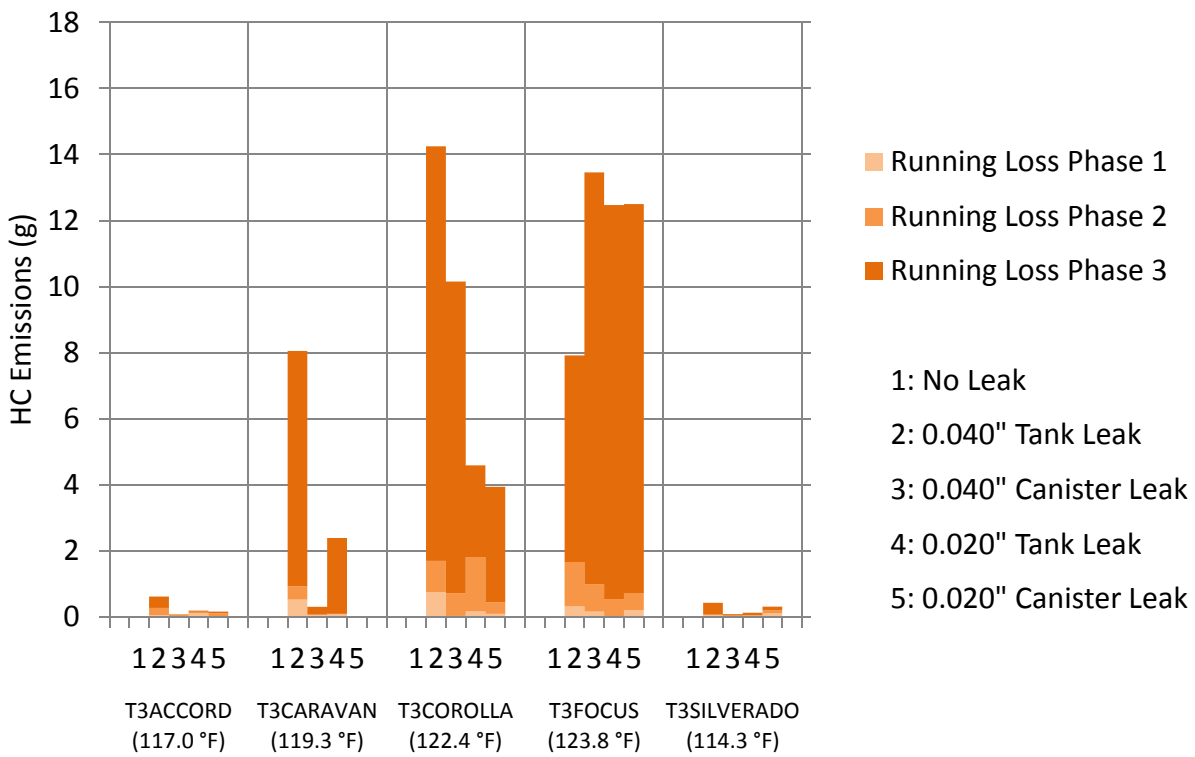


Figure 13. Running Loss Results (7.7 psi RVP Fuel)

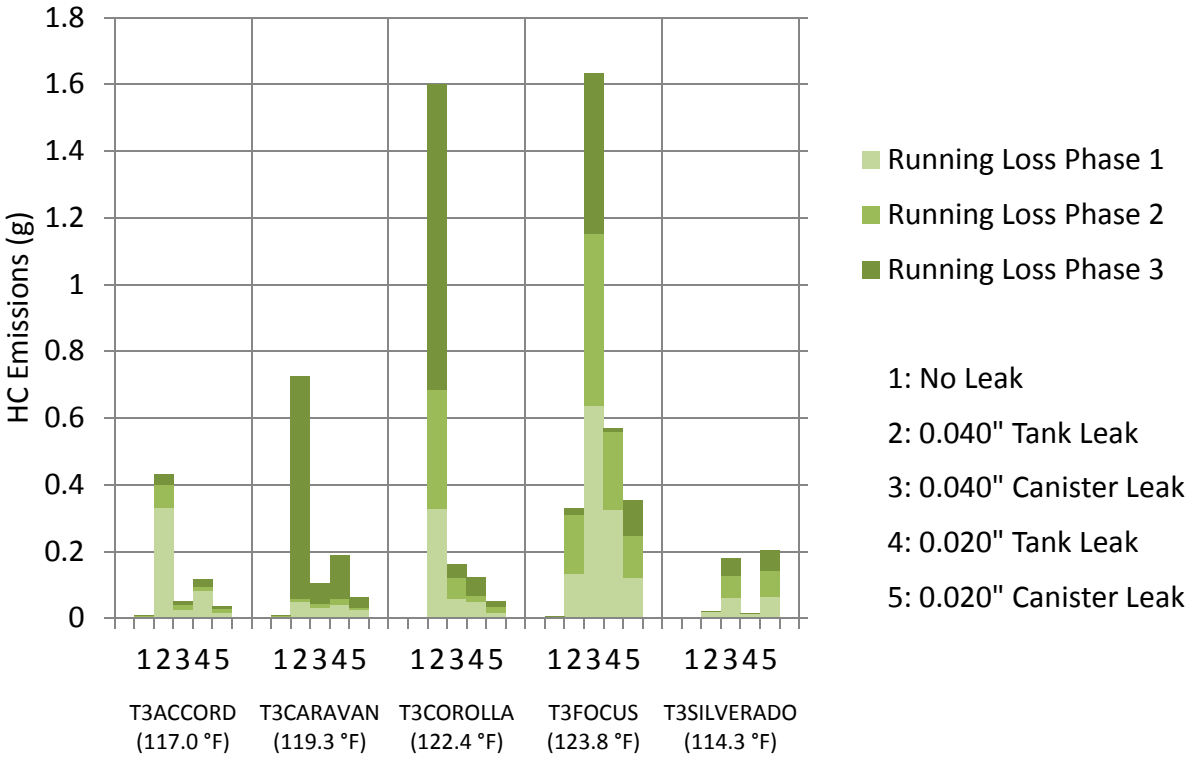
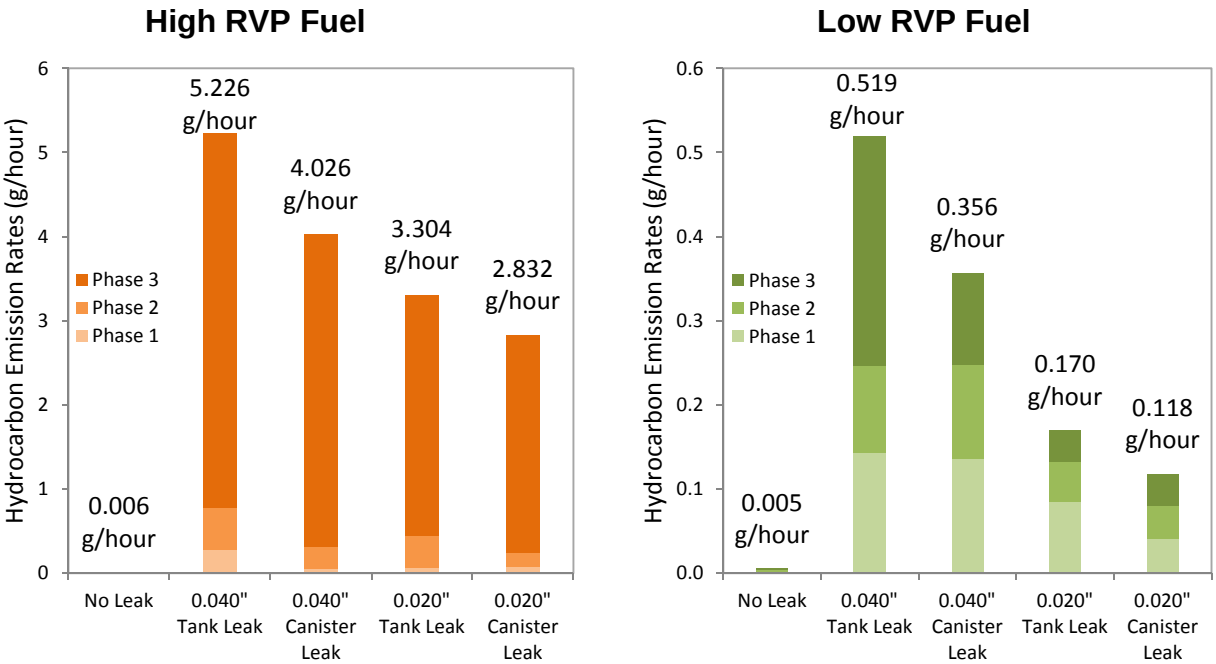


Figure 14. Average Emission Rates for Running Loss Testing



Hot Soak Results

The following table and charts characterize the total emissions measured during the hot soak tests of each vehicle. The charts segregate the emissions for each phase and test sequence, and provide the peak temperature of the tank temperature profile for each vehicle. The average hot soak emission rates were calculated as the average for all vehicles.

The overall average emissions for the 0.020” canister leak were greater than the overall average emissions for the 0.020” tank leak for the hot soak tests. This could suggest that hot soak emissions are greater for leaks at the canister than for leaks at the tank. However, replicate testing was not performed during this study, so it is unknown if this effect is statistically significant.

High RVP emissions are greater than low RVP emissions for the Focus and the Corolla for the no leak condition. The hotter tank temperature profiles of these vehicles, relative to other vehicles in the study, coupled with the small canister capacities could have caused the vapor canister to become saturated, or near saturated at the end of the running loss test. The other vehicles in the study demonstrated comparable emissions levels for the hot soak test on both fuels.

During testing, SGS-ETC was very careful in order to observe the 7-minute window to move the vehicle from the running loss test dynamometer into the SHED for hot soak testing as per §86.138-96(b)(2)(viii). However, the amount of time spent moving the vehicle may not be uniform for all tests. This incorporates a variation that is not accounted for in the analysis.

Table 7. Hot Soak Results

		No Leak	0.040" Tank Leak	0.040" Canister Leak	0.020" Tank Leak	0.020" Canister Leak
ACCORD (g)	High RVP	0.059	0.303	2.036	0.233	0.410
	Low RVP	0.067	0.144	0.837	0.150	0.269
CARAVAN (g)	High RVP	0.127	7.519	0.984	1.492	1.739
	Low RVP	0.093	0.955	0.103	0.093	0.101
COROLLA (g)	High RVP	0.164	3.168	0.657	0.593	0.734
	Low RVP	0.089	0.238	0.104	0.111	0.109
FOCUS (g)	High RVP	1.154	0.589	0.952	0.945	0.558
	Low RVP	0.216	0.481	0.164	0.250	0.210
SILVERADO (g)	High RVP	0.063	0.749	1.435	0.206	0.254
	Low RVP	0.061	0.841	1.165	0.225	0.364
AVERAGE (g/hr)	High RVP	0.313	2.466	1.213	0.694	0.739
	Low RVP	0.105	0.532	0.475	0.166	0.211

Figure 15. Hot Soak Results (10.0 psi RVP Fuel)

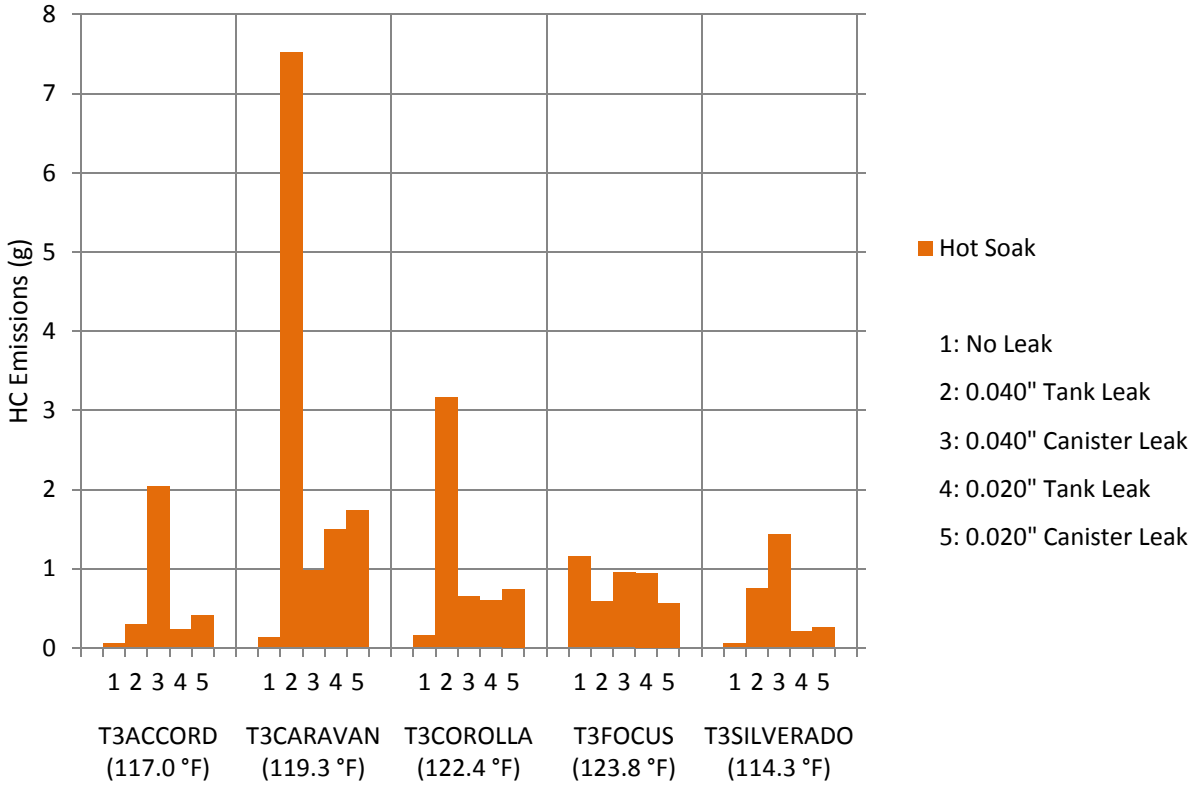


Figure 16. Hot Soak Results (7.7 psi RVP Fuel)

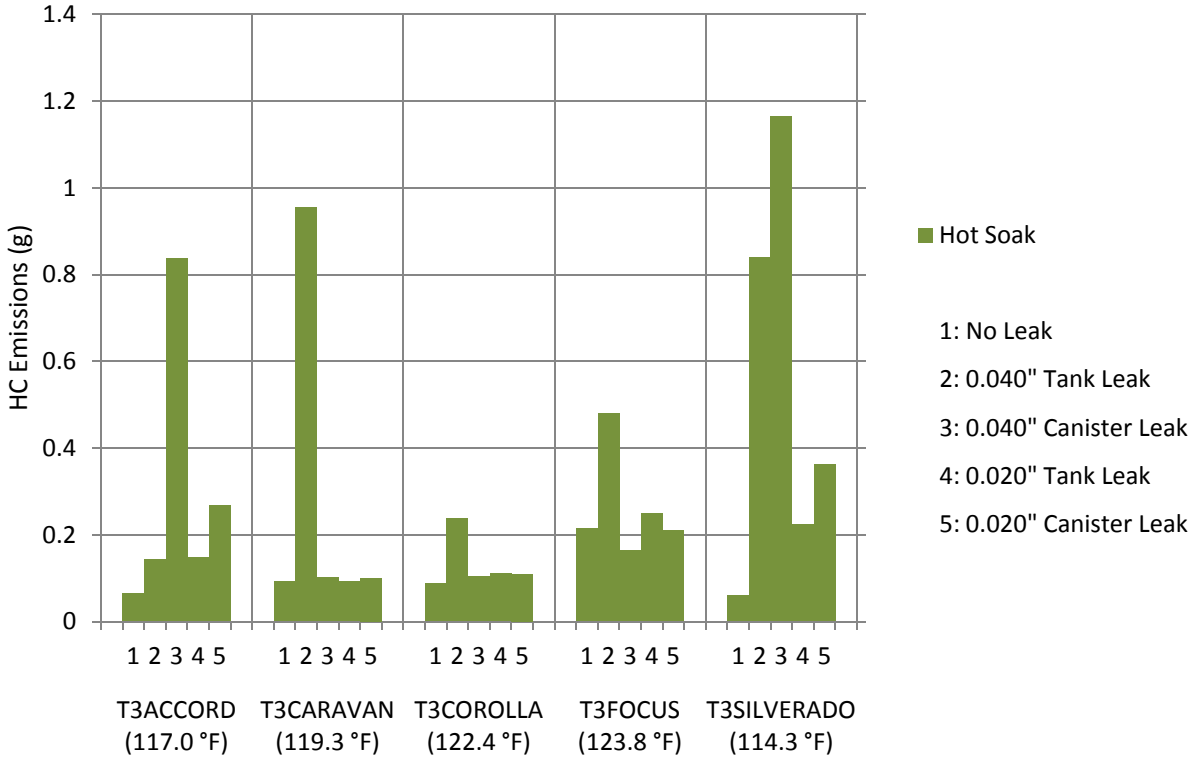
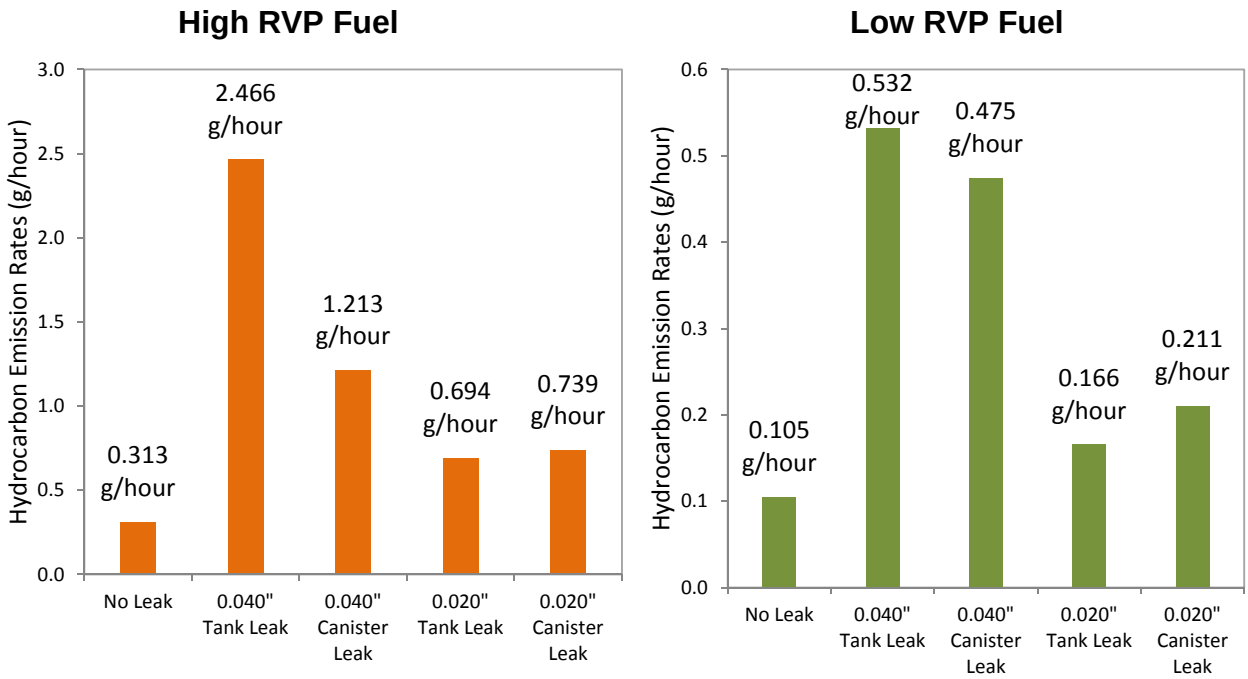


Figure 17. Average Emission Rates for Hot Soak Testing



Static Test Results

The following table and charts characterize the total emissions measured during the static tests on each vehicle. The results are segregated for each phase of the test. The fuel tank was unpressurized during first 15-minute phase of the test, while the fuel tank was pressurized to 1" WC over the second 15-minute phase of the test. The results for the five vehicles were used to calculate an average emissions rate at each leak size and fuel RVP. The charts segregate the emissions for each phase and test sequence, and provide the peak temperature of the tank temperature profile for each vehicle.

Table 8. Unpressurized Static Test Results

		No Leak	0.040" Tank Leak	0.040" Canister Leak	0.020" Tank Leak	0.020" Canister Leak
ACCORD (g)	High RVP	0.012	0.497	0.039	0.061	0.034
	Low RVP	0.013	0.261	0.042	0.124	0.036
CARAVAN (g)	High RVP	0.104	1.265	0.031	0.037	0.012
	Low RVP	0.018	0.133	0.018	0.012	0.016
COROLLA (g)	High RVP	0.024	1.464	0.032	1.357	0.630
	Low RVP	0.017	0.770	0.561	0.642	0.059
FOCUS (g)	High RVP	0.040	0.156	0.060	0.107	0.202
	Low RVP	0.056	0.240	0.053	0.393	0.063
SILVERADO (g)	High RVP	0.010	0.371	0.010	0.015	0.008
	Low RVP	0.013	0.230	0.010	0.303	0.071
AVERAGE (g/hr)	High RVP	0.152	3.003	0.138	1.262	0.709
	Low RVP	0.093	1.307	0.548	1.179	0.197

Figure 18. Unpressurized Static Test Results

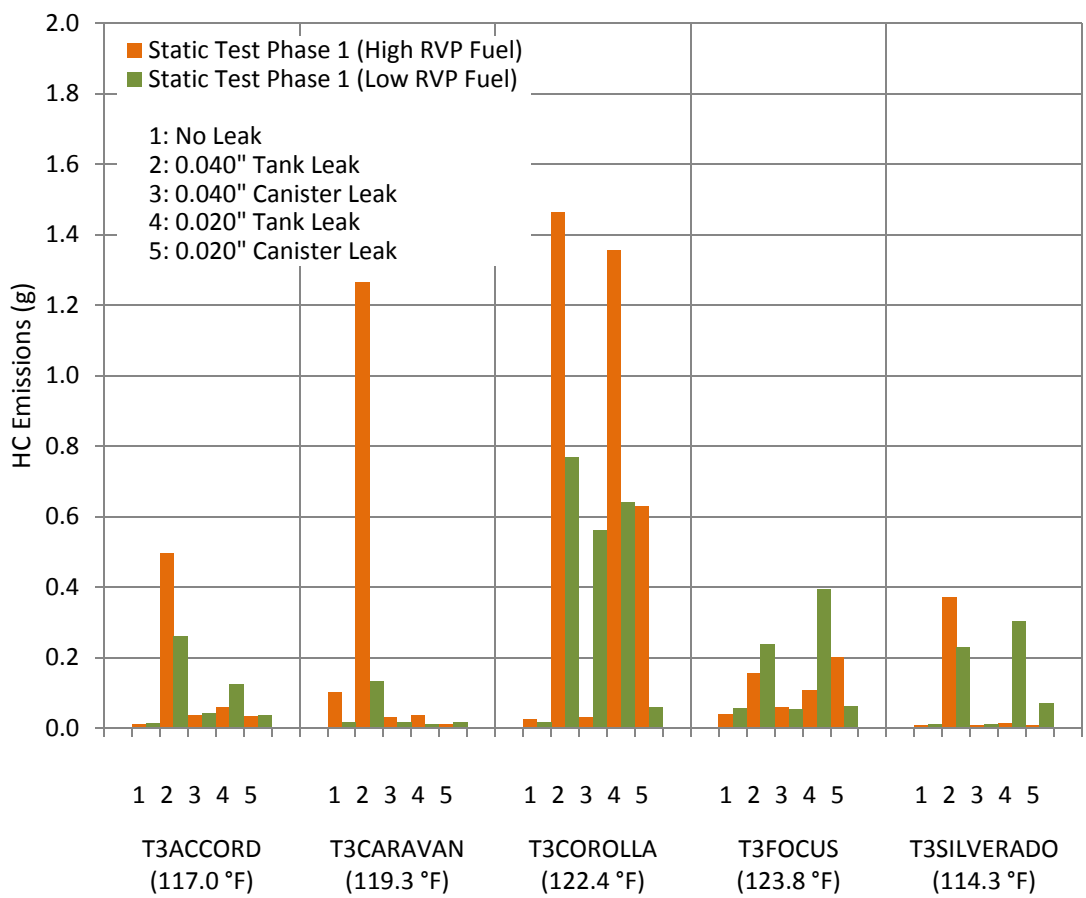
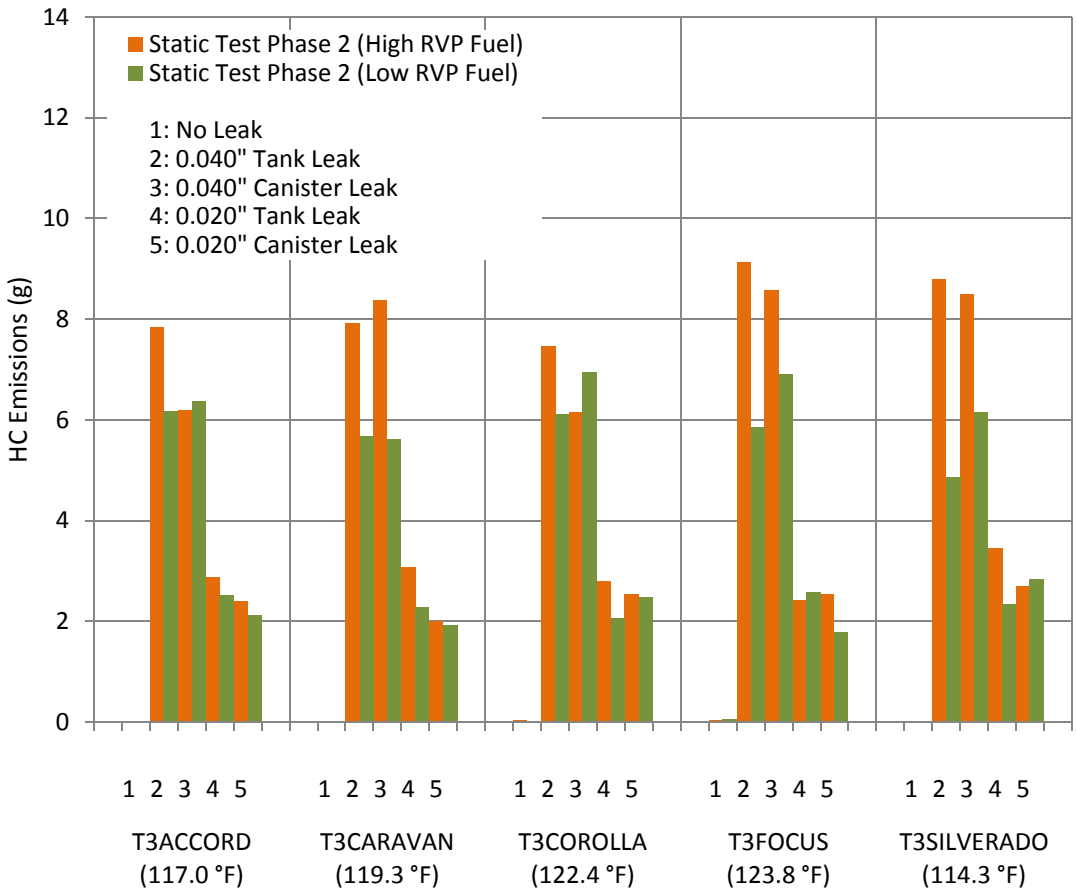


Table 9. Pressurized Static Test Results

		No Leak	0.040" Tank Leak	0.040" Canister Leak	0.020" Tank Leak	0.020" Canister Leak
ACCORD (g)	High RVP	0.011	7.829	6.194	2.876	2.392
	Low RVP	0.009	6.172	6.370	2.522	2.125
CARAVAN (g)	High RVP	0.014	7.915	8.367	3.067	2.001
	Low RVP	0.012	5.680	5.604	2.276	1.920
COROLLA (g)	High RVP	0.036	7.460	6.157	2.795	2.526
	Low RVP	0.013	6.116	6.945	2.050	2.485
FOCUS (g)	High RVP	0.040	9.130	8.563	2.407	2.525
	Low RVP	0.043	5.849	6.895	2.574	1.773
SILVERADO (g)	High RVP	0.007	8.796	8.483	3.441	2.691
	Low RVP	0.008	4.862	6.156	2.330	2.830
AVERAGE (g/hr)	High RVP	0.086	32.904	30.211	11.668	9.708
	Low RVP	0.068	22.943	25.576	9.401	8.907

Figure 19. Pressurized Static Test Results



3.5 Observations and Conclusions

Figures 8 through 11 indicate the running loss tank temperature profile has a strong influence on running loss emission rates in vehicles with induced leaks (vehicles with higher tank temperatures exhibit higher emission rates). However, Figure 7 suggests the tank temperature does not have an influence on running loss emissions for vehicles with no evaporative emissions control system leaks.

Similarly, Tables 5, 6 and7 and Figures 12 through 17 indicate fuel RVP has a strong effect on running loss and hot soak emission rates in vehicles with induced leaks (vehicles with higher RVP fuels exhibit higher emission rates), but the influence of RVP on vehicles with no evaporative emissions control system leaks was much less pronounced. These same tables and figures also demonstrate a correlation between leak size (0.020” vs. 0.040” diameter leaks) for running loss, hot soak, and pressurized static test evaporative emission rates. In general, the larger leak sizes resulted in higher evaporative emission rates for each respective location (tank or canister).

Tables 5 and 6 and Figures 12 through 14 suggest leak location (fuel tank vapor space or evaporative canister) may have an influence on running loss evaporative emission rates. On average, induced leaks in the tank vapor space resulted in higher running loss emission rates than induced leaks in the canister for leaks of the same size. Comparatively, the leak size proved to be more important than the leak location. The 0.040” leak at the canister resulted in greater running loss emissions rates on average than did the 0.020” in the tank vapor space leak. In aggregate, the 0.040” leak in the tank vapor space produced the most running loss emissions.

For hot soak emissions, leak location (tank or canister) did not seem to have a strong influence on emission rates (as can be seen in Table 7 and Figures 15 through 17). Figures 15 and 16 show a high amount of variation in hot soak emission rates for different tests on the same vehicle and also among vehicles. The Focus, in particular, demonstrates that the “no leak” setup produced the most hot soak emissions of any leak setup for high RVP fuel on that vehicle. The extraordinary amount of variability in these tests may be attributed to real phenomenon which is occurring during testing, such as canisters reaching saturation. This is likely due to vehicle configuration (such as tank and canister capacities and purge volume capabilities) but can also be influenced by experimental parameters such as test and tank temperatures and time between running loss and hot soak tests. It is possible that variation in these parameters may contribute to some emission result differences among tests.

For the static test emission rates (Tables 8 and 9 and Figures 18 and 19), test variation seemed to dominate over any discernible leak location (tank or canister) or leak size trends.

Evaporative purge behavior, as controlled by the ECU, greatly impacts emissions rates on vehicles with induced leaks. This evaporative purge behavior is correlated with the measured vacuum in the fuel vapor, which occurs when the purge valve is open and the engine introduces air intake vacuum to the fuel system vapor space. Evaluation of the fuel vapor vacuum and commanded evaporative purge for the Ford Focus and Toyota Corolla, the only two vehicles in the study that broadcasted commanded evaporative purge through OBDII, did seem to confirm this correlation between commanded purge and measured fuel vapor vacuum. However, for both these vehicles, deviations from the correlation appear at the end of some high RVP fuel tests. It appears that during these deviations, vapor generation overwhelms the purge capability and results in decreases in vacuum despite an open purge valve. When the fuel system vapor vacuum is reduced, either due to a reduction in commanded evaporative purge, or because vapor generation exceeded the capacity of purge, hydrocarbon emission rates were elevated for vehicles with induced leaks. The positive vapor pressure, relative to atmospheric pressure, expelled gaseous hydrocarbons from the evaporative system's induced leaks, bypassing the vapor canister. In systems with no leaks, the hydrocarbon vapors were being effectively captured in the canister and few emissions were measured for the running loss portion of the test.

4.0 References

1. CRC E-77 reports: Haskew, H., Liberty, T. (2008). Vehicle Evaporative Emission Mechanisms: A Pilot study, CRC Project E-77; Haskew, H., Liberty, T. (2010), Enhanced Evaporative Emission Vehicles (CRC E-77-2); Haskew, H., Liberty, T. (2010), Evaporative Emissions from In-Use Vehicles: Test Fleet Expansion (CRC E-77-2b); Haskew, H., Liberty, T. (2010), Study to Determine Evaporative Emission Breakdown, Including Permeation Effects and Diurnal Emissions Using E20 Fuels on Aging Enhanced Evaporative Emissions Certified Vehicles, CRC E-77-2c; DeFries, T., Lindner, J., Kishan, S., Palacios, C. (2011), Investigation of Techniques for High Evaporative Emissions Vehicle Detection: Denver Summer 2008 Pilot Study at Lipan Street Station; DeFries, T., Palacios, C., Weatherby, M., Stanard, A., Kishan, S.(2013) Estimated Summer Hot-Soak Distributions for Denver's Ken Caryl I/M Station Fleet.

2. DeFries, T., Lindner, J., Kishan, S., Palacios, C. (2011), Investigation of Techniques for High Evaporative Emissions Vehicle Detection: Denver Summer 2008 Pilot Study at Lipan Street Station; DeFries, T., Palacios, C., Weatherby, M., Stanard, A., Kishan, S.(2013) Estimated Summer Hot-Soak Distributions for Denver's Ken Caryl I/M Station Fleet.

5.0 Index of Appendices

The following is a list of the appendices to be provided with this report. As noted below, some appendices will be provided as separate electronic files.

Appendix A – Fuel Analysis Results
Appendix B – Test-by-Test Results
Appendix C – Descriptions of Study Data (the following files will be provided electronically, by vehicle)
- FTP 72 Reports (*_74.pdf)
- FTP 75 Report (*.pdf)
- Running Loss Report (*.pdf)
- Running Loss Data File (*.csv)
- Running Loss Continuous Hydrocarbon File (*.csv)
- OBD2 Data (*.csv)
- Hot Soak Data (*.xls)
- Static Test Data (*.xls)
- Static Test Data (*.txt)
- Vehicle Data (*.xls)

Appendix D – Issues Encountered and Solutions
Appendix E – Induced Leak Configurations

Appendix A
Fuel Analysis Results

A1 Low RVP Test Results

10-Feb-14

NVFEL Fuel Analysis Report

23986

WAI-08

Batch#

Facility Name: EPA (NVFEL) Facility Type: In House
Owner: EPA (NVFEL) Phone: (734) 214-4340
2565 Plymouth Rd.
Ann Arbor MI 48105 USA
Inspector: Connie Hart Inspection Date 1/21/2014
Samples Type: Test Fuel VOC C
Inspection information logged in by RG on 1/21/2014 Season: Winter

WAI-08-20130117LORVP FTAG: 23986 Comments:

Test Code	Test Method	Results	Units	Fuel_ Code	51	Analyst	Analysis Date
5808	Weight Percent Oxygenates by D5599	10.19	Weight Percent			TS	1/29/2014
552	MTBE by D5599	0.00	Oxygen Percent			TS	1/29/2014
562	ETBE by D5599	0.00	Oxygen Percent			TS	1/29/2014
534	Ethanol by D5599	3.54	Oxygen Percent			TS	1/29/2014
572	TAME by D5599	0.00	Oxygen Percent			TS	1/29/2014
421	Sulfur in Gasoline D2622	58.0	Parts Per Million			NST	2/4/2014
62	Vapor Pressure by D5191 (Modified)	7.67	PS I			NST	1/27/2014
65	Percent Evaporated at 200 Degrees F D86	48.7	Volume Percent			RG	1/30/2014
66	Percent Evaporated at 300 Degrees F D86	86.3	Volume Percent			RG	1/30/2014
48	Aromatics in Gasoline MSD D5769	27.71	Volume Percent			TW	2/4/2014
49	Olefins in by FIA D1319	8.0	Volume Percent			RCG	1/27/2014
64	Benzene in Gasoline D3606	1.91	Volume Percent			TW	1/31/2014
532	Ethanol by D5599	9.70	Volume Percent			TS	1/29/2014
57	TAME by D5599	0.00	Volume Percent			TS	1/29/2014
593	Volume Percent Oxygenates by D5599	9.70	Volume Percent			TS	1/29/2014
59	Weight Percent Oxygen by D5599	3.54	Weight Percent			TS	1/29/2014
55	MTBE by D5599	0.00	Volume Percent			TS	1/29/2014
56	ETBE by D5599	0.00	Volume Percent			TS	1/29/2014
63	Benzene in Gasoline by GC/MSD D5769	1.87	Volume Percent			TW	2/4/2014
630	Toluene in gasoline by MSD D5769	7.02	Volumn Percent			TW	2/4/2014
46	Aromatics by FIA D1319	28.3	Volume Percent			RCG	1/27/2014
69	Specific Gravity @ 60 deg F D4052	0.75669	60/60F			NT	1/27/2014
692	Degrees API D4052	55.45	Degrees API			NT	1/27/2014
691	Density @ 60 deg F D4052	0.75615	g/cm-03 @ 60 deg F			NT	1/27/2014
101	Initial Boiling Point D86	104.1	Degrees F			RG	1/30/2014
110	10 Percent D86	133.2	Degrees F			RG	1/30/2014
150	50 Percent D86	206.9	Degrees F			RG	1/30/2014
190	90 Percent D86	316.0	Degrees F			RG	1/30/2014
200	End Point D86	407.2	Degrees F			RG	1/30/2014
201	Residue D86	1.0	mL			RG	1/30/2014
202	Total Recovery D86	97.6	mL			RG	1/30/2014
203	Loss D86	1.4	mL			RG	1/30/2014
543	Methanol by D5599	0.00	Volume Percent			TS	1/29/2014

NVFEL Fuel Analysis Report 23986

584	Isopropanol	by D5599	0.00	Volume Percent	TS	1/29/2014
585	t-Butanol	by D5599	0.00	Volume Percent	TS	1/29/2014
586	n-Propanol	by D5599	0.00	Volume Percent	TS	1/29/2014
587	sec-Butanol	by D5599	0.00	Volume Percent	TS	1/29/2014
588	DIPE	by D5599	0.00	Volume Percent	TS	1/29/2014
589	Isobutanol	by D5599	0.00	Volume Percent	TS	1/29/2014
5801	t-Amyl Alcohol	by D5599	0.00	Volume Percent	TS	1/29/2014
5802	n-Butanol	by D5599	0.00	Volume Percent	TS	1/29/2014

A2 High RVP Test Results

10-Feb-14

NVFEL Fuel Analysis Report 23987

WAI-08 Batch#

Facility Name: EPA (NVFEL) Facility Type: In House
Owner: EPA (NVFEL) Phone: (734) 214-4340
2565 Plymouth Rd.
Ann Arbor MI 48105 USA
Inspector: Connie Hart Inspection Date : 1/21/2014
Samples Type: Test Fuel VOC C
Inspection information logged in by RG on 1/21/2014. Season: Winter

WAI-08-20130117HIRVP FTAG: 23987 Comments:

Test Code	Test Method	Results	Units	Fuel_ Code: 51	Analyst	Analysis Date
5808	Weight Percent Oxygenates by D5599	10.89	Weight Percent		TS	1/29/2014
552	MTBE by D5599	0.00	Oxygen Percent		TS	1/29/2014
562	ETBE by D5599	0.00	Oxygen Percent		TS	1/29/2014
534	Ethanol by D5599	3.78	Oxygen Percent		TS	1/29/2014
572	TAME by D5599	0.00	Oxygen Percent		TS	1/29/2014
421	Sulfur in Gasoline D2622	56.3	Parts Per Million		NST	2/4/2014
62	Vapor Pressure by D5191 (Modified)	10.02	PS I		NST	1/27/2014
85	Percent Evaporated at 200 Degrees F D86	55.0	Volume Percent		RG	1/30/2014
95	Percent Evaporated at 300 Degrees F D86	89.4	Volume Percent		RG	1/30/2014
48	Aromatics in Gasoline MSD D5769	17.79	Volume Percent		TW	2/4/2014
49	Olefins in by FIA D1319	9.5	Volume Percent		RCG	1/27/2014
64	Benzene in Gasoline D3606	1.74	Volume Percent		TW	1/31/2014
532	Ethanol by D5599	10.07	Volume Percent		TS	1/29/2014
57	TAME by D5599	0.00	Volume Percent		TS	1/29/2014
593	Volume Percent Oxygenates by D5599	10.07	Volume Percent		TS	1/29/2014
59	Weight Percent Oxygen by D5599	3.78	Weight Percent		TS	1/29/2014
55	MTBE by D5599	0.00	Volume Percent		TS	1/29/2014
56	ETBE by D5599	0.00	Volume Percent		TS	1/29/2014
63	Benzene in Gasoline by GC/MSD D5769	1.71	Volume Percent		TW	2/4/2014
530	Toluene in gasoline by MSD D5769	8.42	Volume Percent		TW	2/4/2014
46	Aromatics by FIA D1319	18.6	Volume Percent		RCG	1/27/2014
69	Specific Gravity @ 60 deg F D4052	0.73504	60/60F		NT	1/27/2014
692	Degrees API D4052	61.01	Degrees API		NT	1/27/2014
691	Density @ 60 deg F D4052	0.73432	g/cm-03 @ 60 deg F		NT	1/27/2014
101	Initial Boiling Point D86	93.0	Degrees F		RG	1/30/2014
110	10 Percent D86	121.5	Degrees F		RG	1/30/2014
150	50 Percent D86	165.3	Degrees F		RG	1/30/2014
190	90 Percent D86	303.8	Degrees F		RG	1/30/2014
200	End Point D86	395.4	Degrees F		RG	1/30/2014
201	Residue D86	1.1	mL		RG	1/30/2014
202	Total Recovery D86	97.1	mL		RG	1/30/2014
203	Loss D86	1.8	mL		RG	1/30/2014
543	Methanol by D5599	0.00	Volume Percent		TS	1/29/2014

NVFEL Fuel Analysis Report

23987

584	Isopropanol	by D5599	0.00	Volume Percent	TS	1/29/2014
585	t-Butanol	by D5599	0.00	Volume Percent	TS	1/29/2014
586	n-Propanol	by D5599	0.00	Volume Percent	TS	1/29/2014
587	sec-Butanol	by D5599	0.00	Volume Percent	TS	1/29/2014
588	DIPE	by D5599	0.00	Volume Percent	TS	1/29/2014
589	Isobutanol	by D5599	0.00	Volume Percent	TS	1/29/2014
5801	t-Amyl Alcohol	by D5599	0.00	Volume Percent	TS	1/29/2014
5802	n-Butanol	by D5599	0.00	Volume Percent	TS	1/29/2014

Appendix B
Test-by-Test Results

B.1 Overview of results

The following tables and plots present summary cumulative and continuous data measurements results from testing performed throughout the study. All fuel vapor pressures are reported with sign reversal and are in units of pounds per square inch gauge (psig) vacuum, and the "cumulative pressure accumulation" plots represents "cumulative vacuum" throughout test. Mean pressure plots represent the average of pressures measured across various test configurations (no leak, 0.020" and 0.040" at tank and canister) for each type of fuel. Since continuous HC measurements were added mid-study, continuous HC results are not available for the high RVP testing performed during the first half of the study.

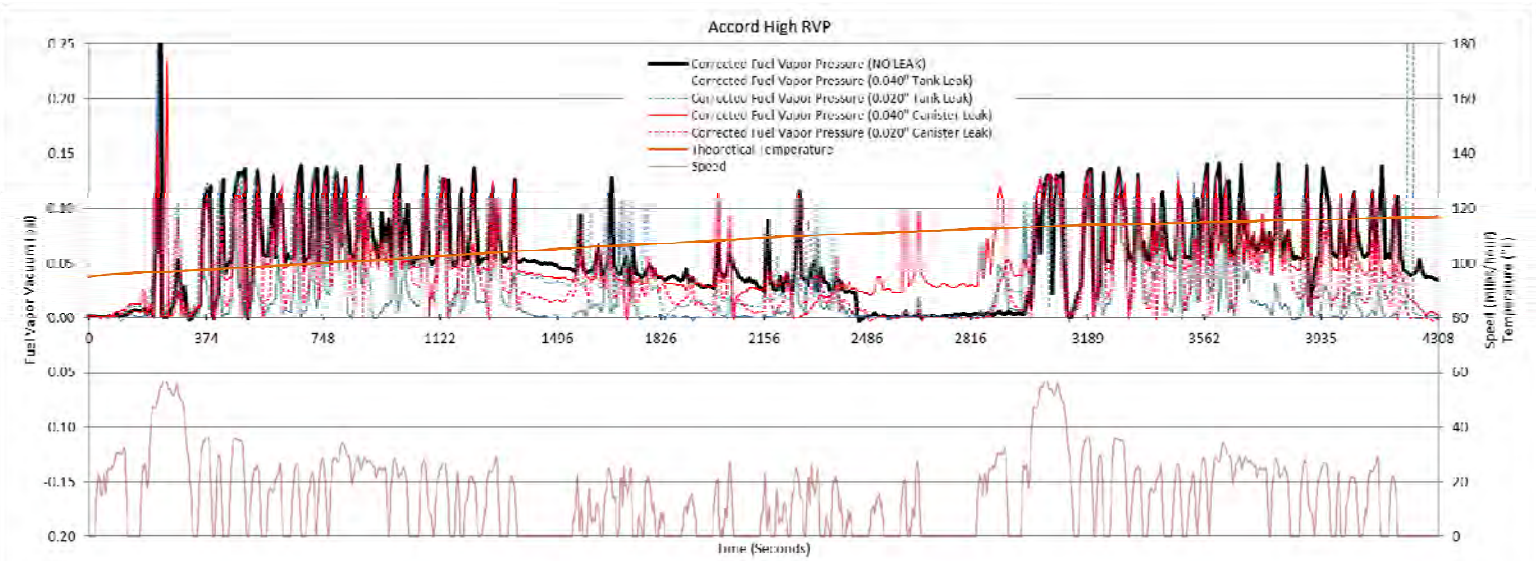
Explanations for anomalous or erroneous results, including any corrections performed on the data, are provided in Section 4.4, Data Validation and Analysis.

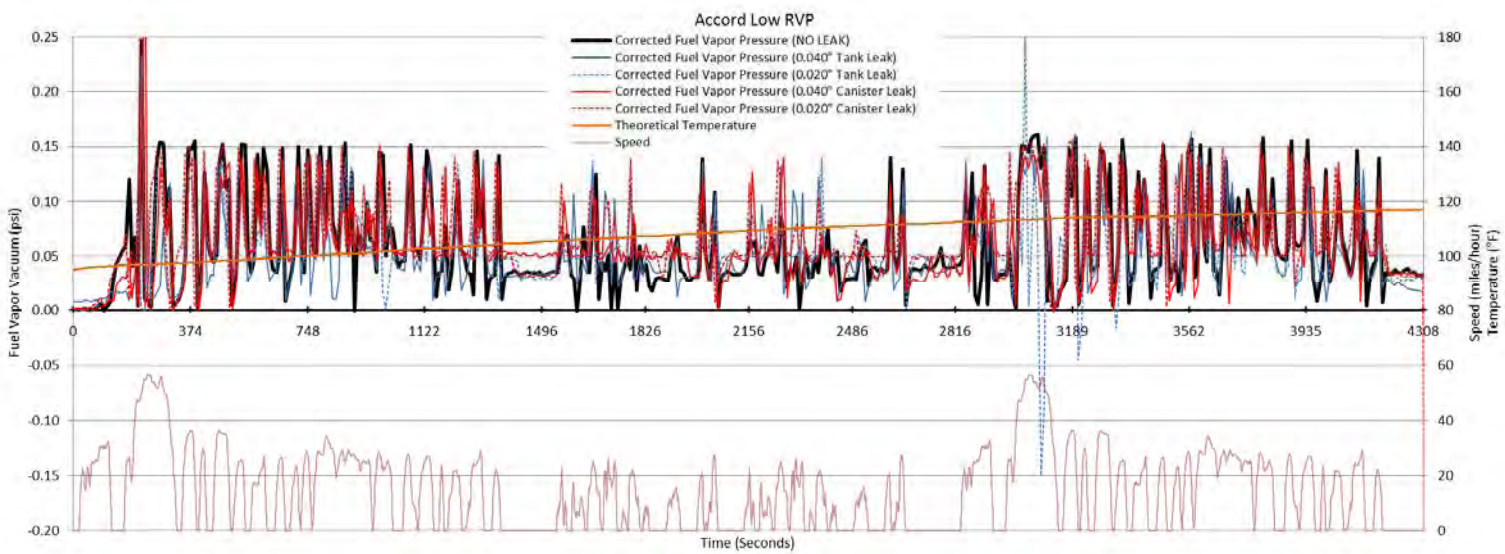
B.2 2007 Honda Accord

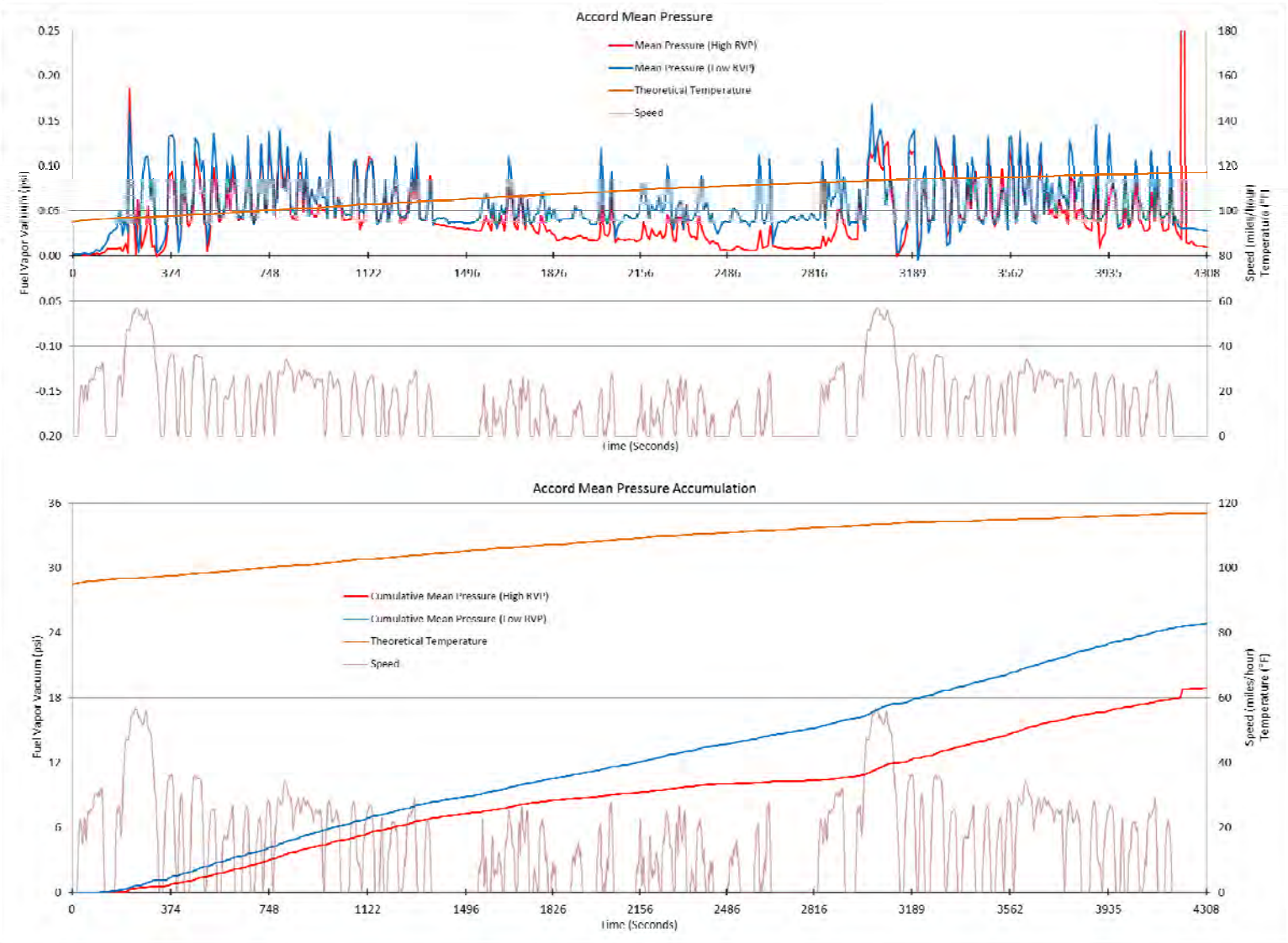
VIN:	1HGCM56727A241399
ENGINE FAMILY:	7HNXV02.4KKC
EVAPORATIVE FAMILY:	7HNXR0140BBA
EMISSIONS STANDARD:	Tier 2 Bin 5
ENGINE DISPLACEMENT:	2.40 Liters
INERTIA WEIGHT:	3500 Pounds
TANK CAPACITY:	17.00 Gallons
ROAD LOAD A:	9.76
ROAD LOAD B:	0.2918
ROAD LOAD C:	0.01602
PEAK FUEL TEMP:	117.0 °F

Sequence:		1	2	3	4	5	6	7	8	9	10
Fuel:		High RVP Fuel (10.0 RVP)					Low RVP Fuel (7.7 RVP)				
Leak Location:		No Leak	Tank	Canister	Tank	Canister	No Leak	Tank	Canister	Tank	Canister
Leak Size:		No Leak	0.040”	0.040”	0.020”	0.020”	No Leak	0.040”	0.040”	0.020”	0.020”
Results in Grams:											
Running Loss	P1	0.005	0.057	0.023	0.112	0.027	0.004	0.331	0.024	0.082	0.015
	P2	0.002	0.216	0.044	0.044	0.084	0.003	0.068	0.017	0.009	0.012
	P3	0.002	0.346	0.014	0.037	0.051	0.001	0.032	0.011	0.027	0.008
	TOTAL	0.009	0.619	0.081	0.193	0.162	0.008	0.431	0.052	0.118	0.035
Hot Soak		0.059	0.303	2.036	0.233	0.410	0.067	0.144	0.837	0.150	0.269
Static Test	P1	0.012	0.497	0.039	0.061	0.034	0.013	0.261	0.042	0.124	0.036
	P2	0.011	7.829	6.194	2.876	2.392	0.009	6.172	6.370	2.522	2.125
	TOTAL	0.023	8.326	6.232	2.937	2.426	0.022	6.433	6.412	2.646	2.162
RL + HS + ST		0.091	9.248	8.350	3.363	2.998	0.097	7.008	7.301	2.914	2.466

B.2.1 Running Loss Fuel Vapor Pressure Comparisons

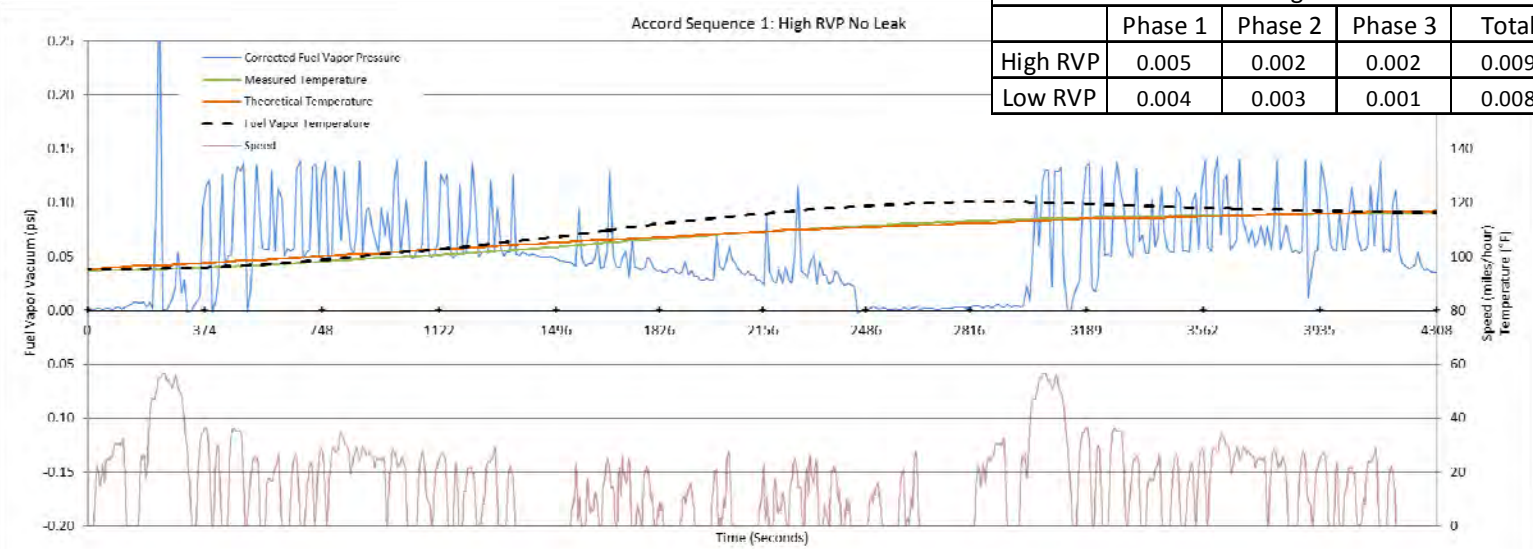


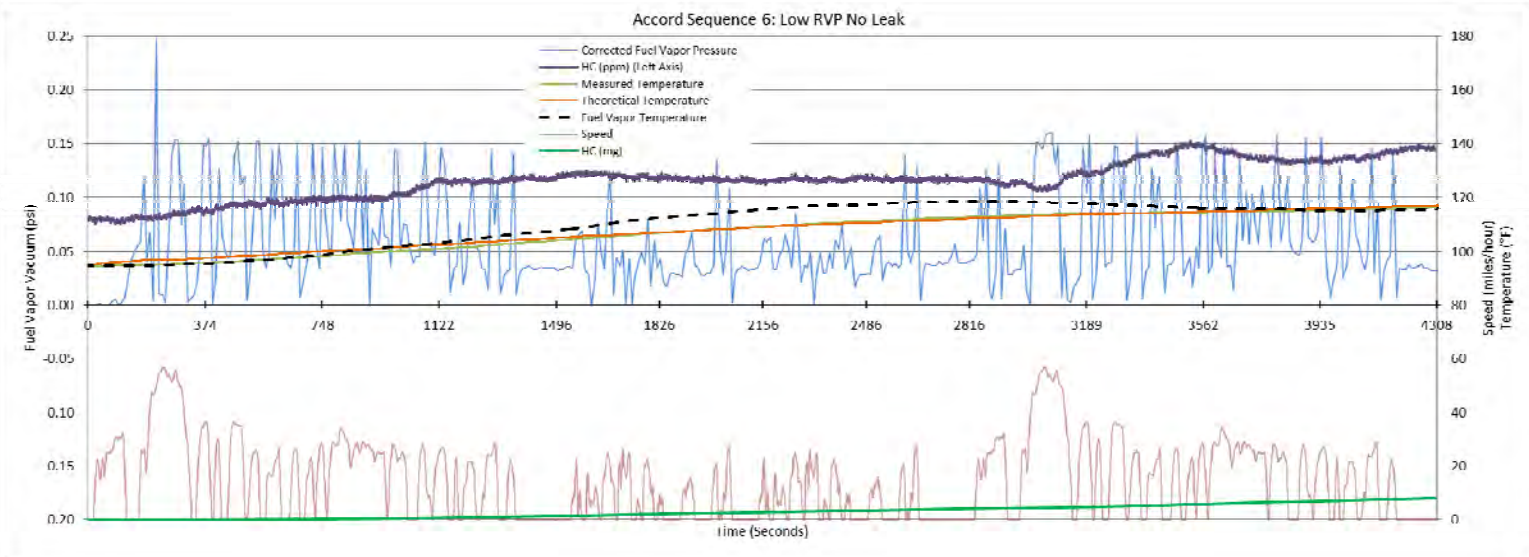



Accord Mean Pressure
Mean Pressure (High RVP)
Mean Pressure (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)
Accord Mean Pressure Accumulation
Cumulative Mean Pressure (High RVP)
Cumulative Mean Pressure (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)

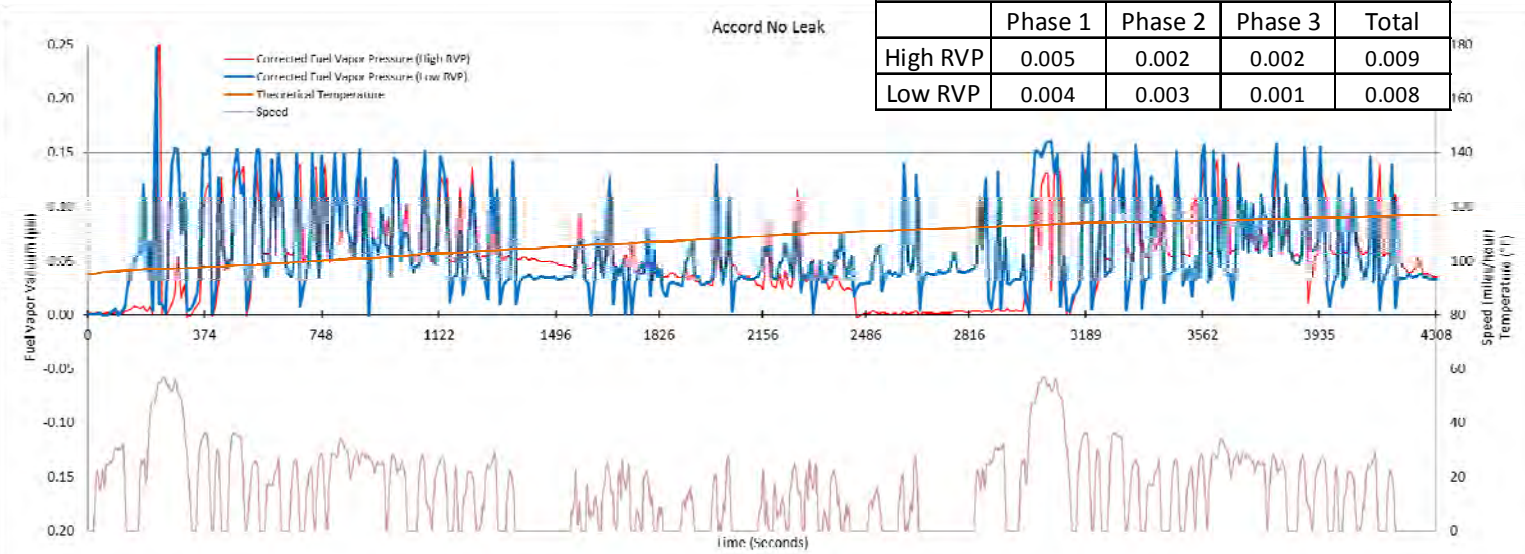
B.2.2 No Leak

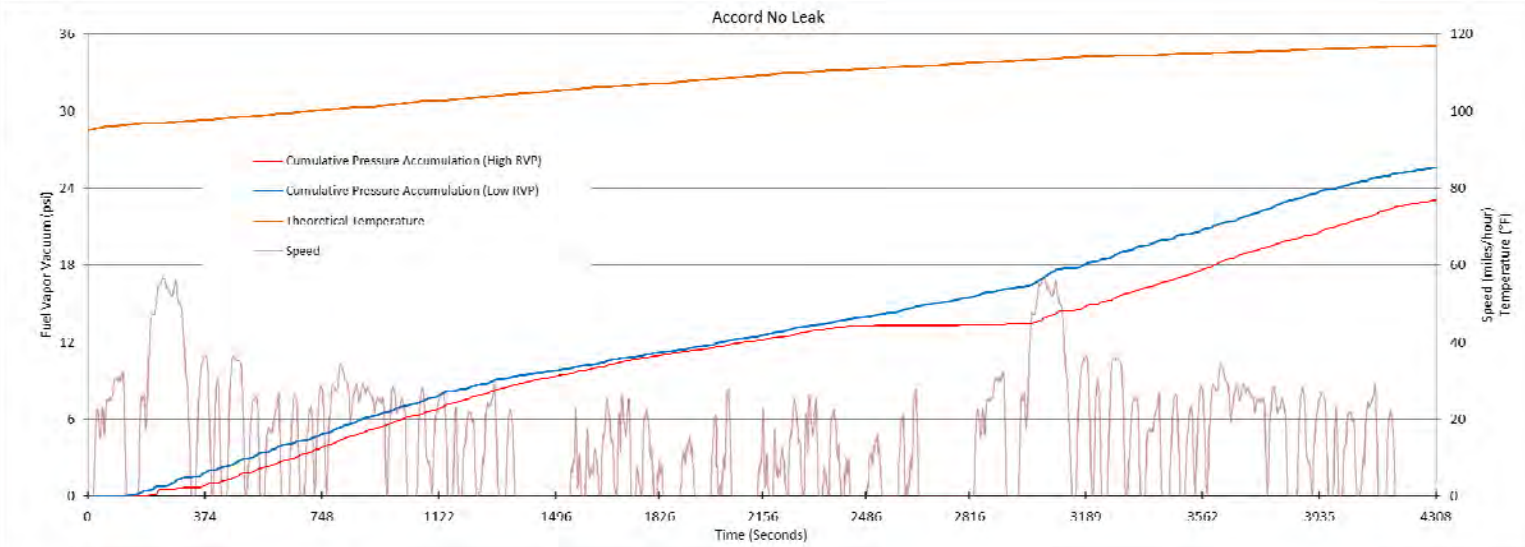
No Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.005	0.002	0.002	0.009
Low RVP	0.004	0.003	0.001	0.008





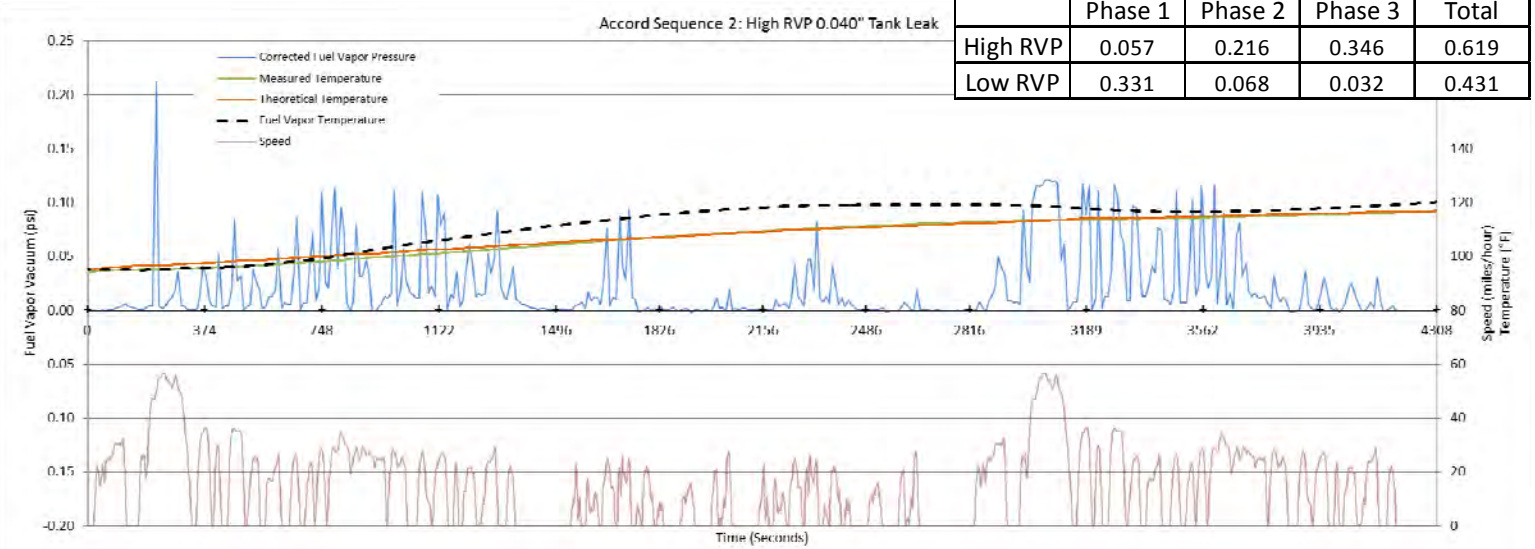
No Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.005	0.002	0.002	0.009
Low RVP	0.004	0.003	0.001	0.008

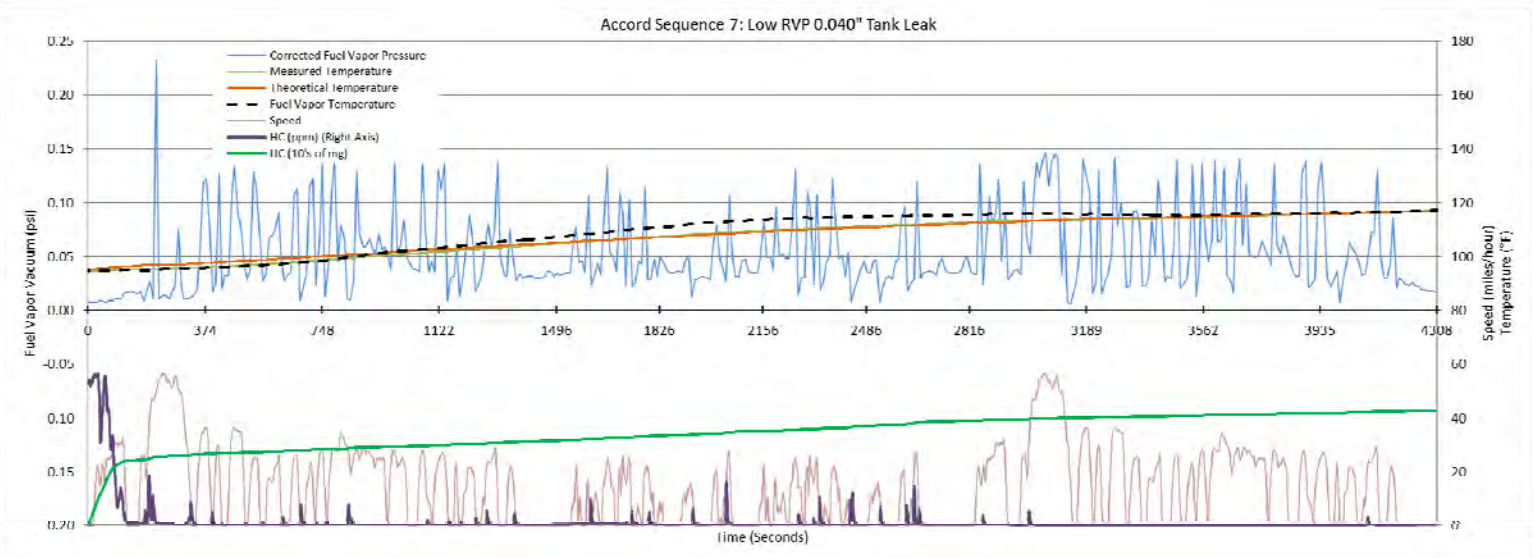




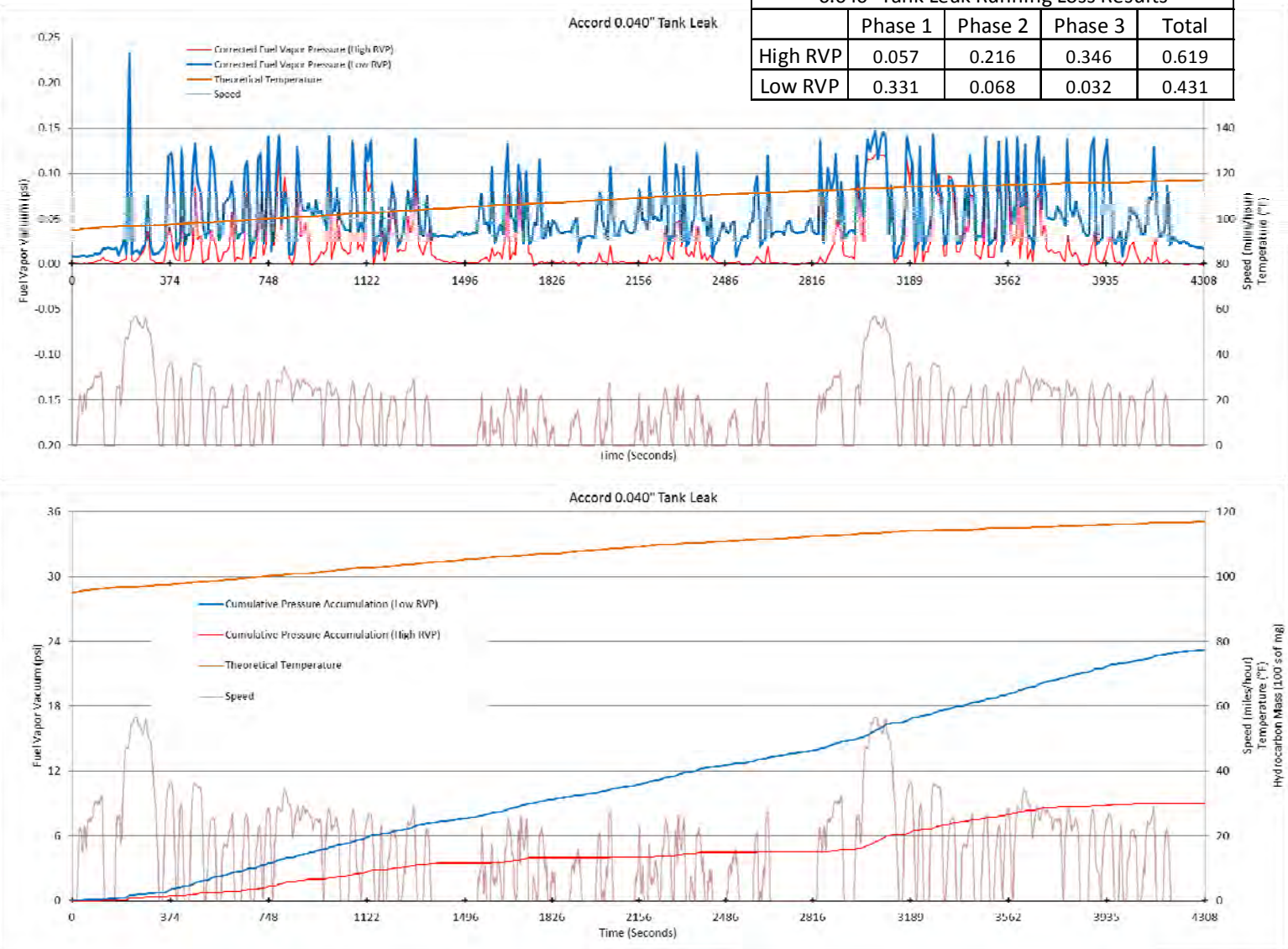
B.2.3 0.040” Tank Leak

0.040" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.057	0.216	0.346	0.619
Low RVP	0.331	0.068	0.032	0.431



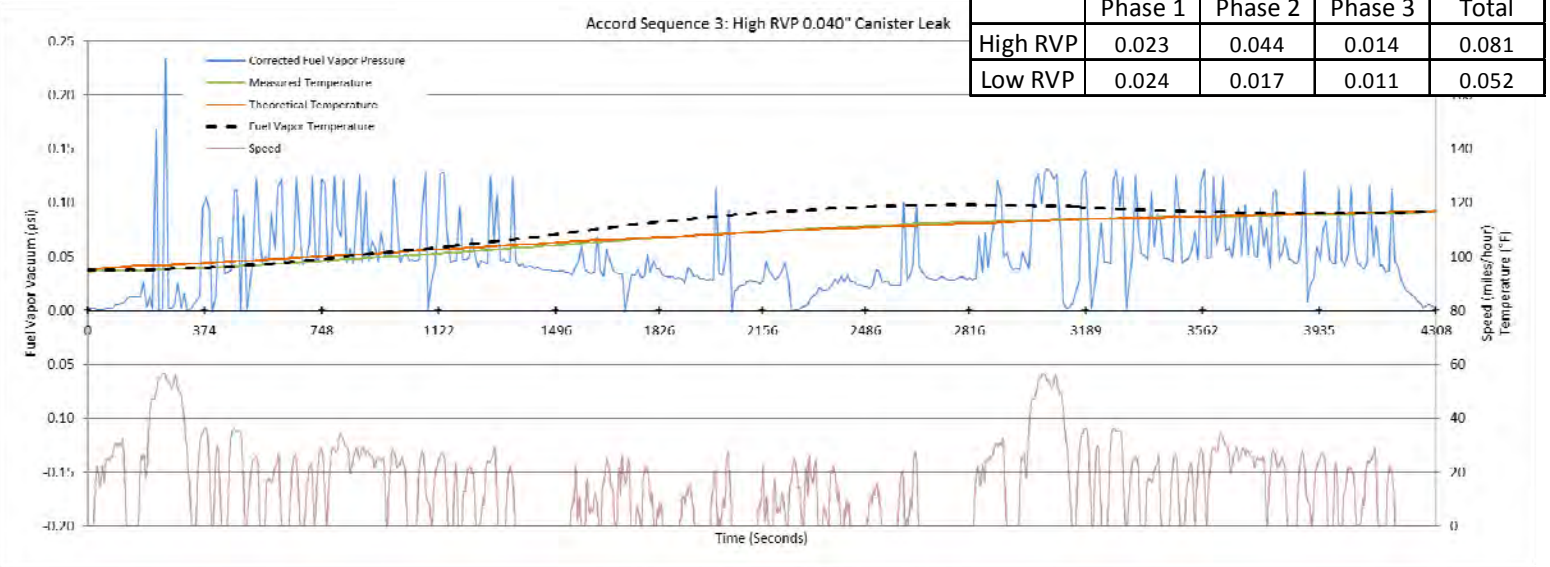


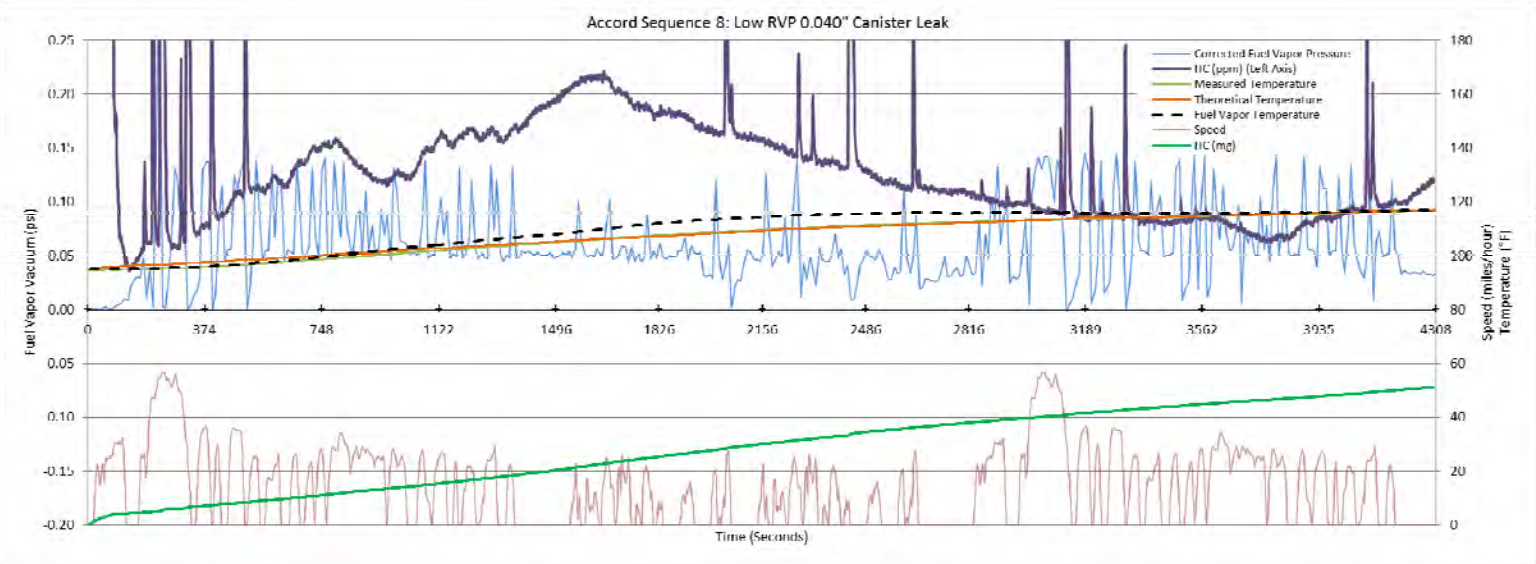
0.040" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.057	0.216	0.346	0.619
Low RVP	0.331	0.068	0.032	0.431



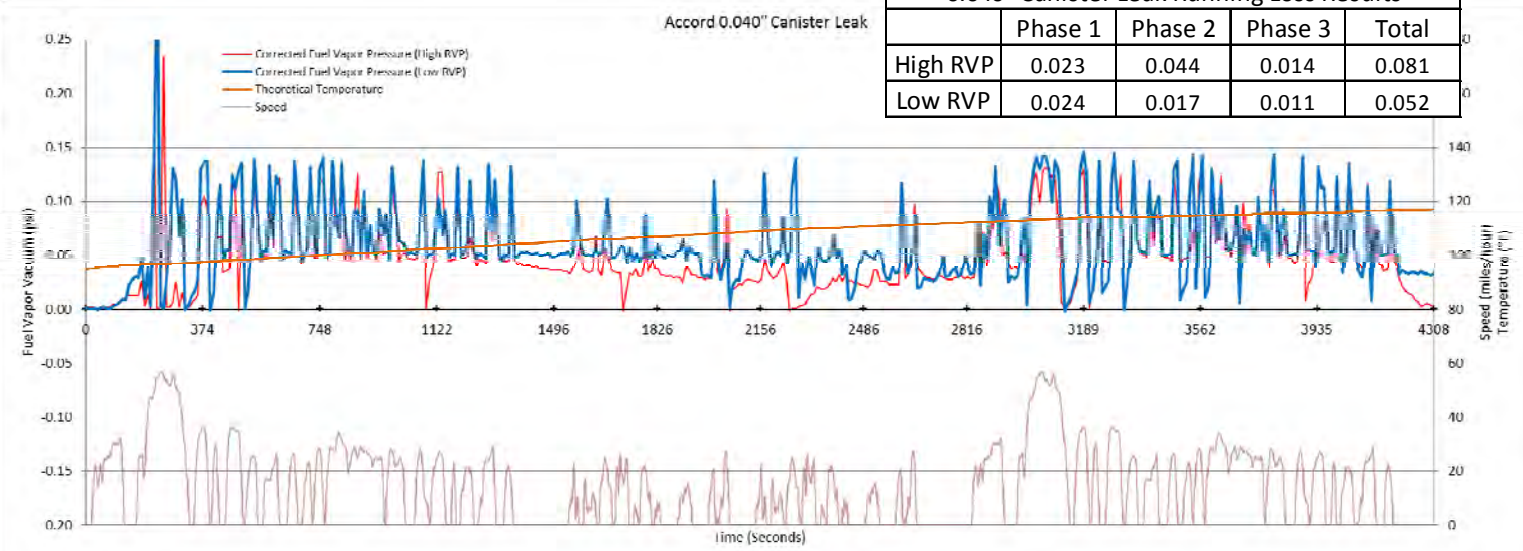
B.2.4 0.040” Canister Leak

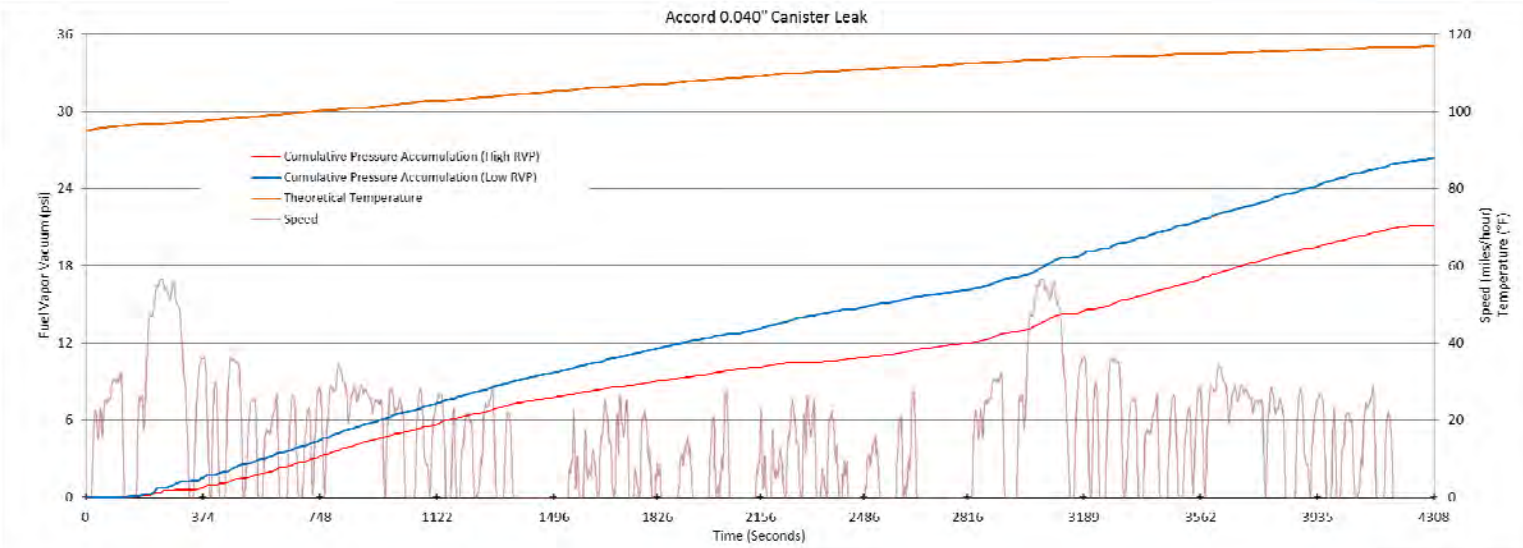
0.040" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.023	0.044	0.014	0.081
Low RVP	0.024	0.017	0.011	0.052





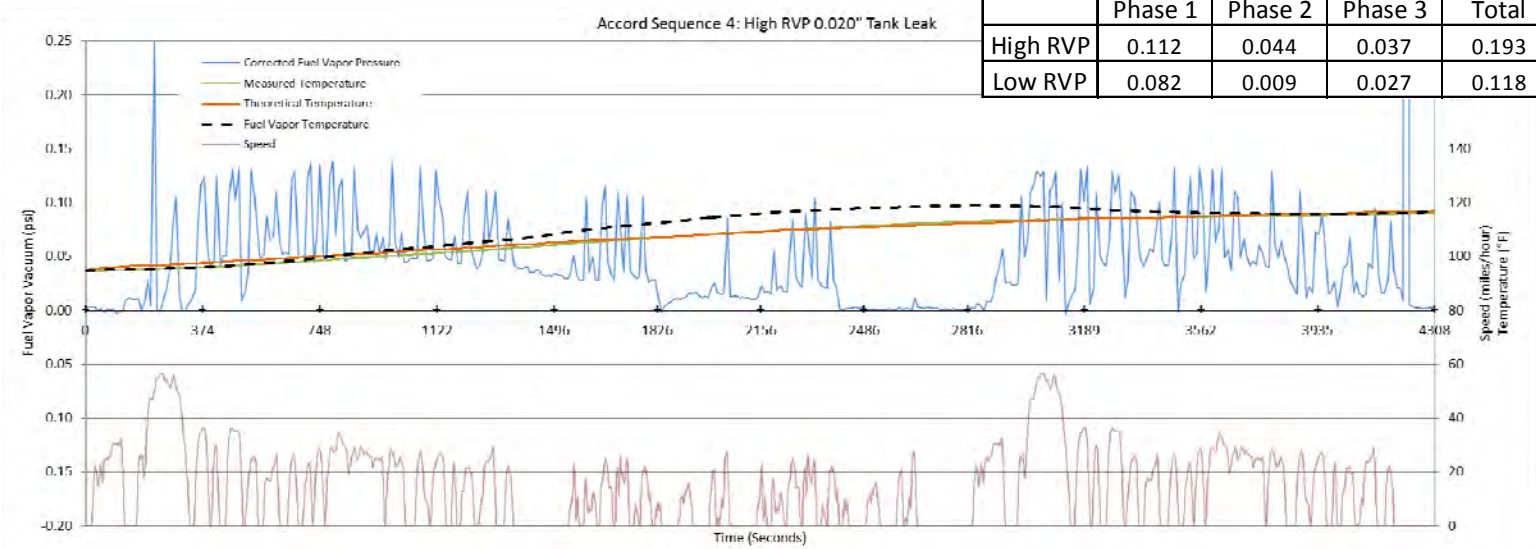
0.040" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.023	0.044	0.014	0.081
Low RVP	0.024	0.017	0.011	0.052

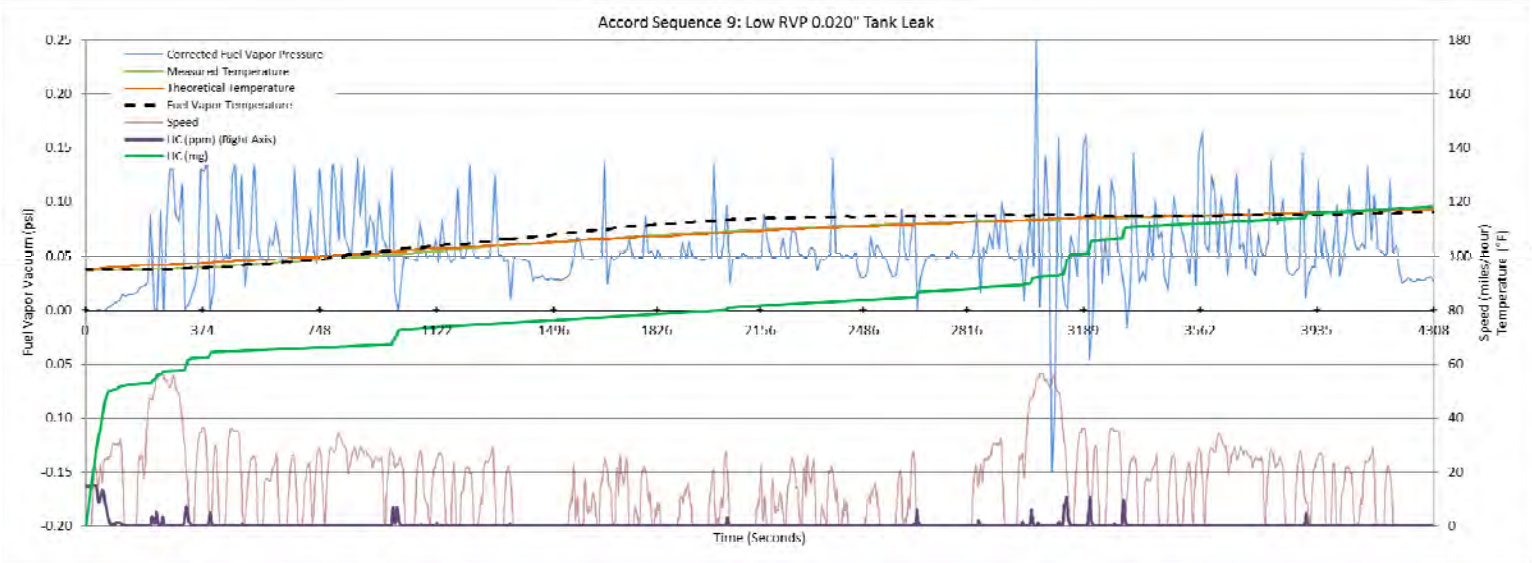




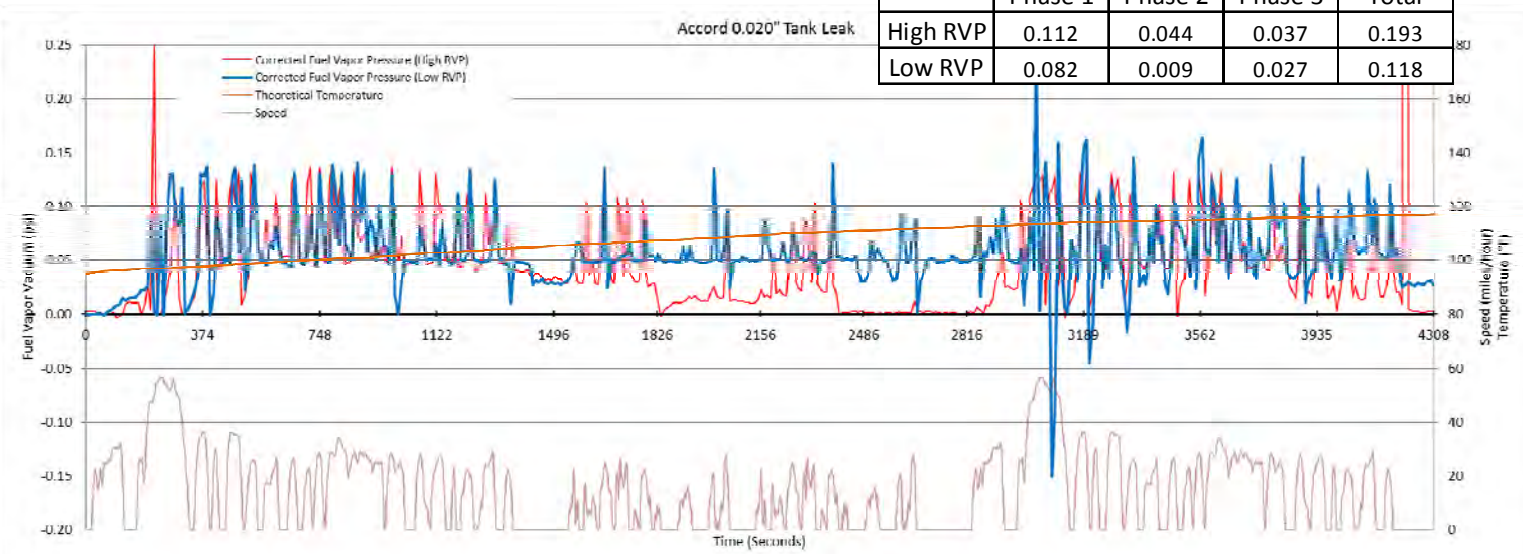
B.2.5 0.020” Tank Leak

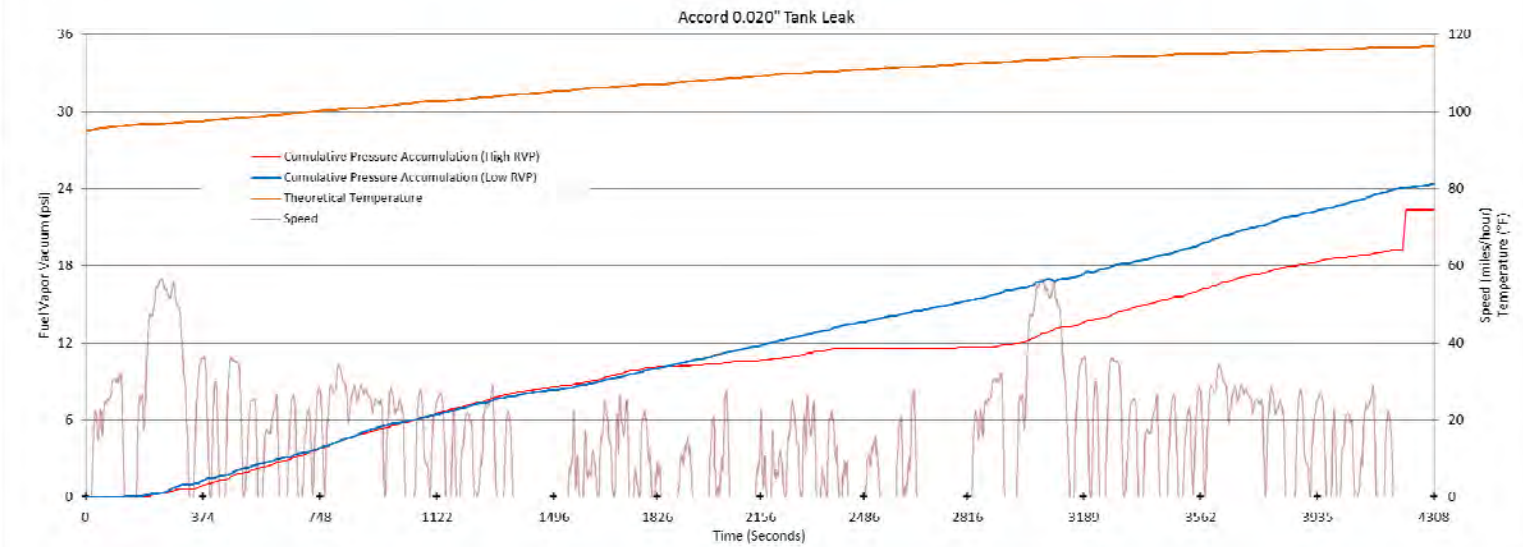
0.020" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.112	0.044	0.037	0.193
Low RVP	0.082	0.009	0.027	0.118





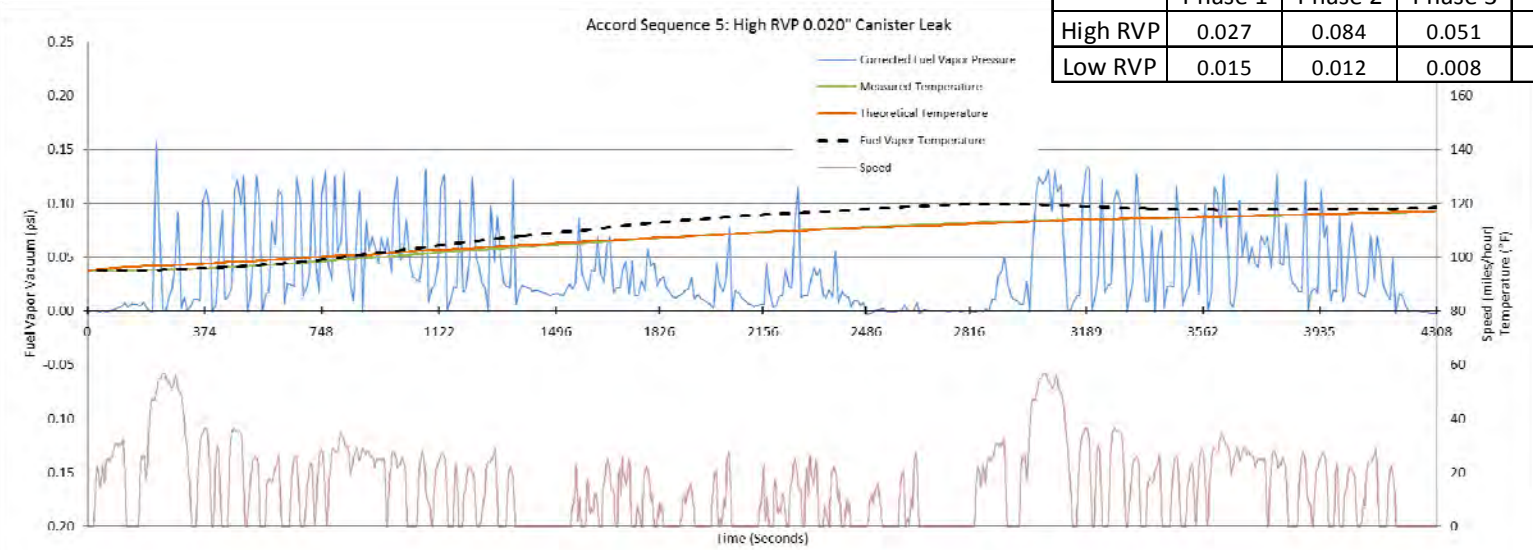
0.020" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.112	0.044	0.037	0.193
Low RVP	0.082	0.009	0.027	0.118

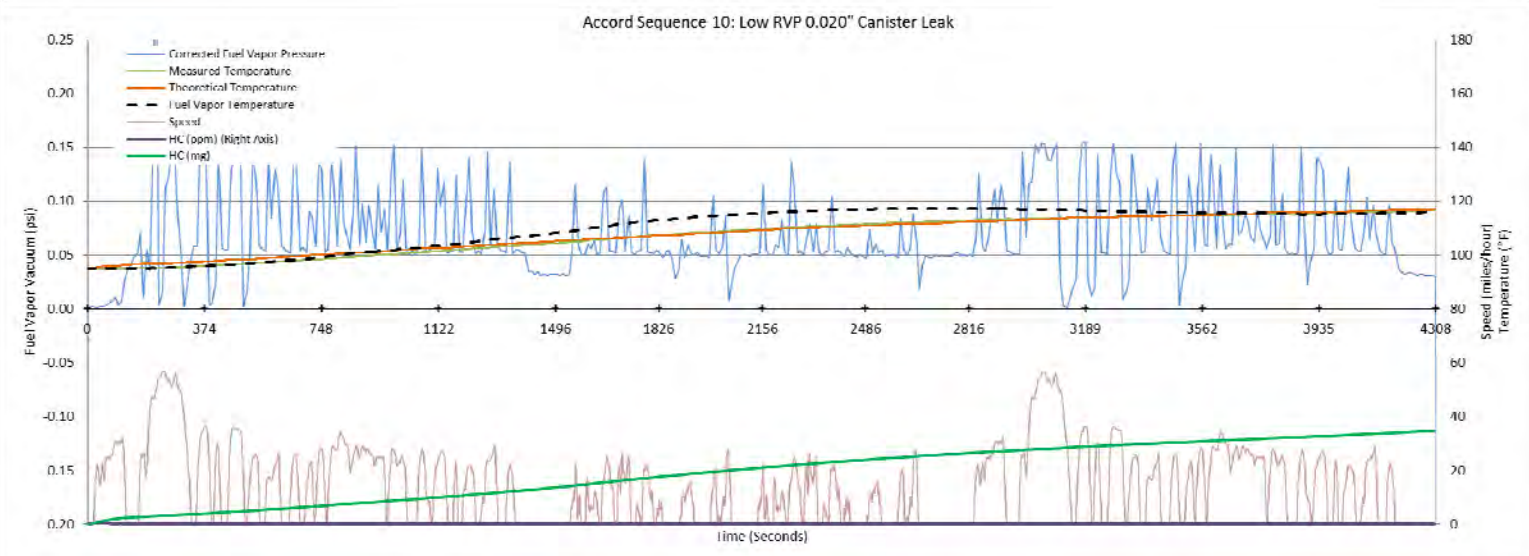




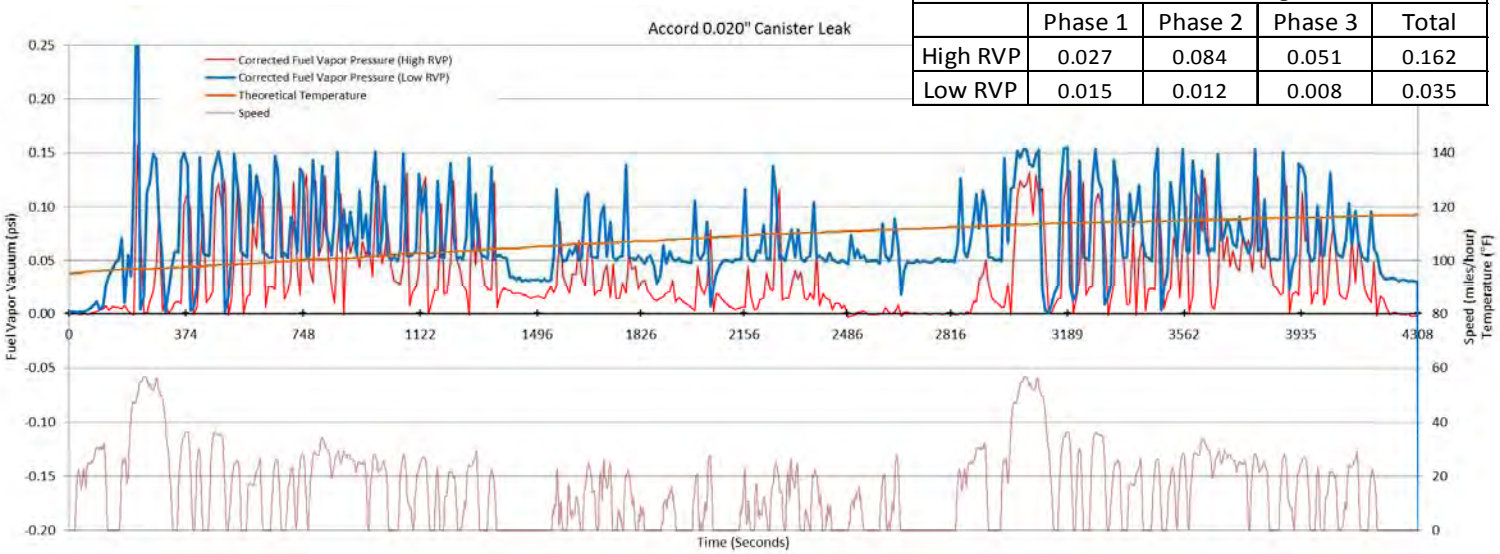
B.2.6 0.020” Canister Leak

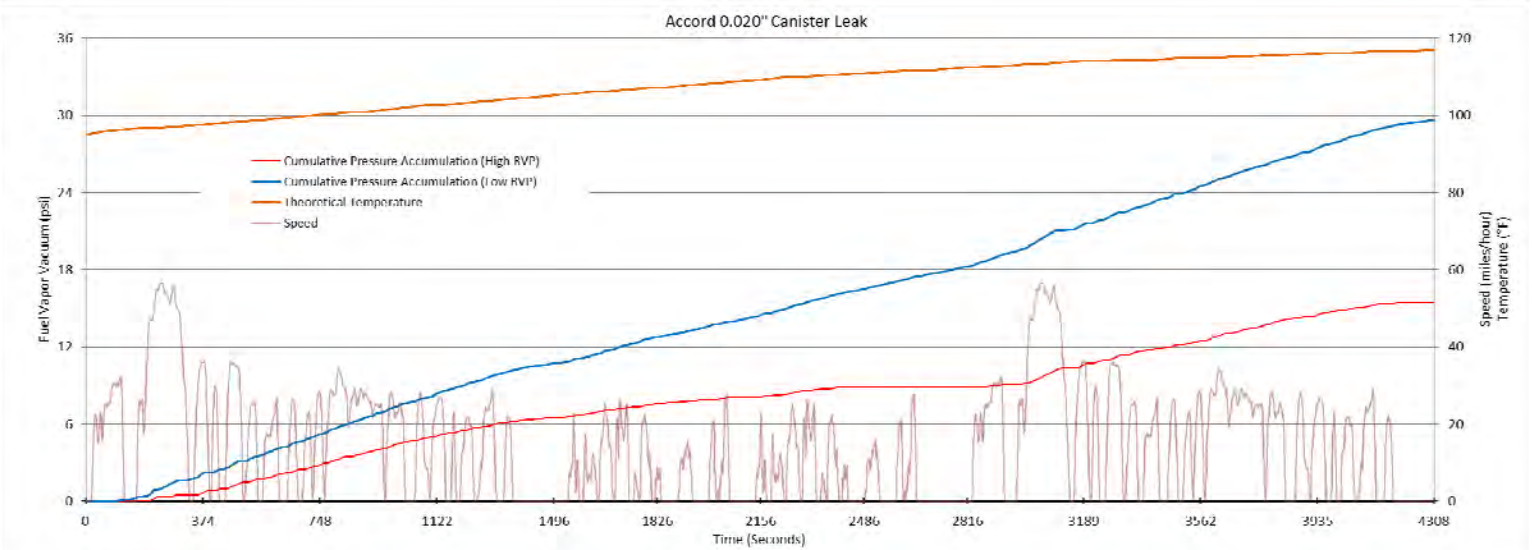
0.020" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.027	0.084	0.051	0.162
Low RVP	0.015	0.012	0.008	0.035





0.020" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.027	0.084	0.051	0.162
Low RVP	0.015	0.012	0.008	0.035



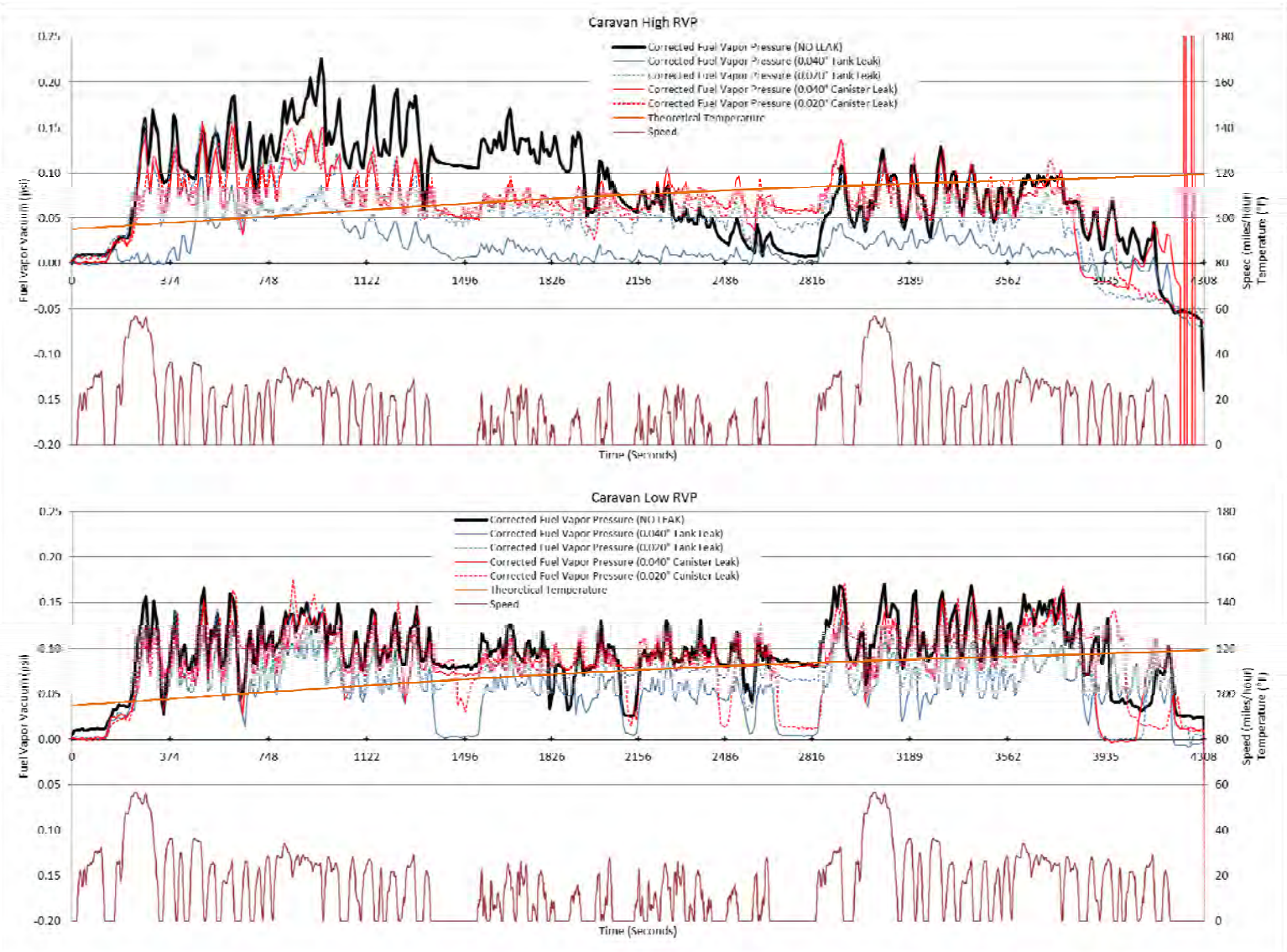


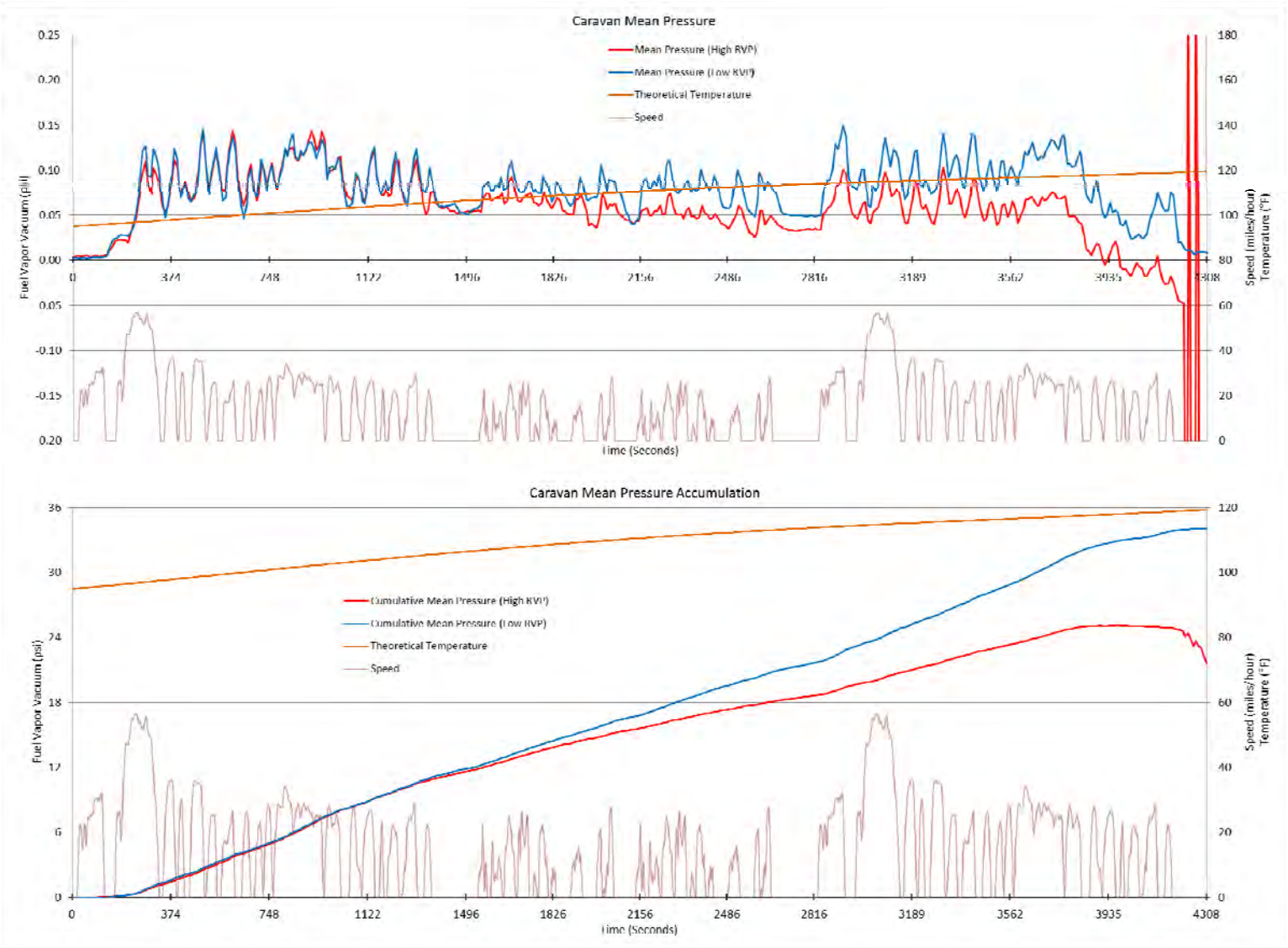
B.3 2007 Dodge Caravan

VIN:	1D4GP24RX7B138127
ENGINE FAMILY:	7CRXT03.8NEO
EVAPORATIVE FAMILY:	7CRXR0177GHA
EMISSIONS STANDARD:	Tier 2 Bin 5
ENGINE DISPLACEMENT:	3.80 Liters
INERTIA WEIGHT:	4750 Pounds
Tank CAPACITY:	20.00 Gallons
ROAD LOAD A:	15.32
ROAD LOAD B:	0.0948
ROAD LOAD C:	0.02662
PEAK FUEL TEMP:	119.3 °F

Sequence:		1	2	3	4	5	6	7	8	9	10
Fuel:		High RVP Fuel (10.0 RVP)					Low RVP Fuel (7.7 RVP)				
Leak location:		No Leak	Tank	Canister	Tank	Canister	No Leak	Tank	Canister	Tank	Canister
Leak Size:		No Leak	0.040	0.040	0.020	0.020	No Leak	0.040	0.040	0.020	0.020
Purge Flow LA-4 Precon.											
Purge Flow LA-92 Precon.											
Results in Grams:											
Running Loss	P1	0.006	0.528	0.063	0.077	0.004	0.003	0.049	0.030	0.042	0.026
	P2	0.001	0.398	0.010	0.018	0.003	0.003	0.010	0.011	0.016	0.005
	P3	0.000	7.128	0.235	2.294	0.018	0.002	0.667	0.063	0.130	0.032
	TOTAL	0.007	8.054	0.308	2.389	0.025	0.008	0.726	0.104	0.188	0.063
Hot Soak		0.127	7.519	0.984	1.492	1.739	0.093	0.955	0.103	0.093	0.101
Static Test	P1	0.104	1.265	0.031	0.037	0.012	0.018	0.133	0.018	0.012	0.016
	P2	0.014	7.915	8.367	3.067	2.001	0.012	5.680	5.604	2.276	1.920
	TOTAL	0.117	9.181	8.398	3.103	2.013	0.030	5.812	5.622	2.287	1.937
RL + HS + ST		0.251	24.754	9.690	6.984	3.777	0.131	7.493	5.829	2.568	2.101

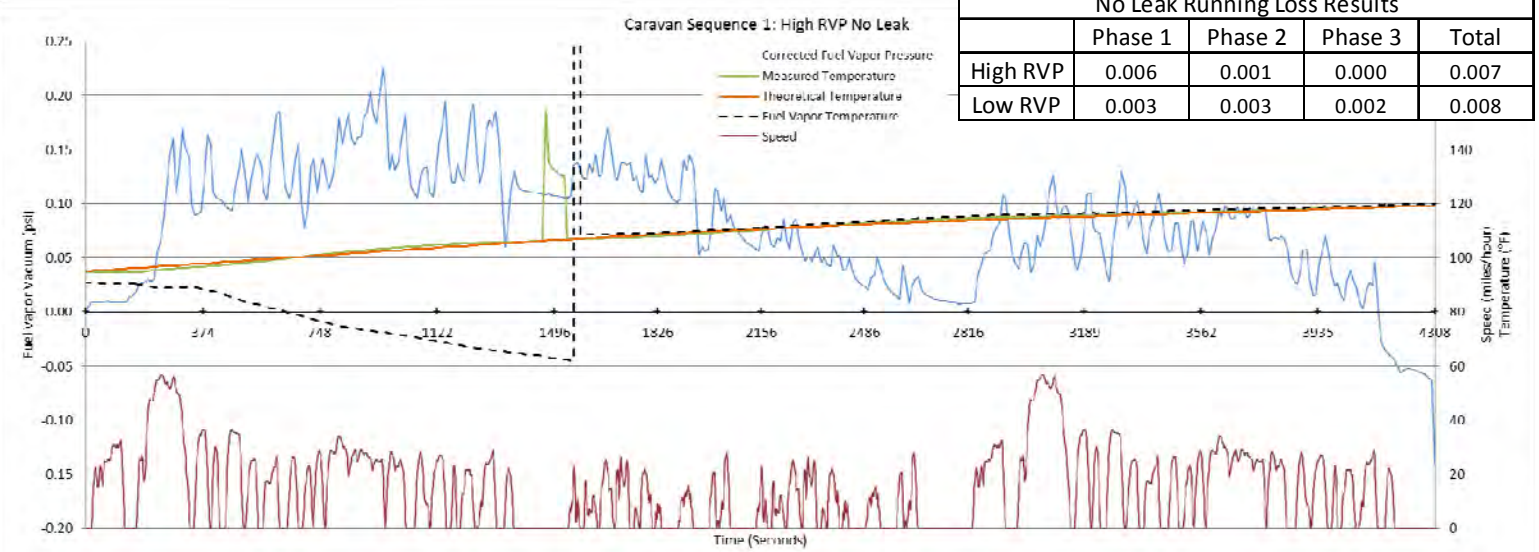
B.3.1 Running Loss Fuel Vapor Pressure Comparisons

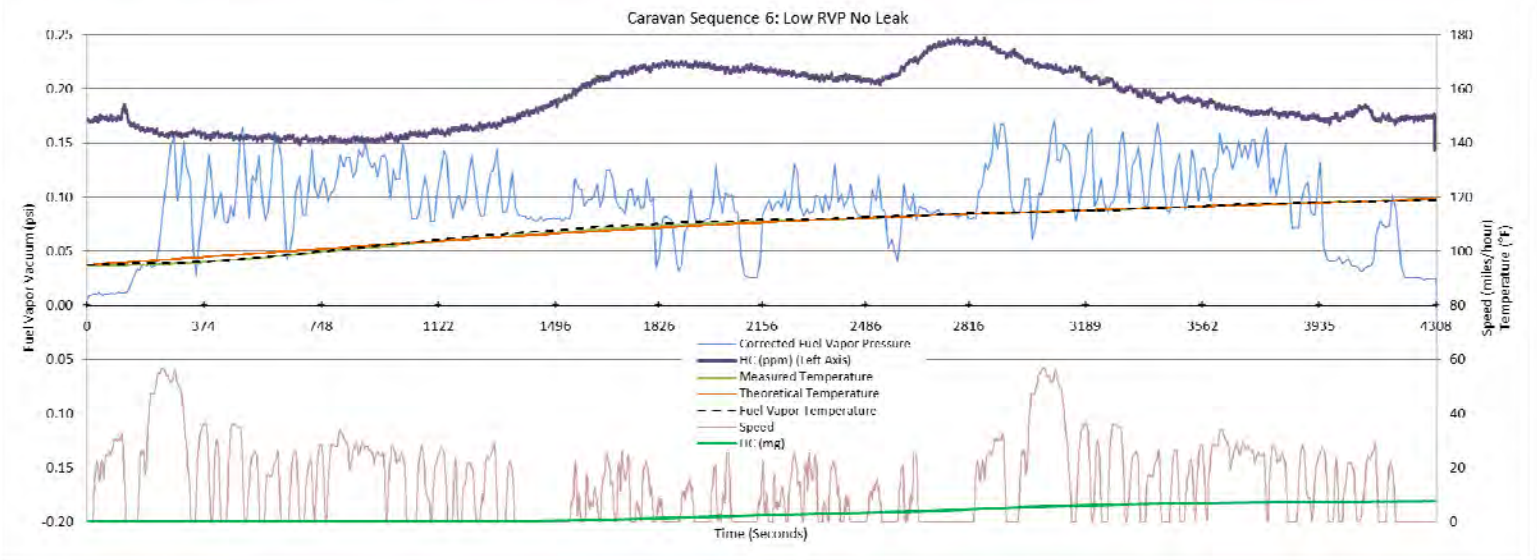



Caravan Mean Pressure
Mean Pressure (High RVP)
Mean Pressure (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)
Caravan Mean Pressure Accumulation
Cumulative Mean Pressure (High RVP)
Cumulative Mean Pressure (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)

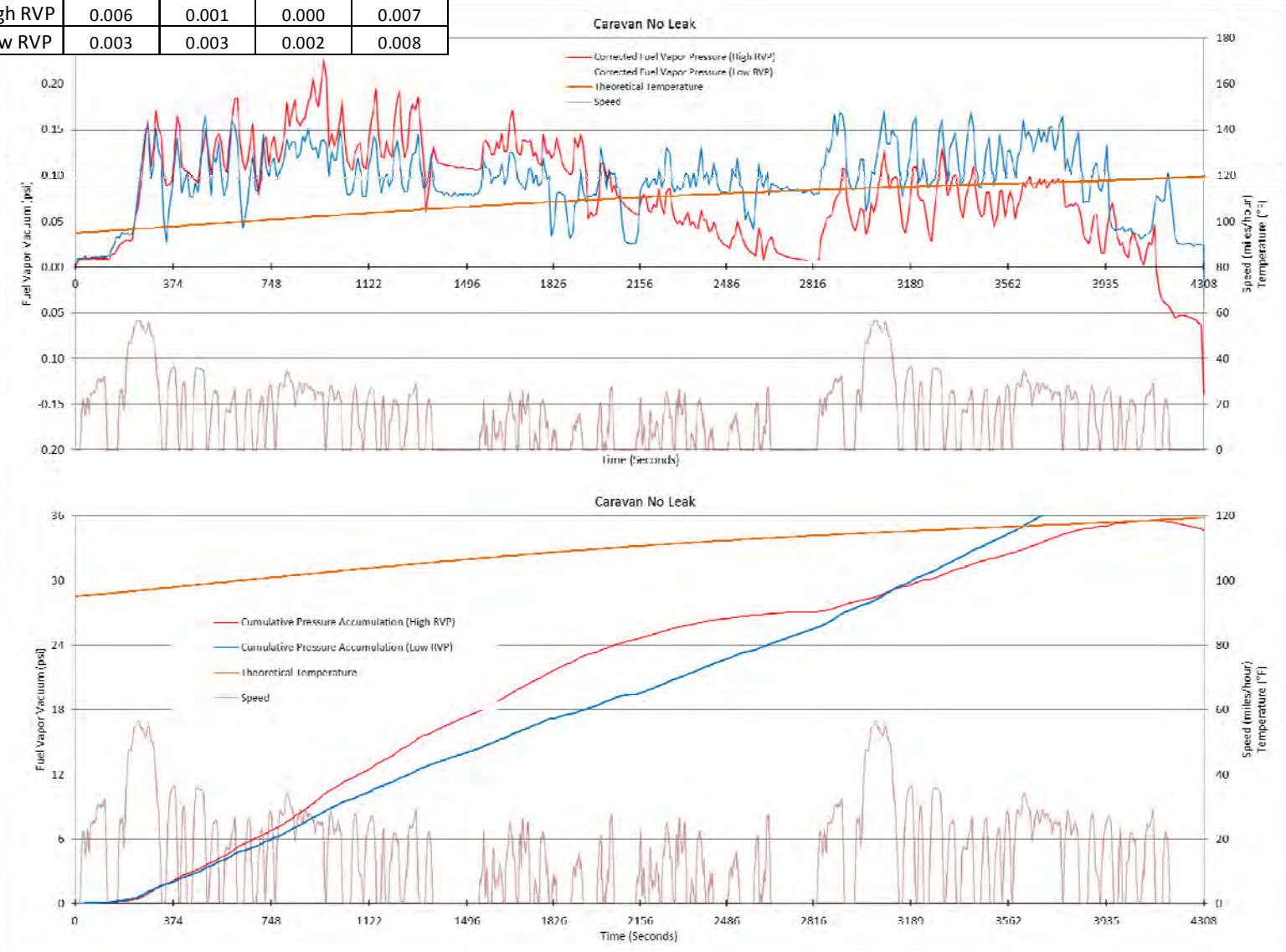
B.3.2 No Leak

No Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.006	0.001	0.000	0.007
Low RVP	0.003	0.003	0.002	0.008



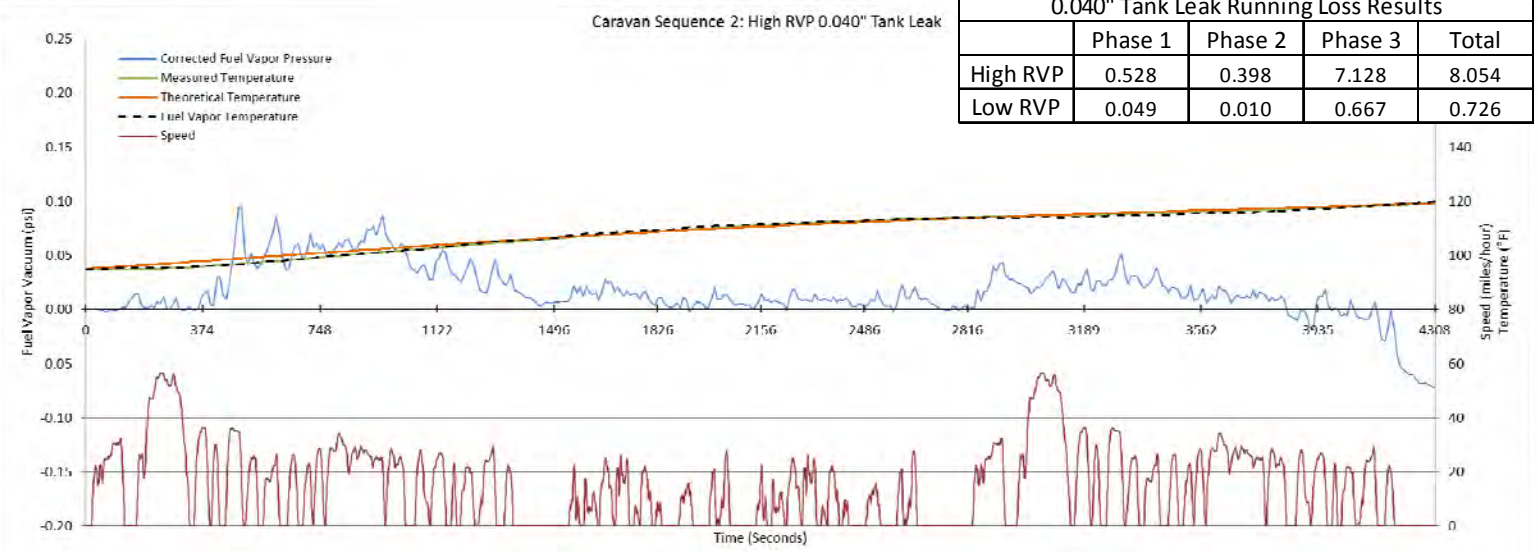


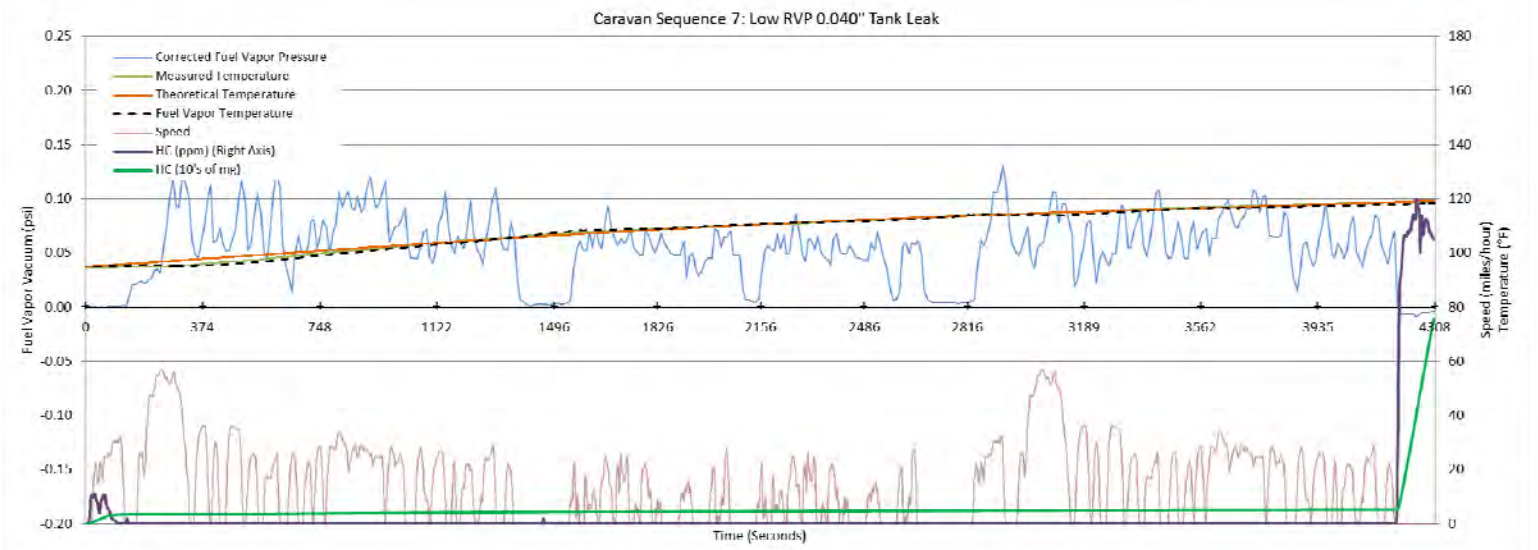
No Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.006	0.001	0.000	0.007
Low RVP	0.003	0.003	0.002	0.008



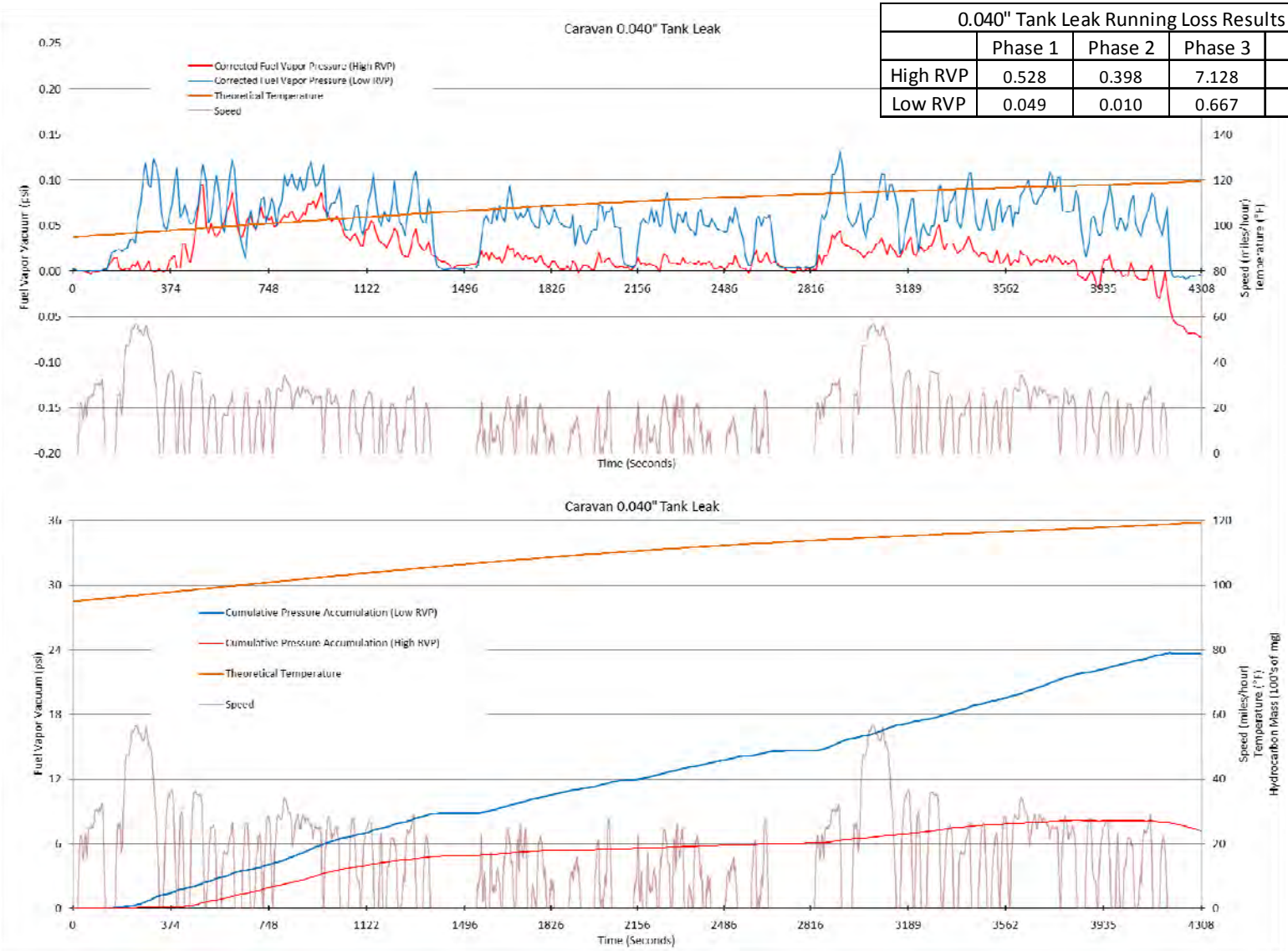
B.3.3 0.040” Tank Leak

0.040" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.528	0.398	7.128	8.054
Low RVP	0.049	0.010	0.667	0.726



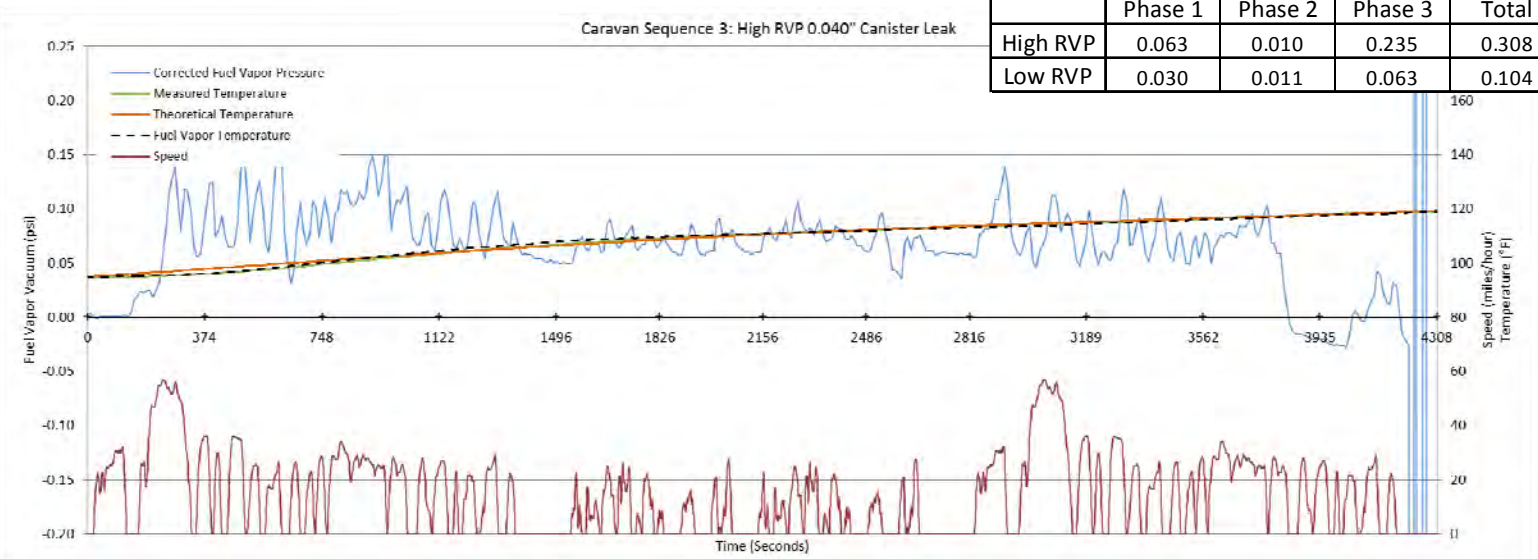


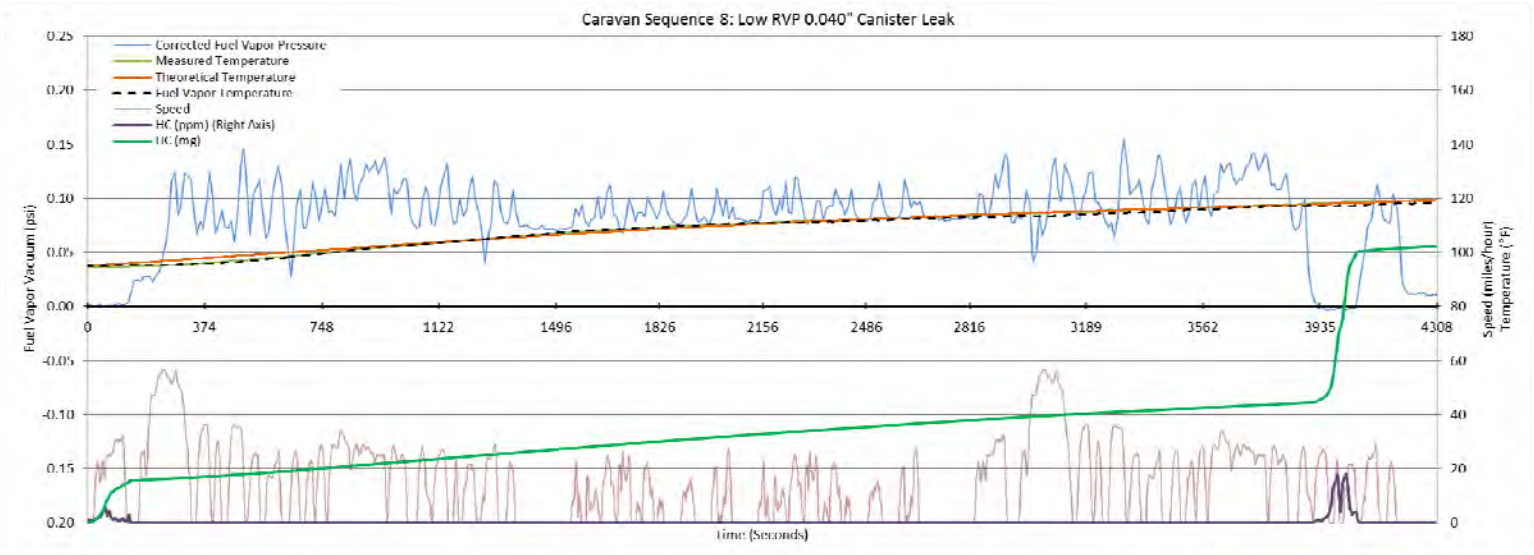
0.040" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.528	0.398	7.128	8.054
Low RVP	0.049	0.010	0.667	0.726



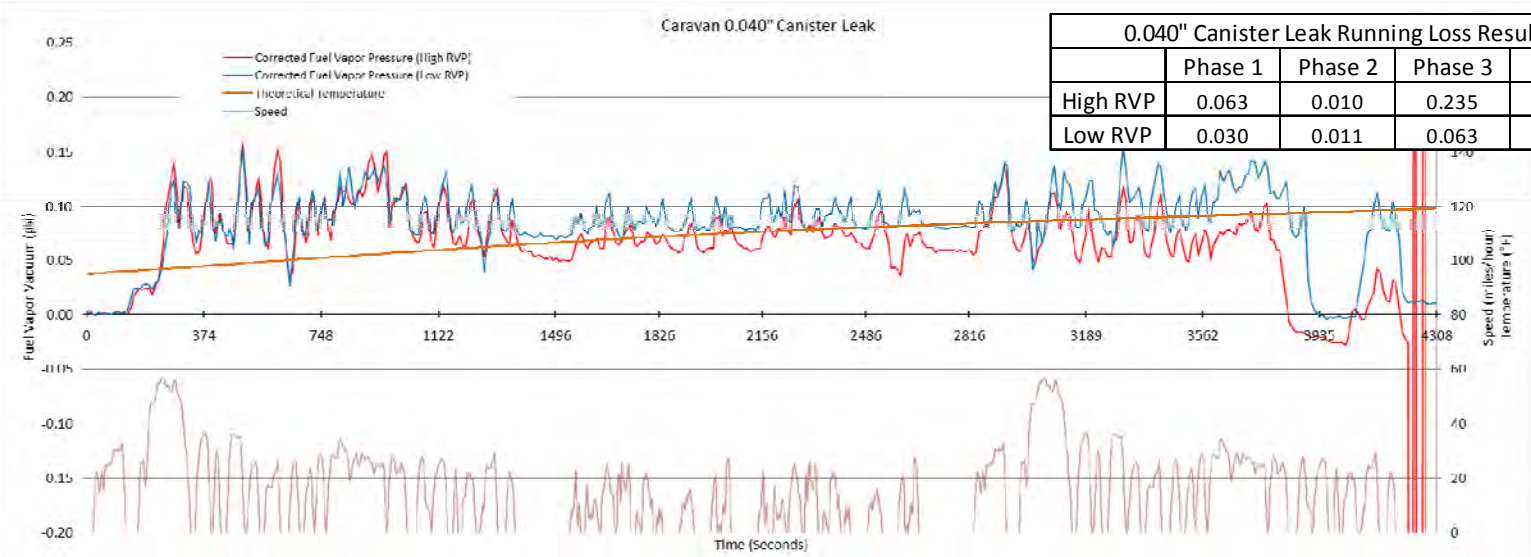
B.3.4 0.040” Canister Leak

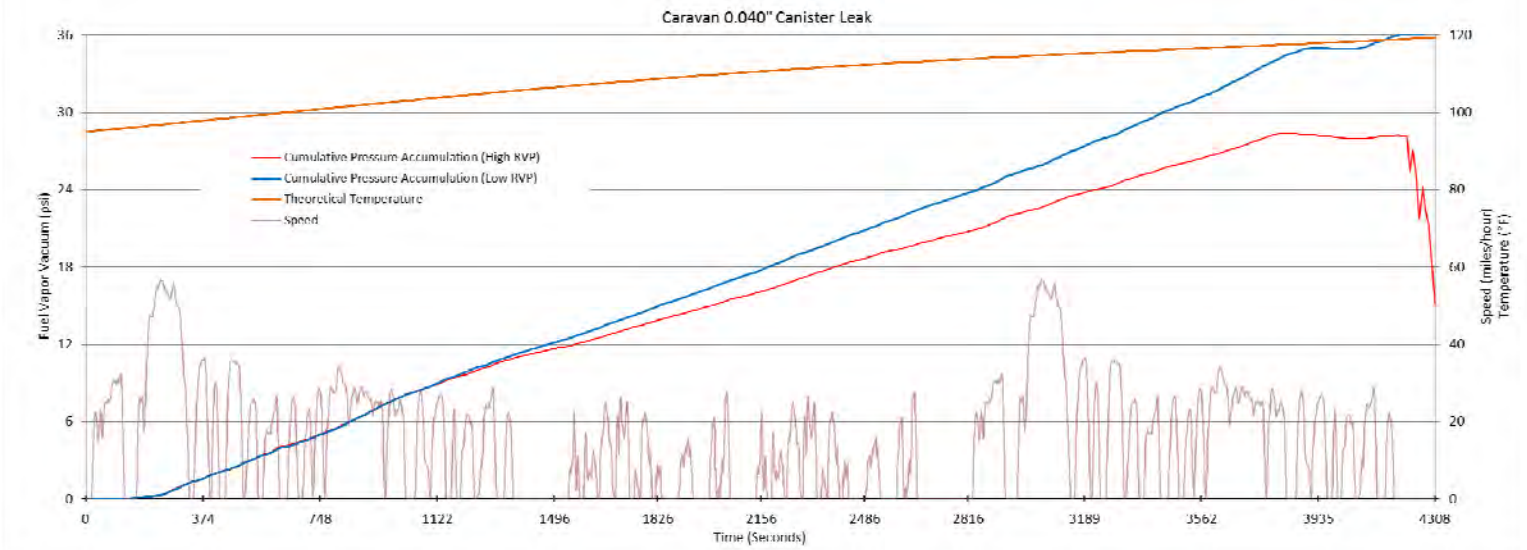
0.040" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.063	0.010	0.235	0.308
Low RVP	0.030	0.011	0.063	0.104





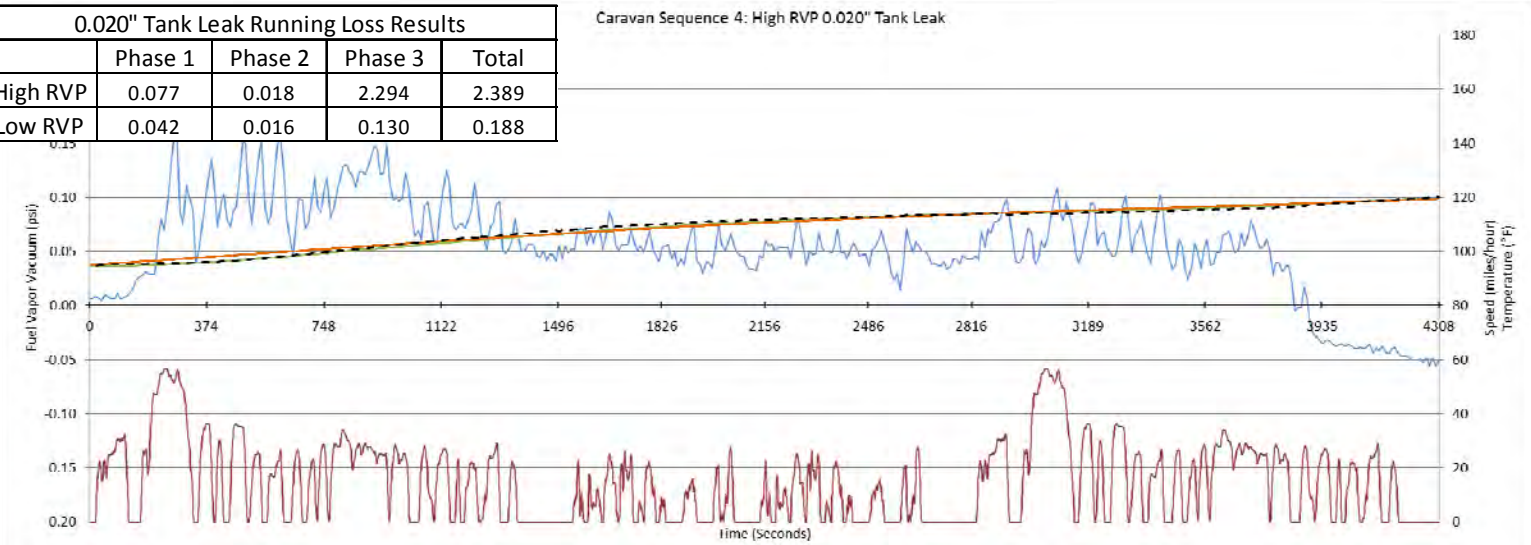
0.040" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.063	0.010	0.235	0.308
Low RVP	0.030	0.011	0.063	0.104

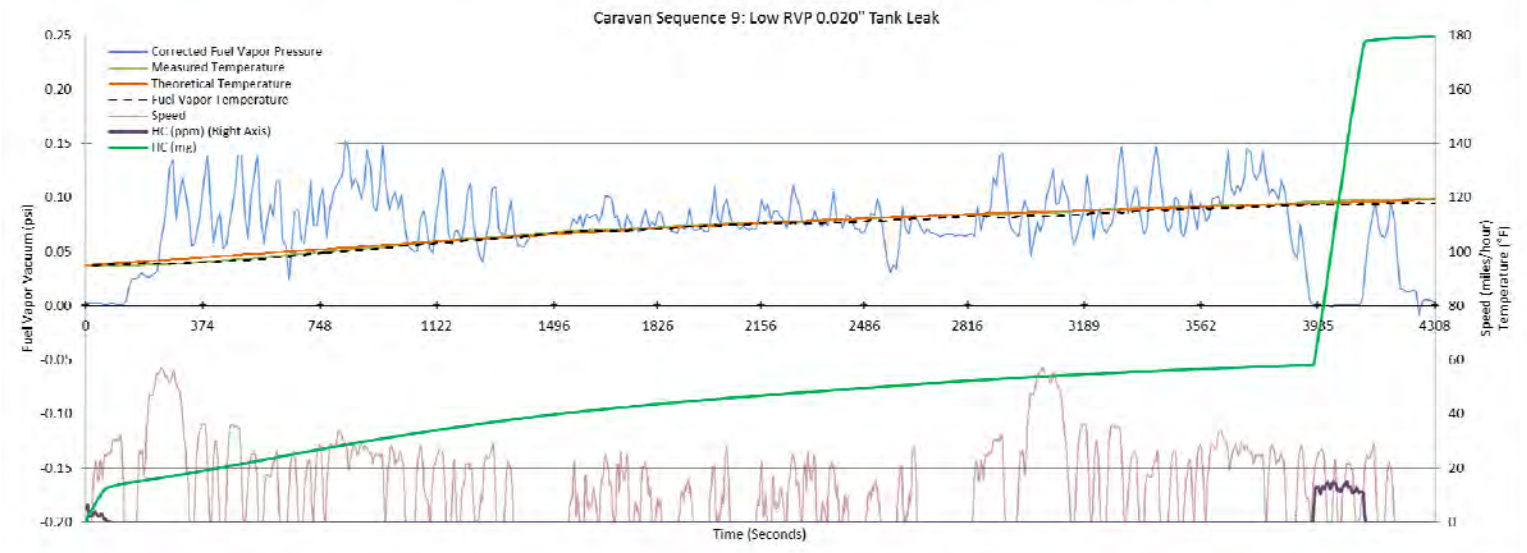




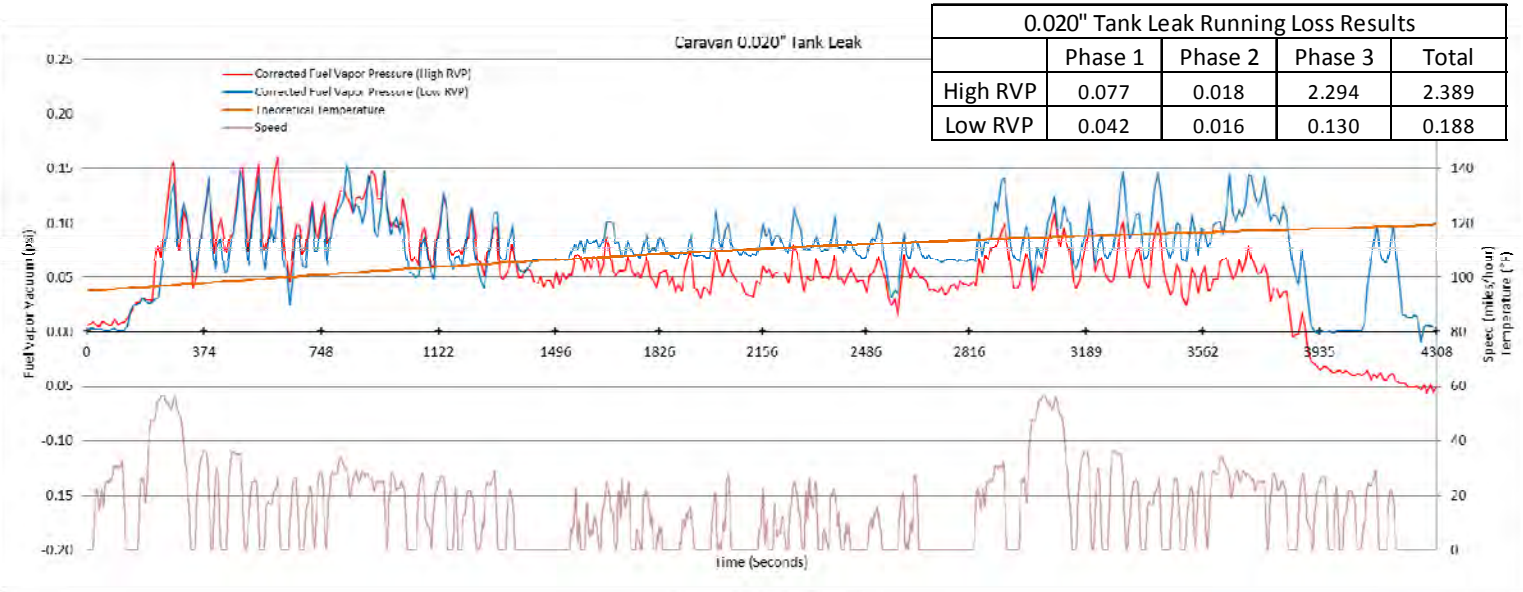
B.3.5 0.020” Tank Leak

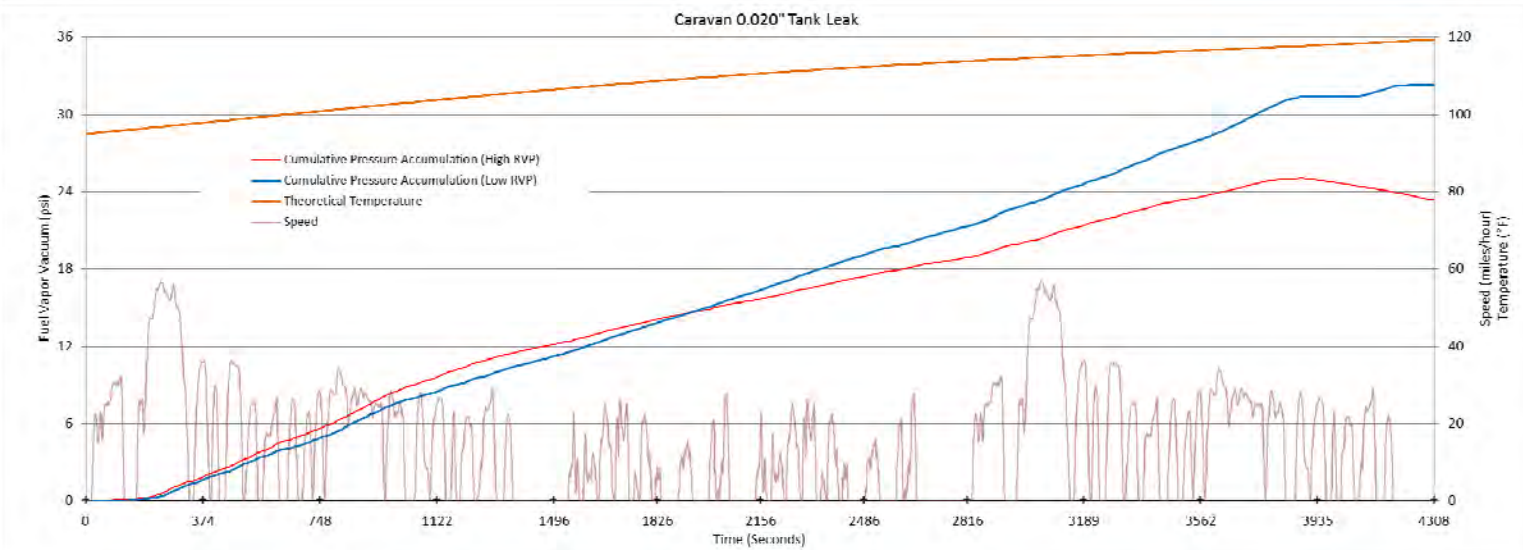
0.020" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.077	0.018	2.294	2.389
Low RVP	0.042	0.016	0.130	0.188





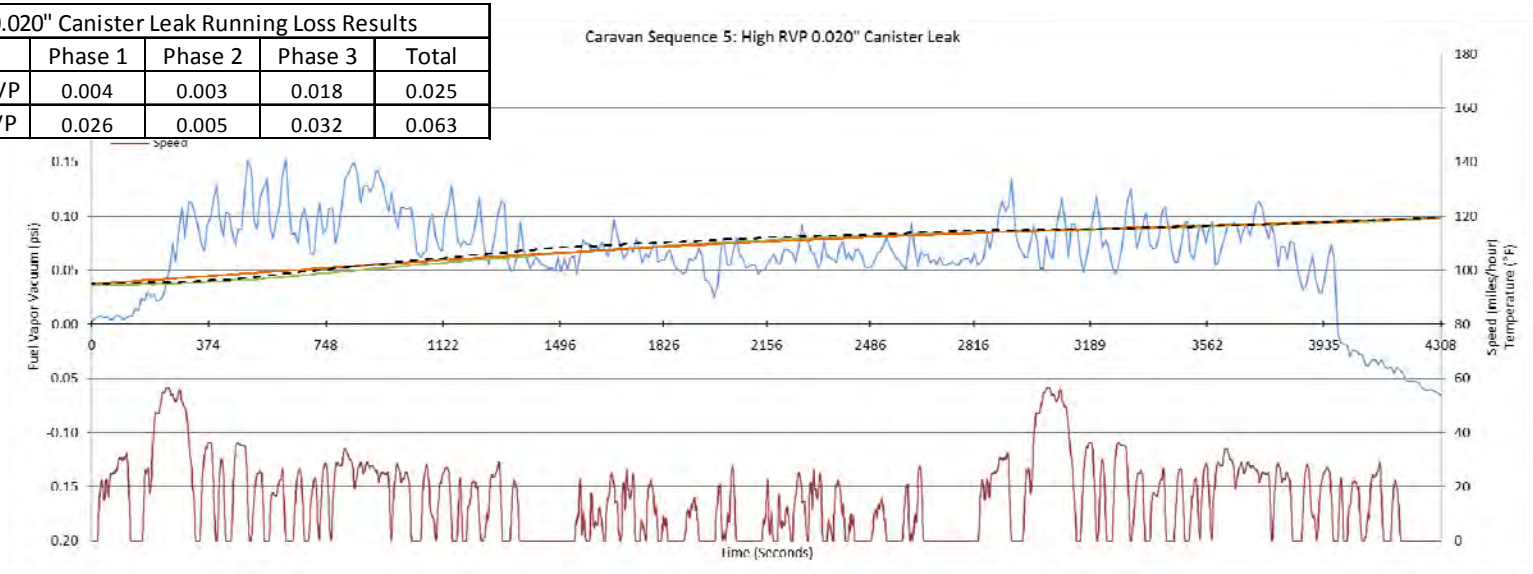
0.020" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.077	0.018	2.294	2.389
Low RVP	0.042	0.016	0.130	0.188

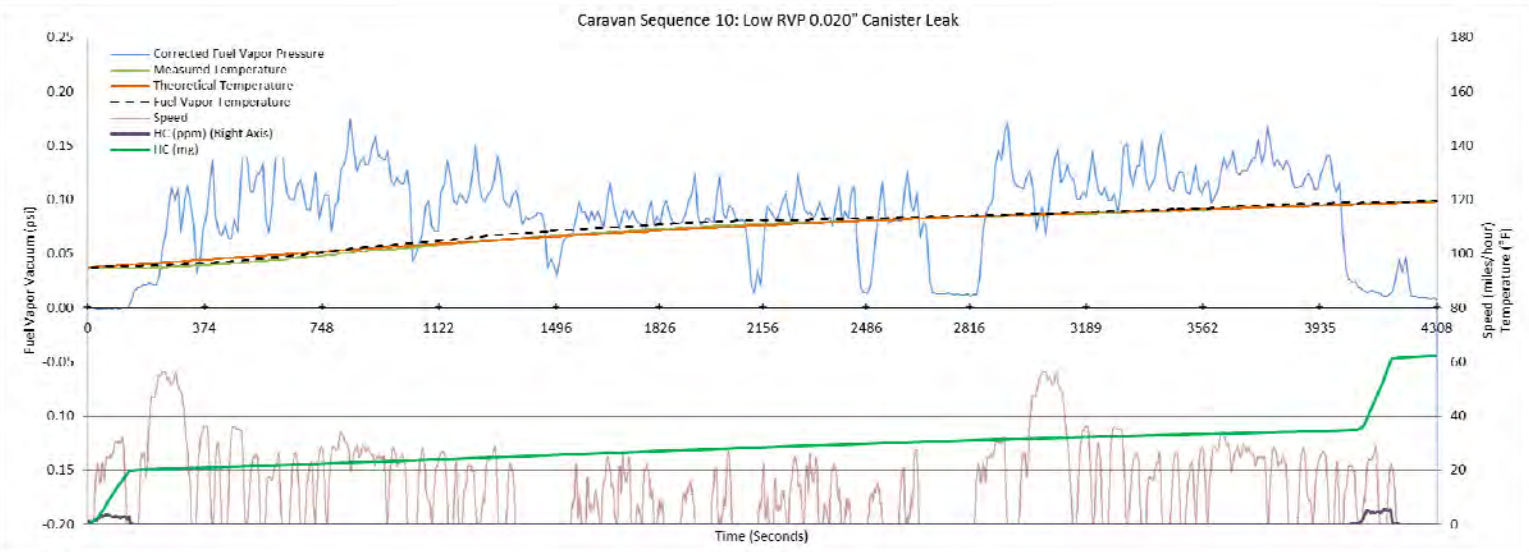




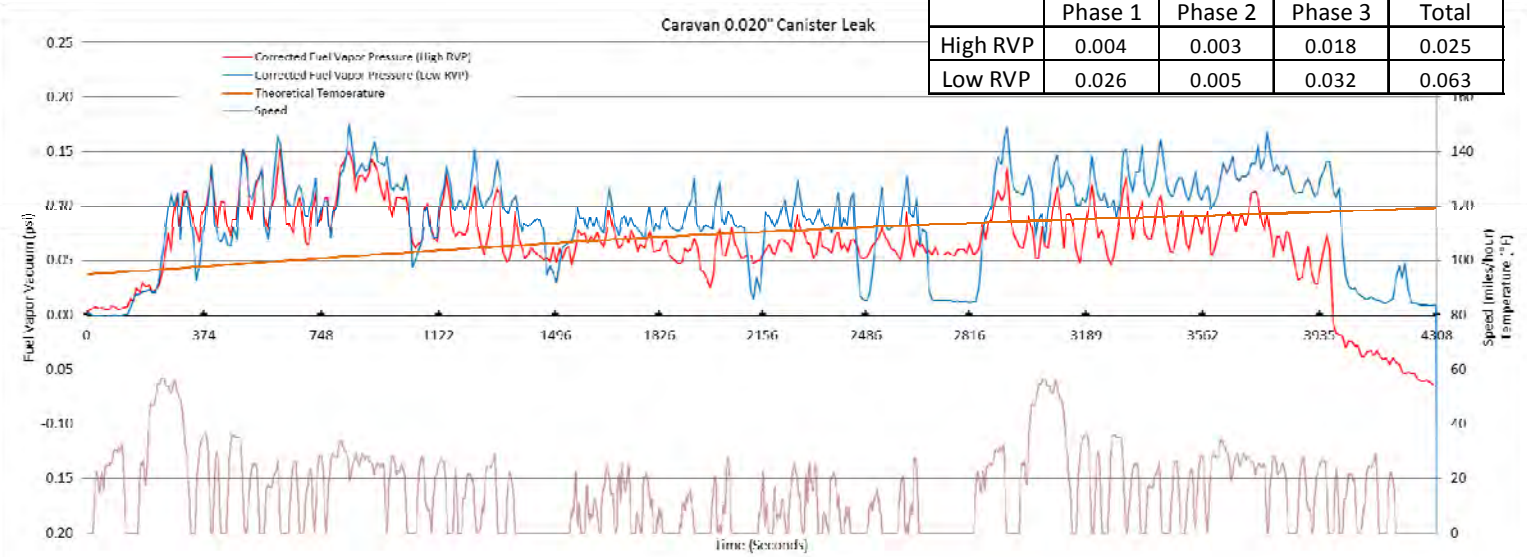
B.3.6 0.020” Canister Leak

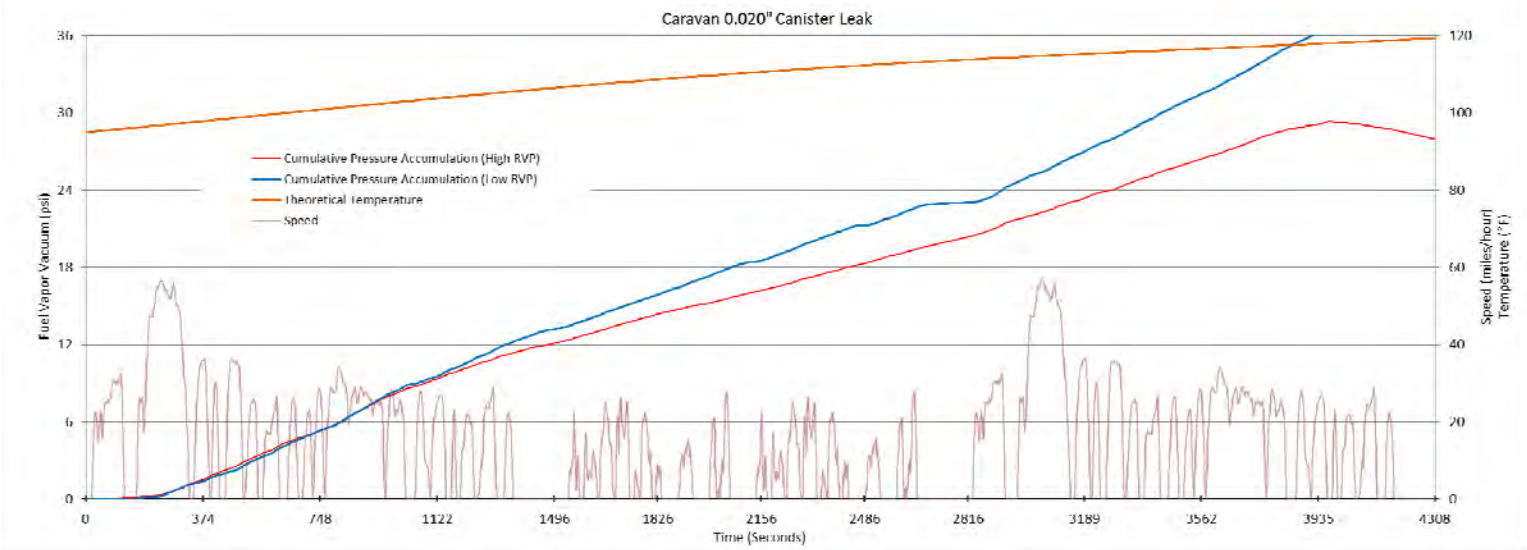
0.020" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.004	0.003	0.018	0.025
Low RVP	0.026	0.005	0.032	0.063





0.020" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.004	0.003	0.018	0.025
Low RVP	0.026	0.005	0.032	0.063



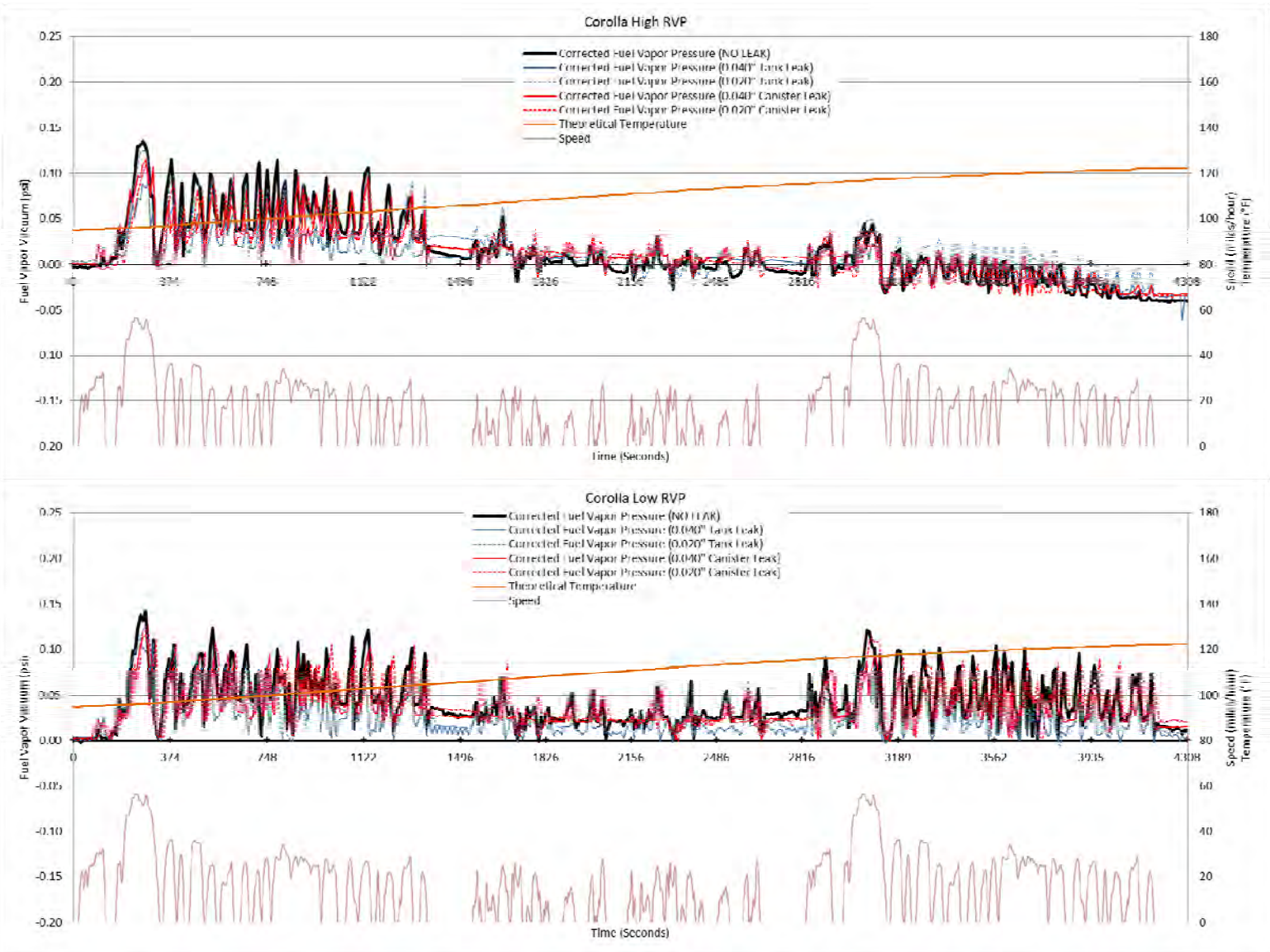


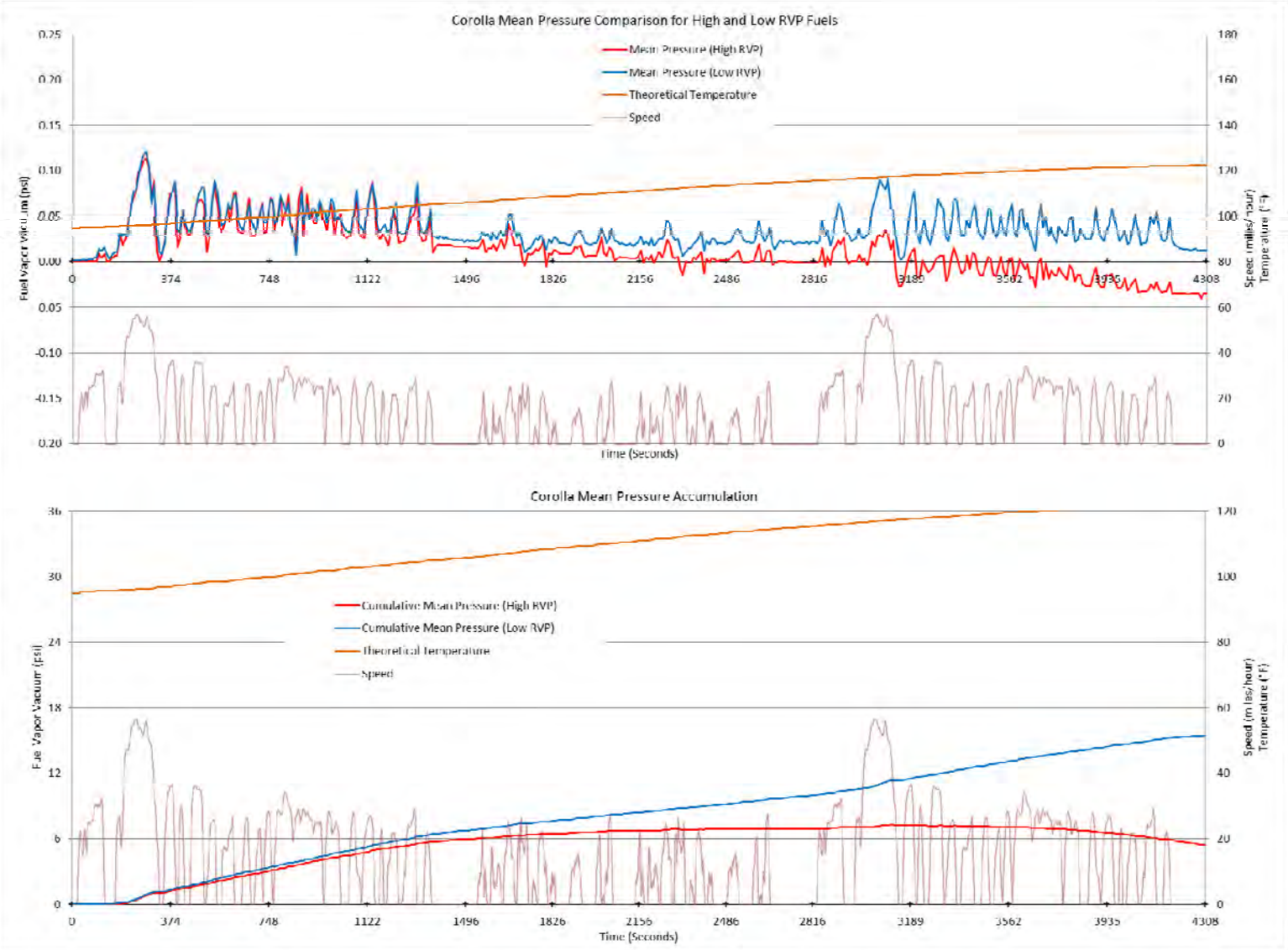
B.4 2009 Toyota Corolla

VIN:	2T1BU40E89C145385	
ENGINE FAMILY:	9TYXV01.8BEA	
EVAPORATIVE FAMILY:	9TYXR0115P12	
EMISSIONS STANDARD:	Tier 2 Bin 5	
ENGINE DISPLACEMENT:	1.80	Liters
INERTIA WEIGHT:	3250	Pounds
Tank CAPACITY:	13.25	Gallons
ROAD LOAD A:	11.93	
ROAD LOAD B:	0.0068	
ROAD LOAD C:	0.02276	
PEAK FUEL TEMP:	122.4 °F	

Sequence:		1	2	3	4	5	6	7	8	9	10
Fuel:		High RVP Fuel (10.0 RVP)					Low RVP Fuel (7.7 RVP)				
Leak location:		No Leak	Tank	Canister	Tank	Canister	No Leak	Tank	Canister	Tank	Canister
Leak Size:		No Leak	0.040	0.040	0.020	0.020	No Leak	0.040	0.040	0.020	0.020
Purge Flow LA-4 Precon.											
Purge Flow LA-92 Precon.											
Results in Grams:											
Running Loss	P1	0.003	0.749	0.034	0.166	0.096	0.001	0.328	0.058	0.050	0.016
	P2	0.002	0.951	0.685	1.648	0.348	0.001	0.358	0.065	0.019	0.020
	P3	0.002	12.550	9.436	2.778	3.497	0.002	0.916	0.040	0.055	0.016
	TOTAL	0.007	14.250	10.155	4.592	3.941	0.004	1.602	0.163	0.124	0.052
Hot Soak		0.164	3.168	0.657	0.593	0.734	0.089	0.238	0.104	0.111	0.109
Static Test	P1	0.024	1.464	0.032	1.357	0.630	0.017	0.770	0.561	0.642	0.059
	P2	0.036	7.460	6.157	2.795	2.526	0.013	6.116	6.945	2.050	2.485
	TOTAL	0.060	8.924	6.190	4.152	3.157	0.029	6.886	7.505	2.692	2.544
RL + HS + ST		0.231	26.342	17.002	9.337	7.832	0.122	8.726	7.772	2.927	2.705

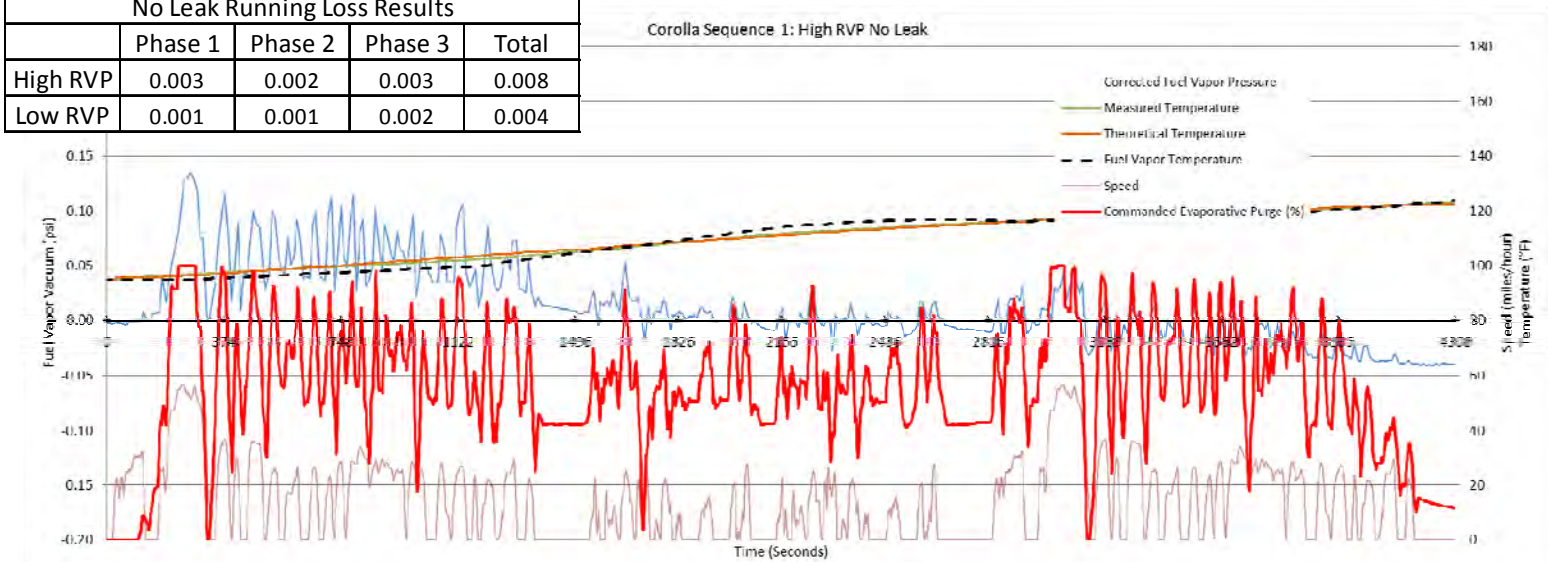
B.4.1 Running Loss Fuel Vapor Pressure Comparisons

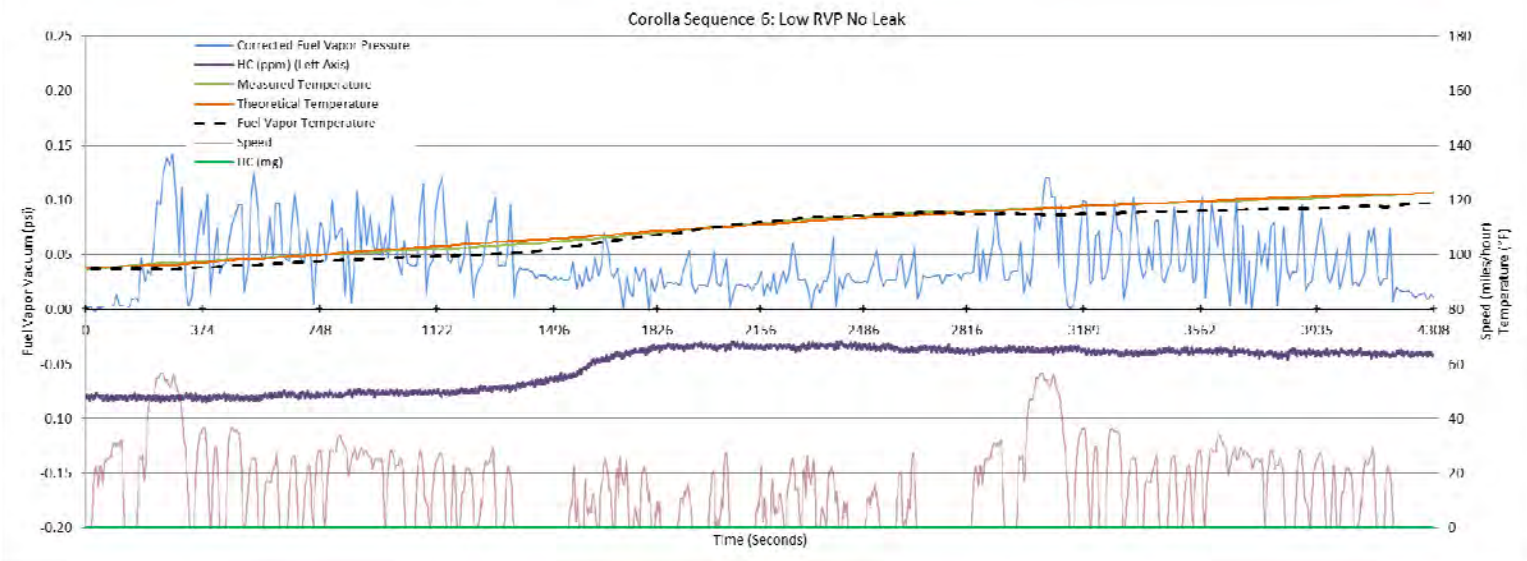



Corolla Mean Pressure Comparison for High and Low RVP Fuels
Mean Pressure (High RVP)
Mean Pressure (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)
Corolla Mean Pressure Accumulation
Cumulative Mean Pressure (High RVP)
Cumulative Mean Pressure (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)

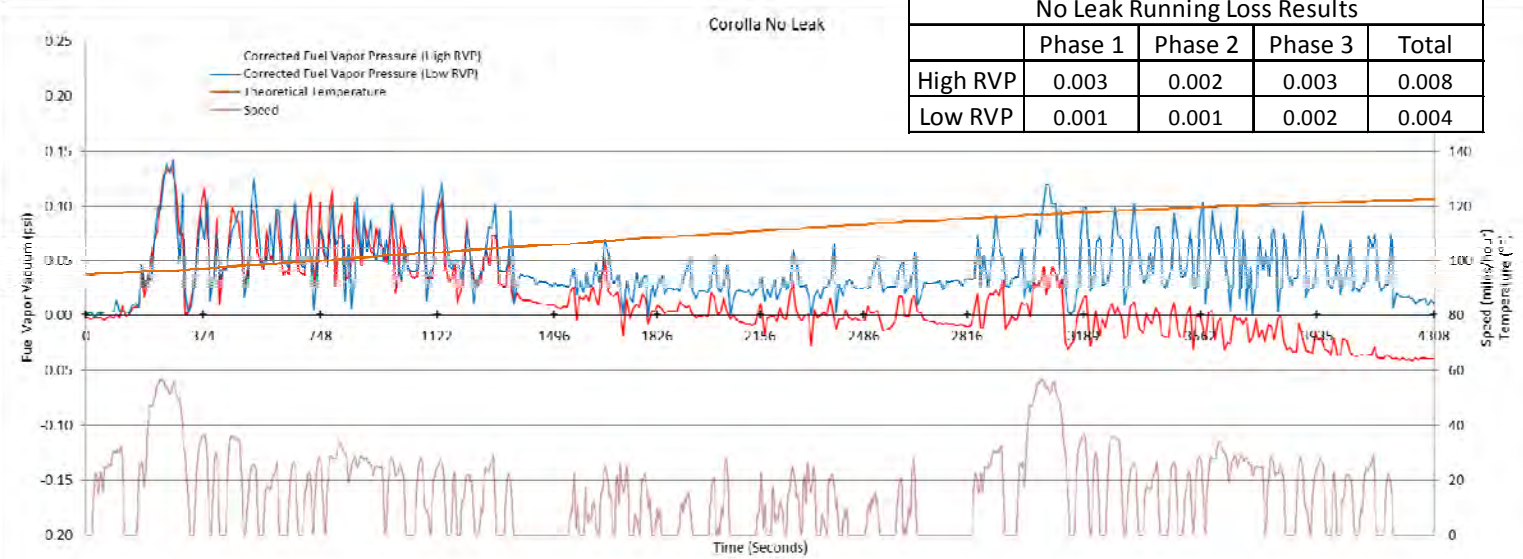
B.4.2 No Leak

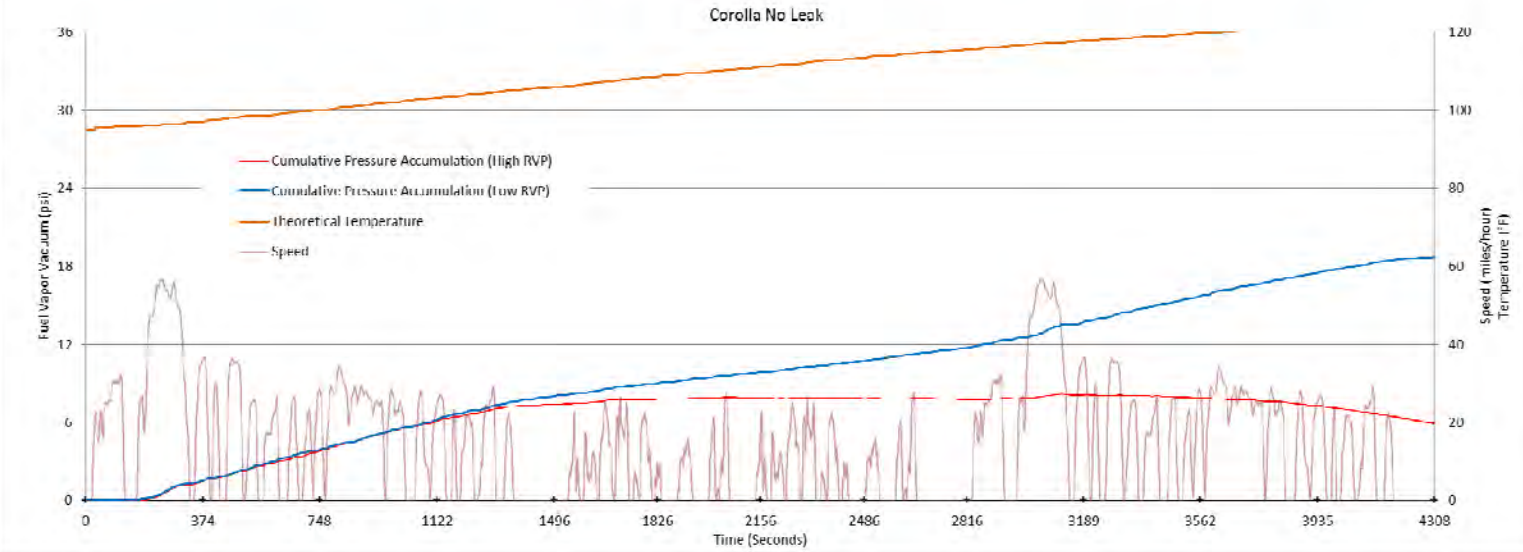
No Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.003	0.002	0.003	0.008
Low RVP	0.001	0.001	0.002	0.004





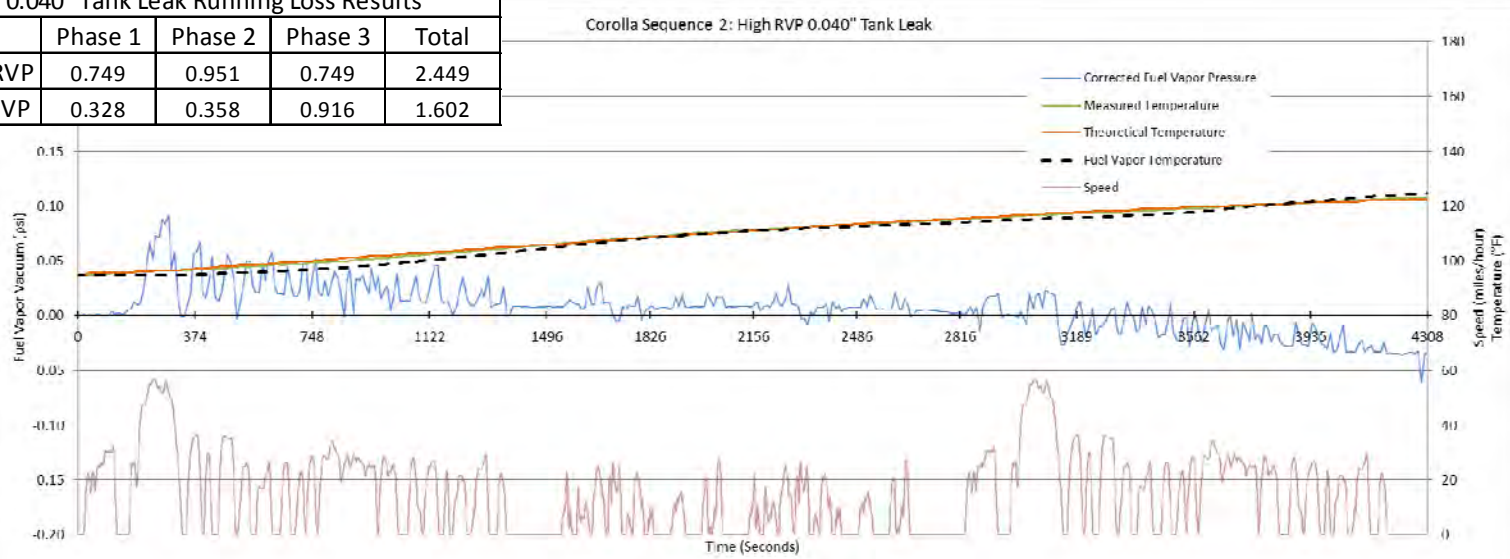
No Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.003	0.002	0.003	0.008
Low RVP	0.001	0.001	0.002	0.004

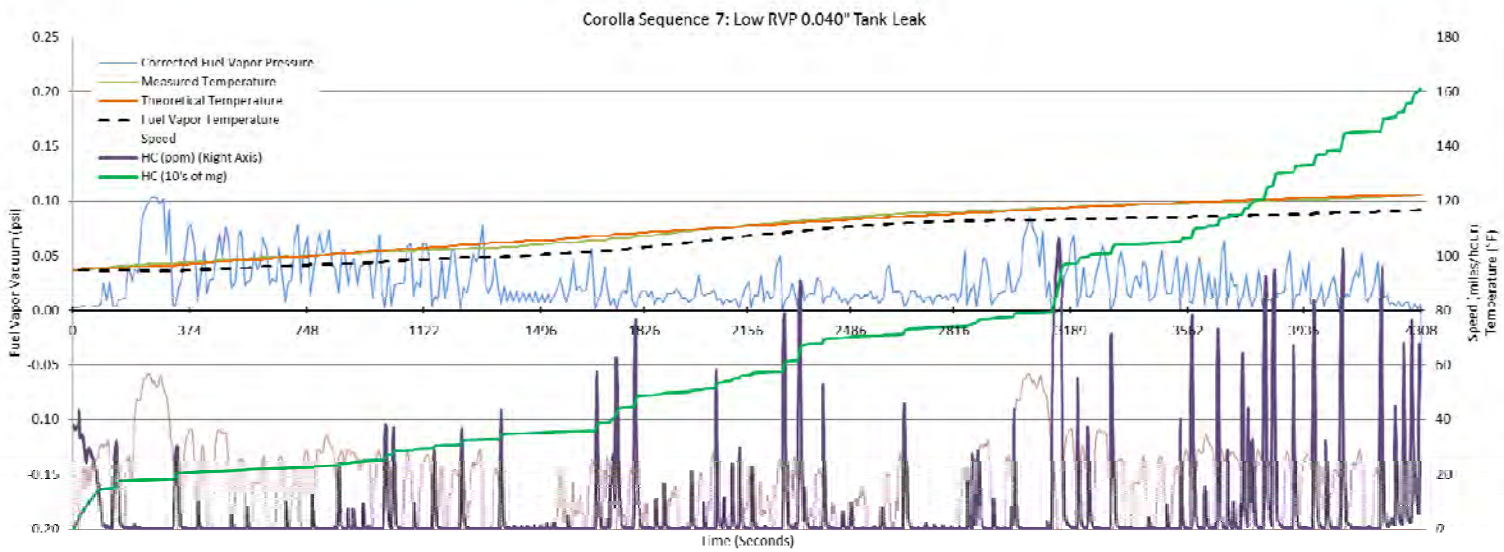


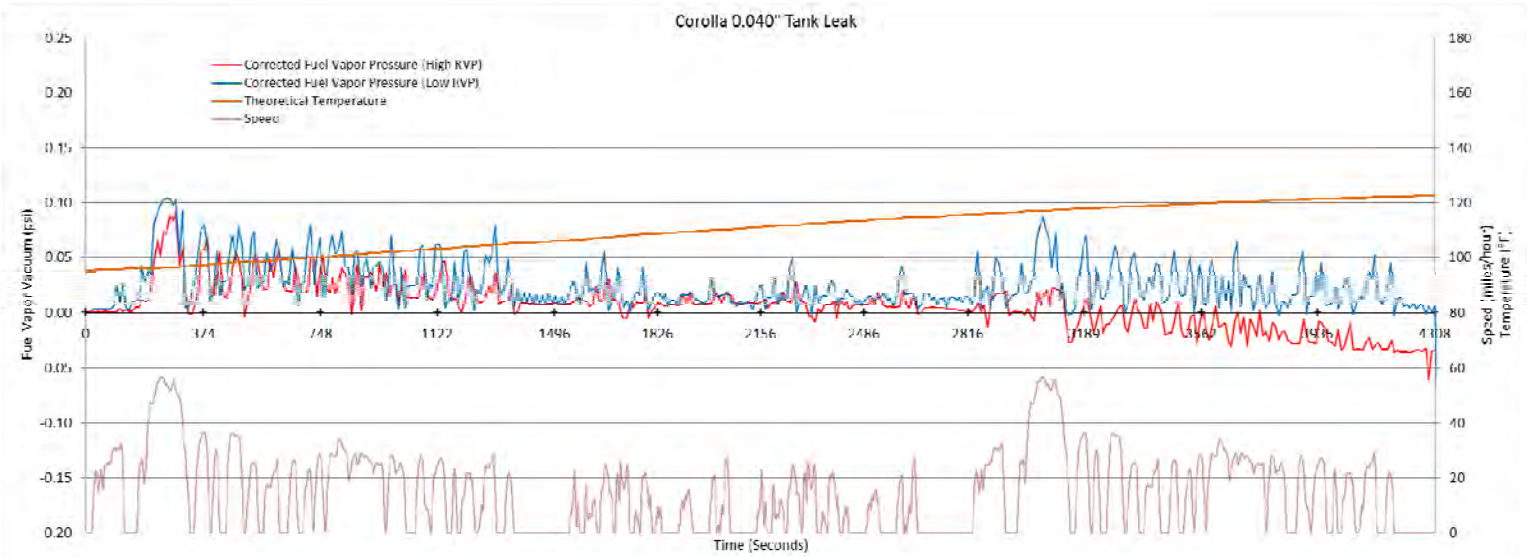


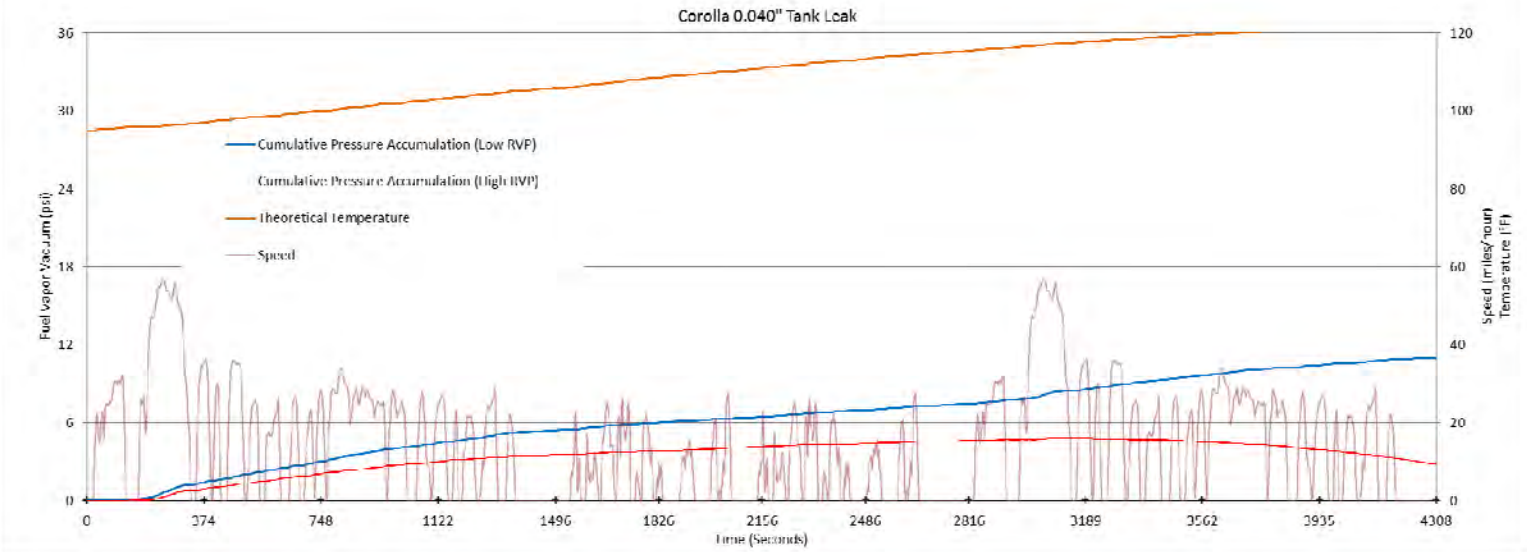
B.4.3 0.040” Tank Leak

0.040" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.749	0.951	0.749	2.449
Low RVP	0.328	0.358	0.916	1.602



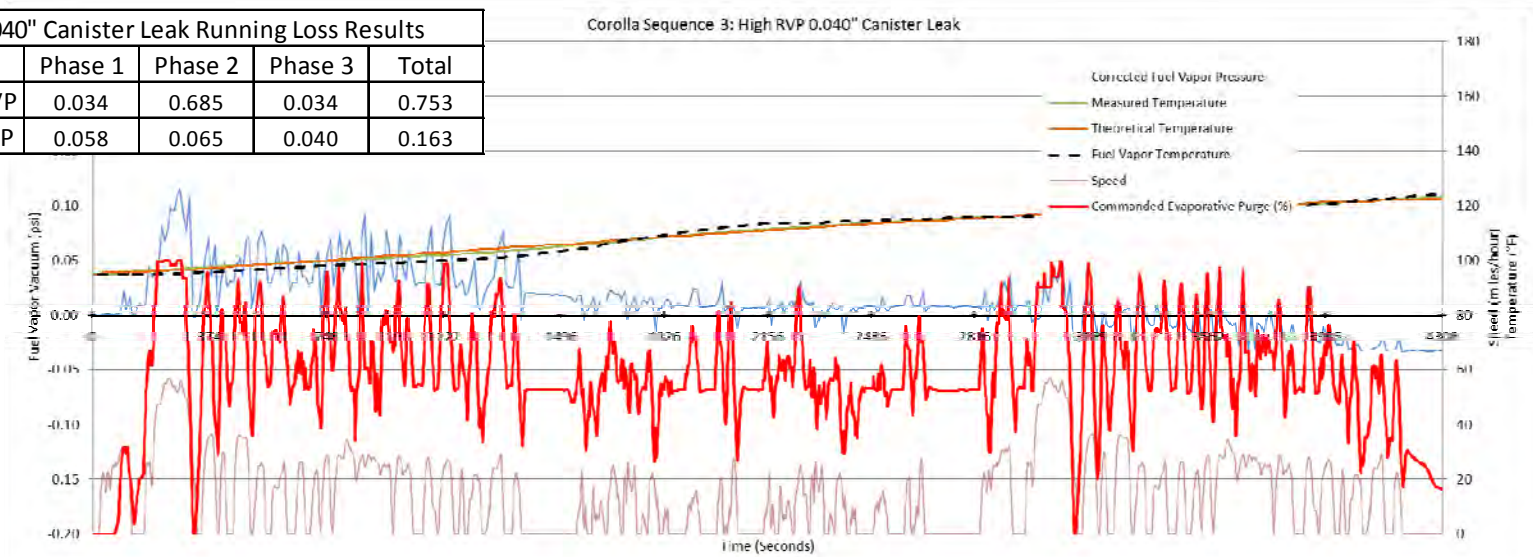


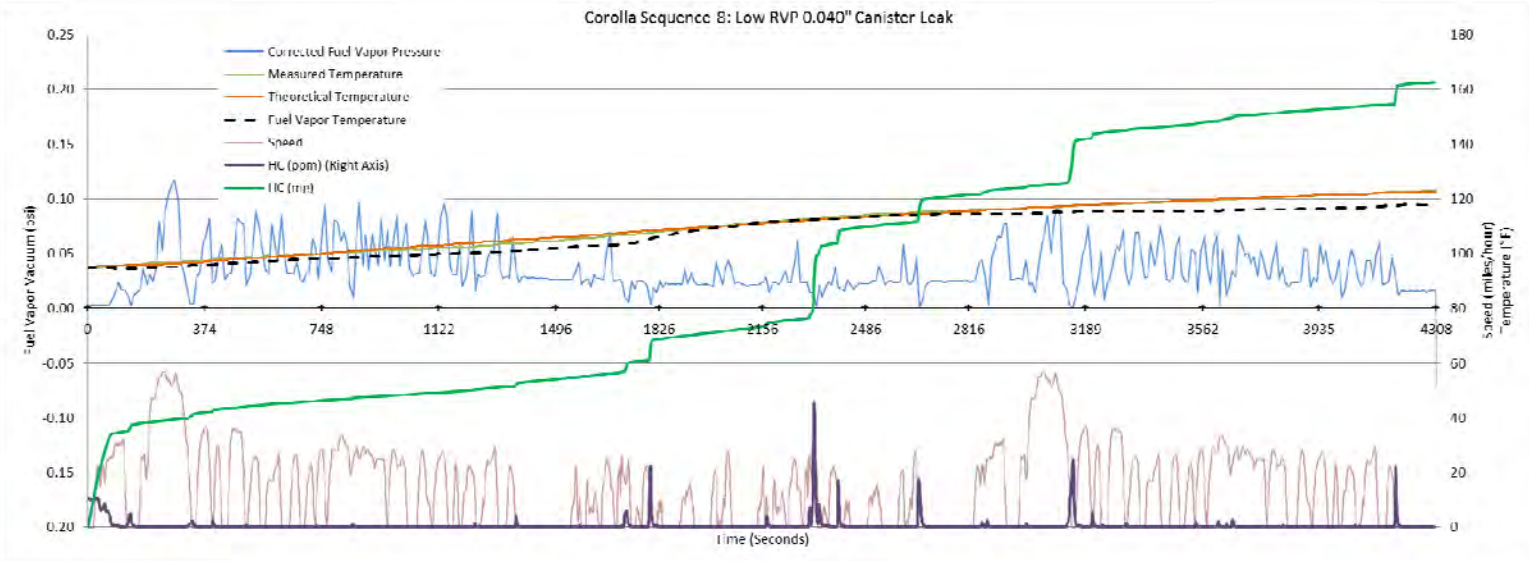

Corolla 0.040" Tank Leak
Corrected Fuel Vapor Pressure (High RVP)
Corrected Fuel Vapor Pressure (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)


Corolla 0.040" Tank Leak
Cumulative Pressure Accumulation (Low RVP)
Cumulative Pressure Accumulation (High RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)

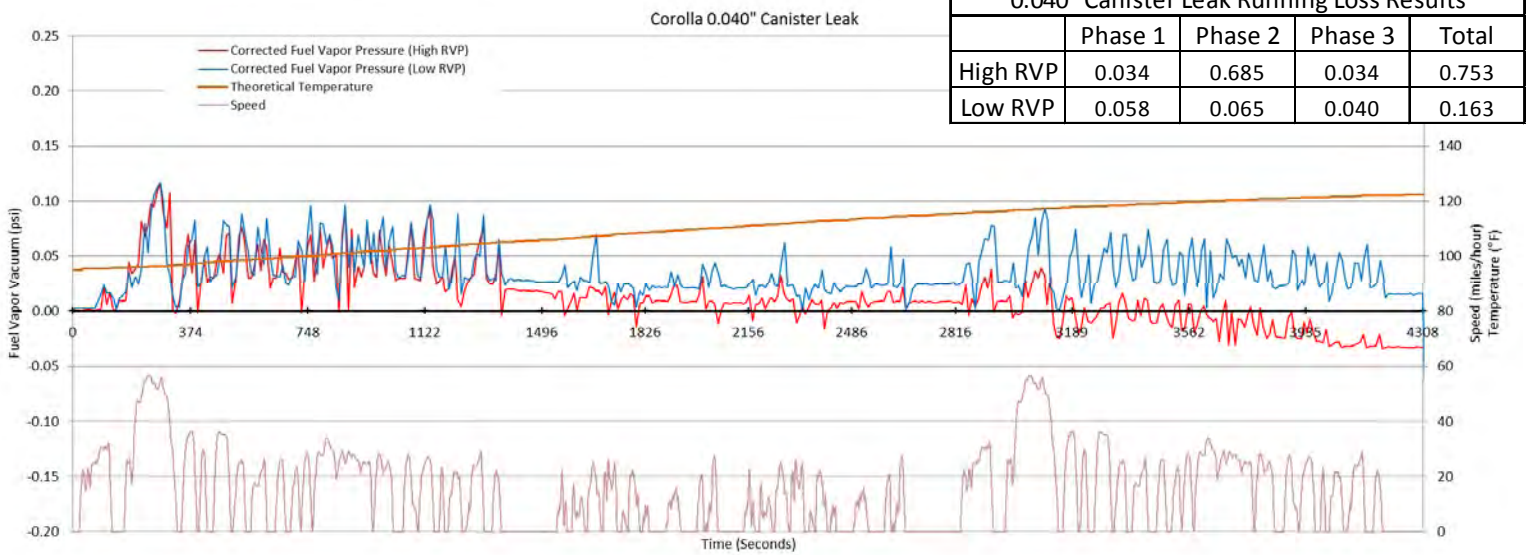
B.4.4 0.040” Canister Leak

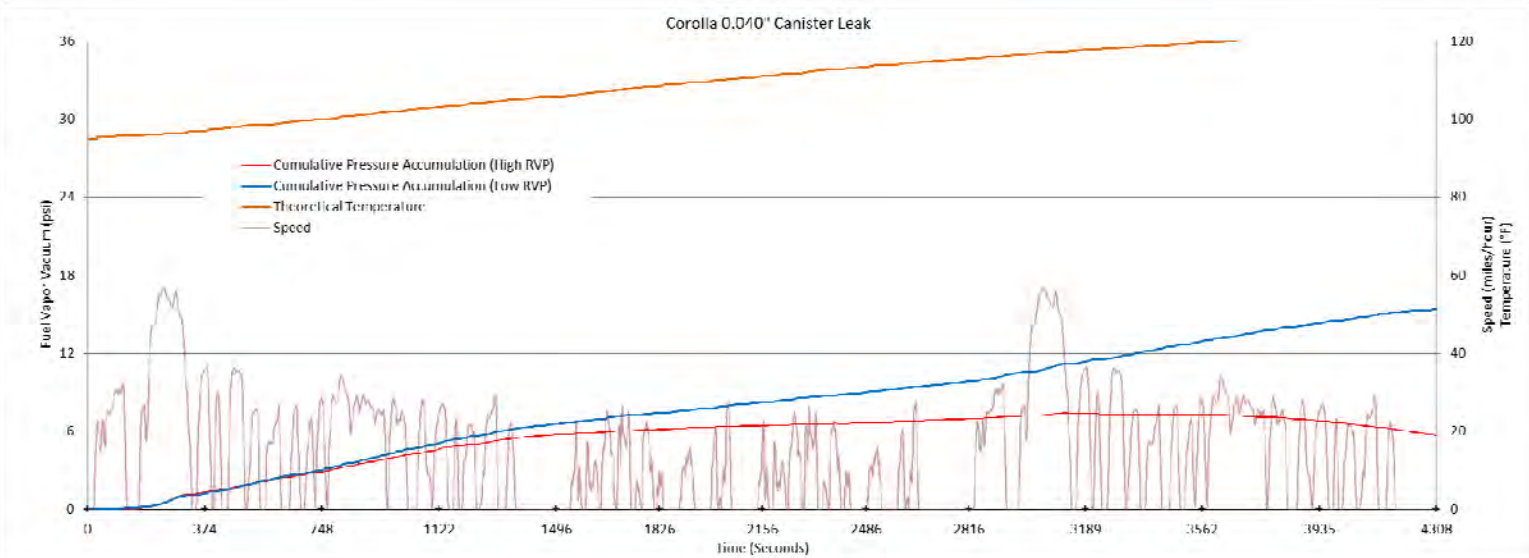
0.040" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.034	0.685	0.034	0.753
Low RVP	0.058	0.065	0.040	0.163





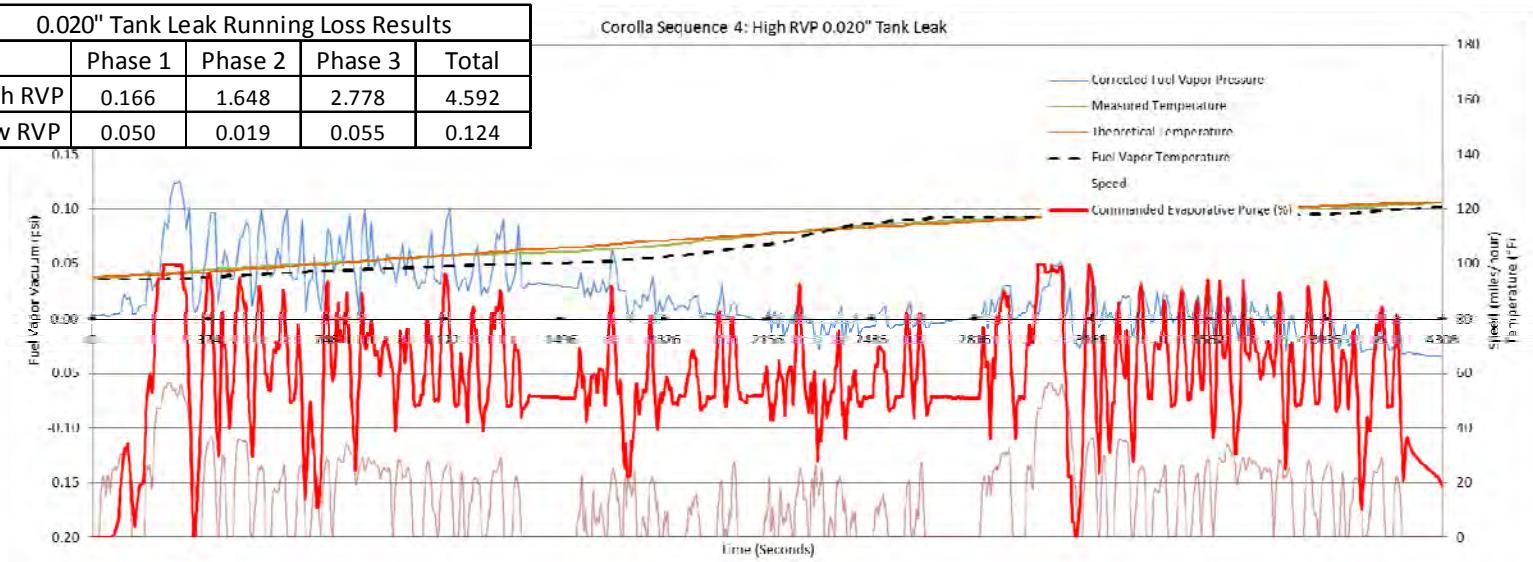
0.040" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.034	0.685	0.034	0.753
Low RVP	0.058	0.065	0.040	0.163

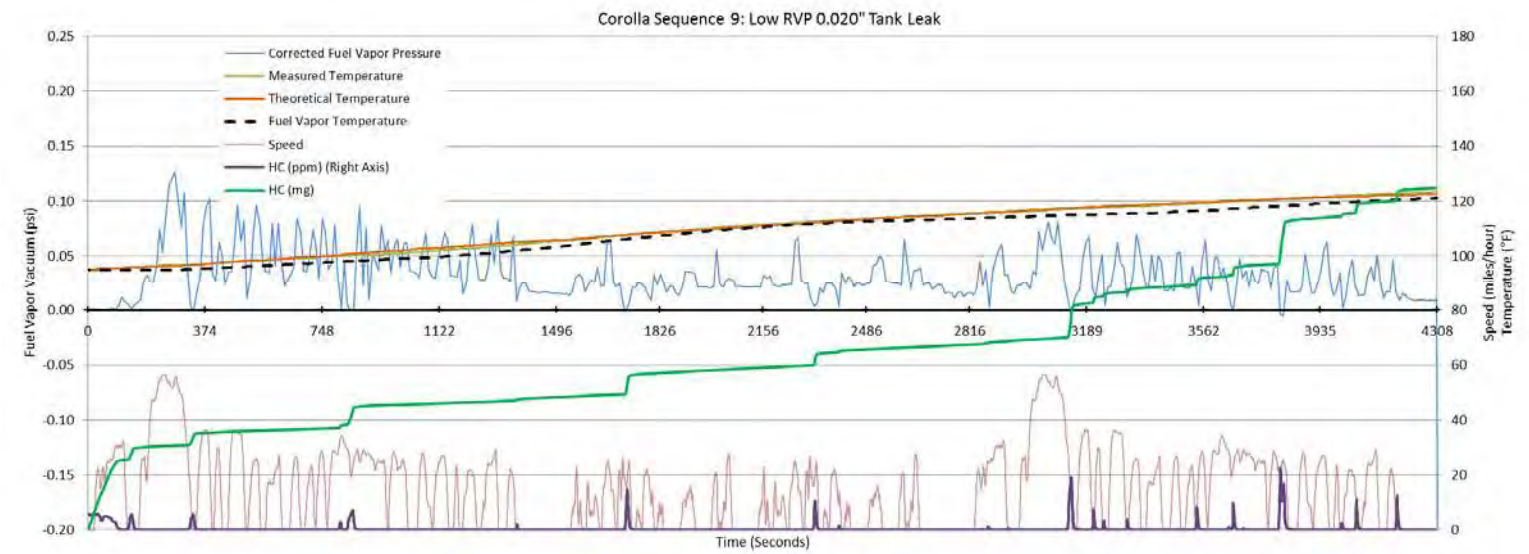




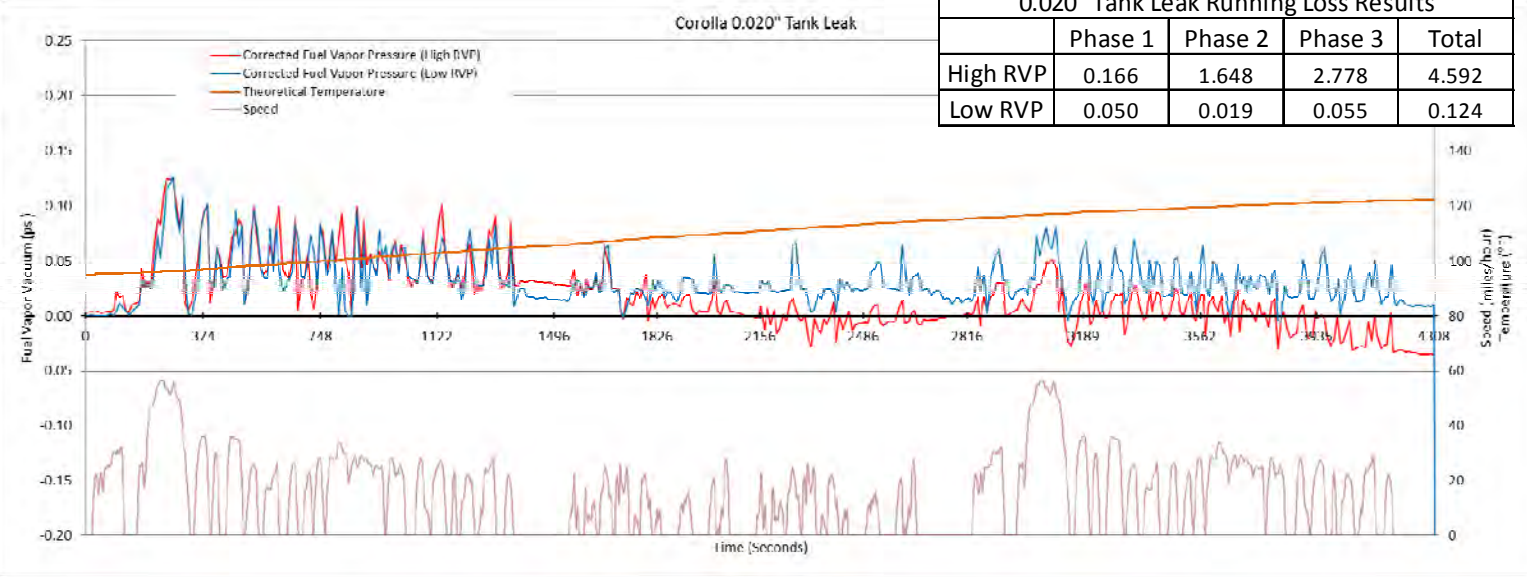
B.4.5 0.020” Tank Leak

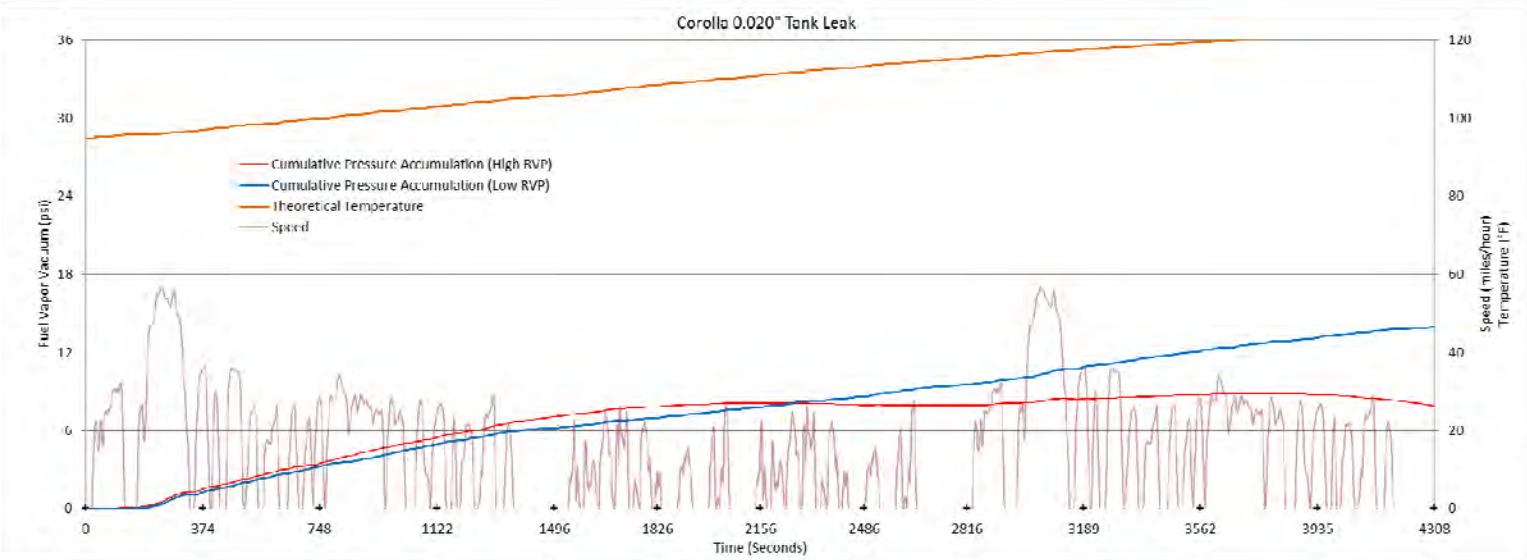
0.020" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.166	1.648	2.778	4.592
Low RVP	0.050	0.019	0.055	0.124





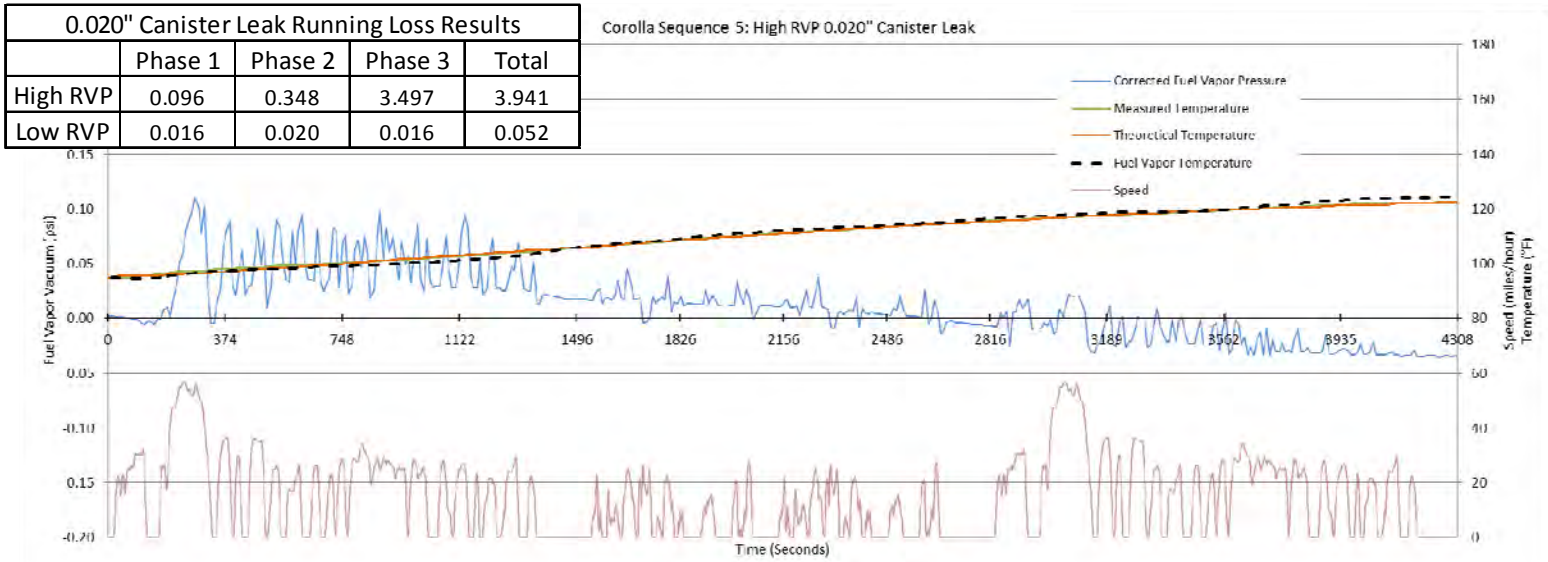
0.020" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.166	1.648	2.778	4.592
Low RVP	0.050	0.019	0.055	0.124

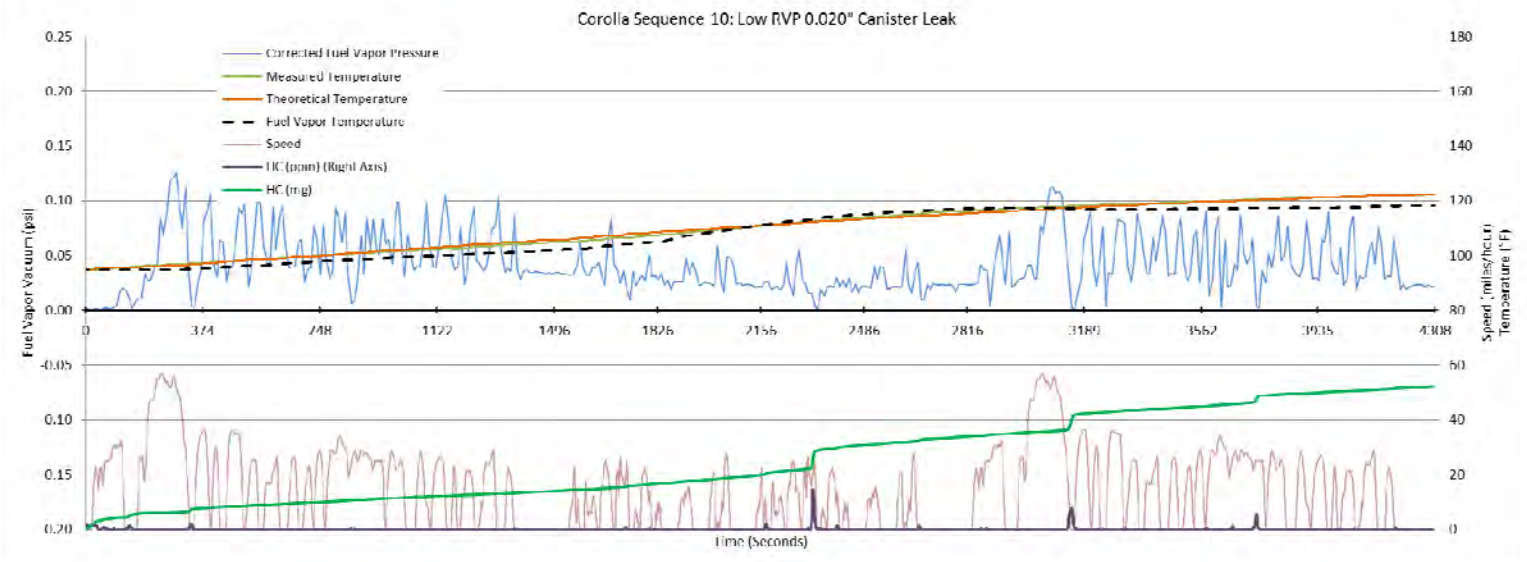


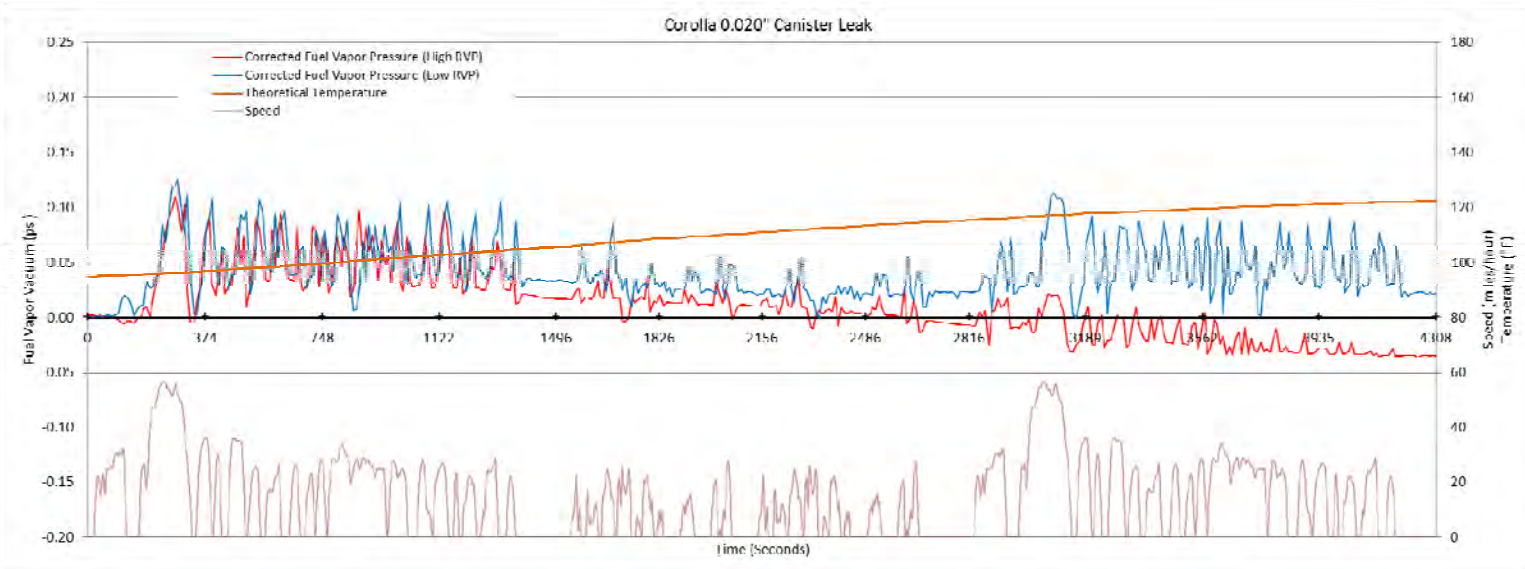


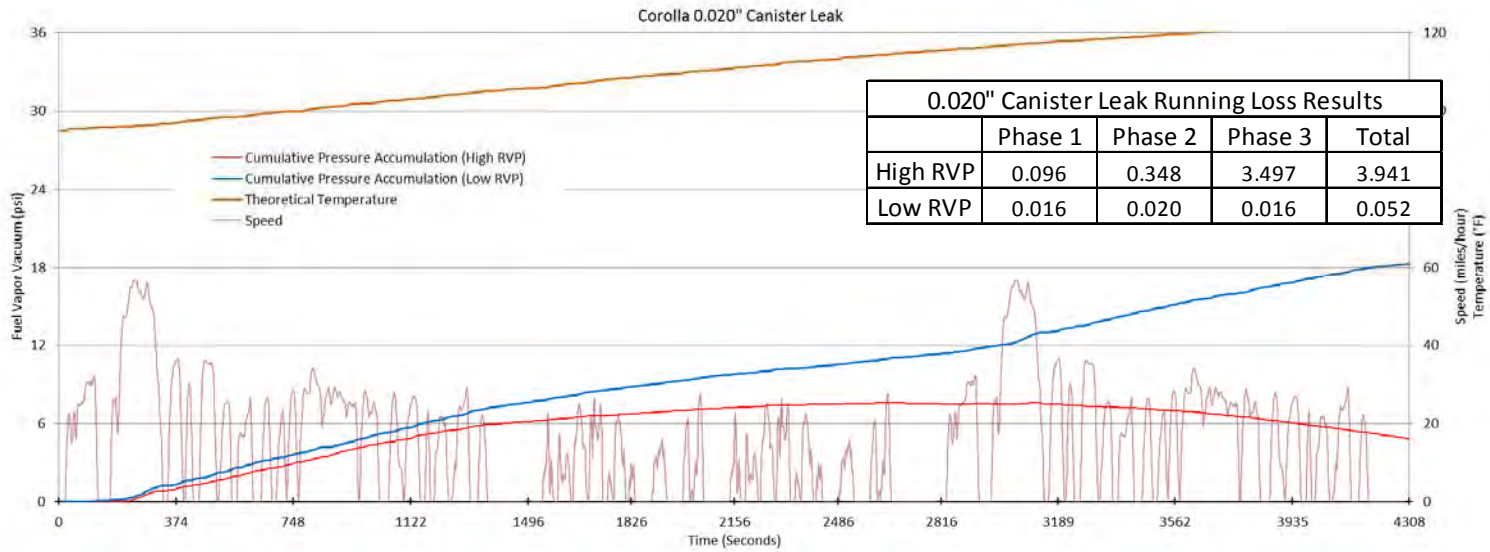
B.4.6 0.020” Canister Leak

0.020" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.096	0.348	3.497	3.941
Low RVP	0.016	0.020	0.016	0.052









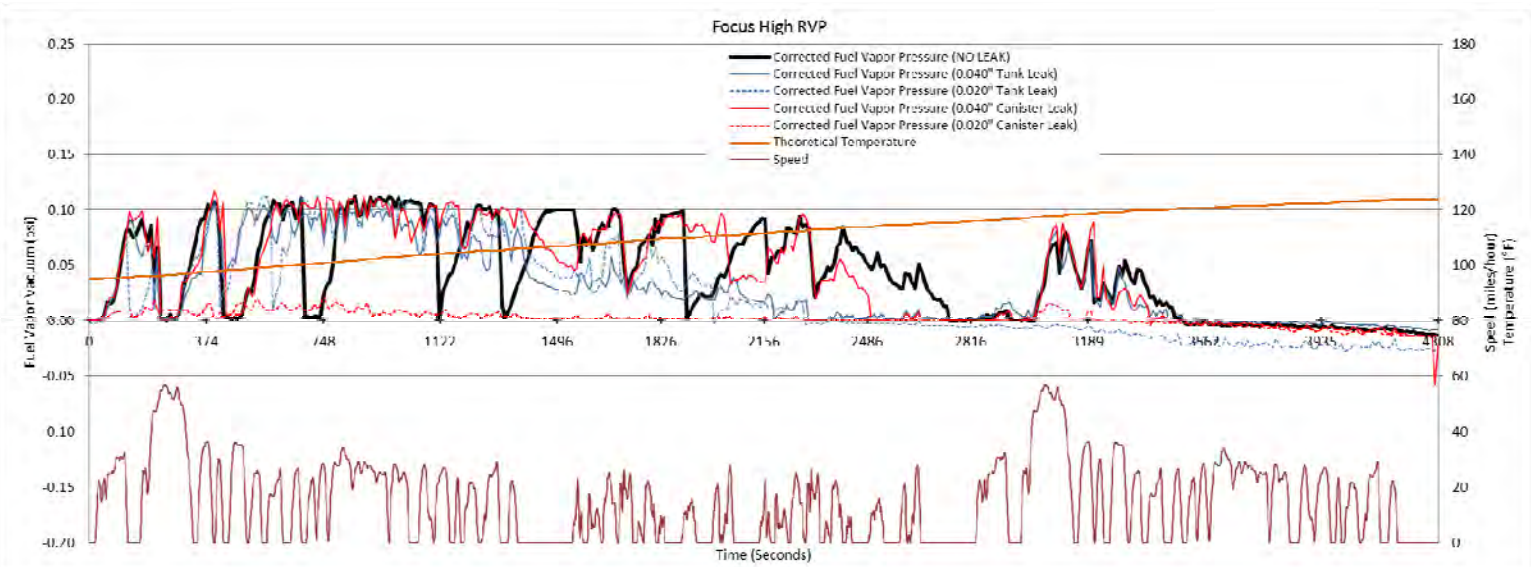
0.020" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.096	0.348	3.497	3.941
Low RVP	0.016	0.020	0.016	0.052

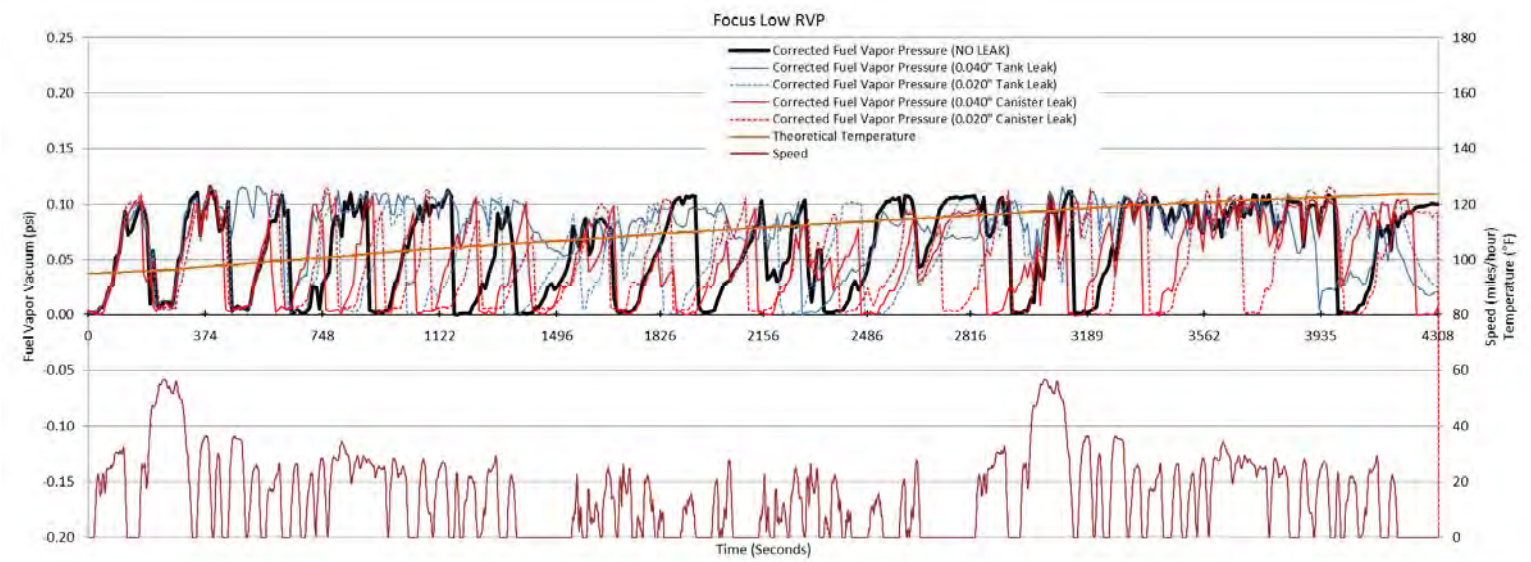
B.5 2010 Ford Focus

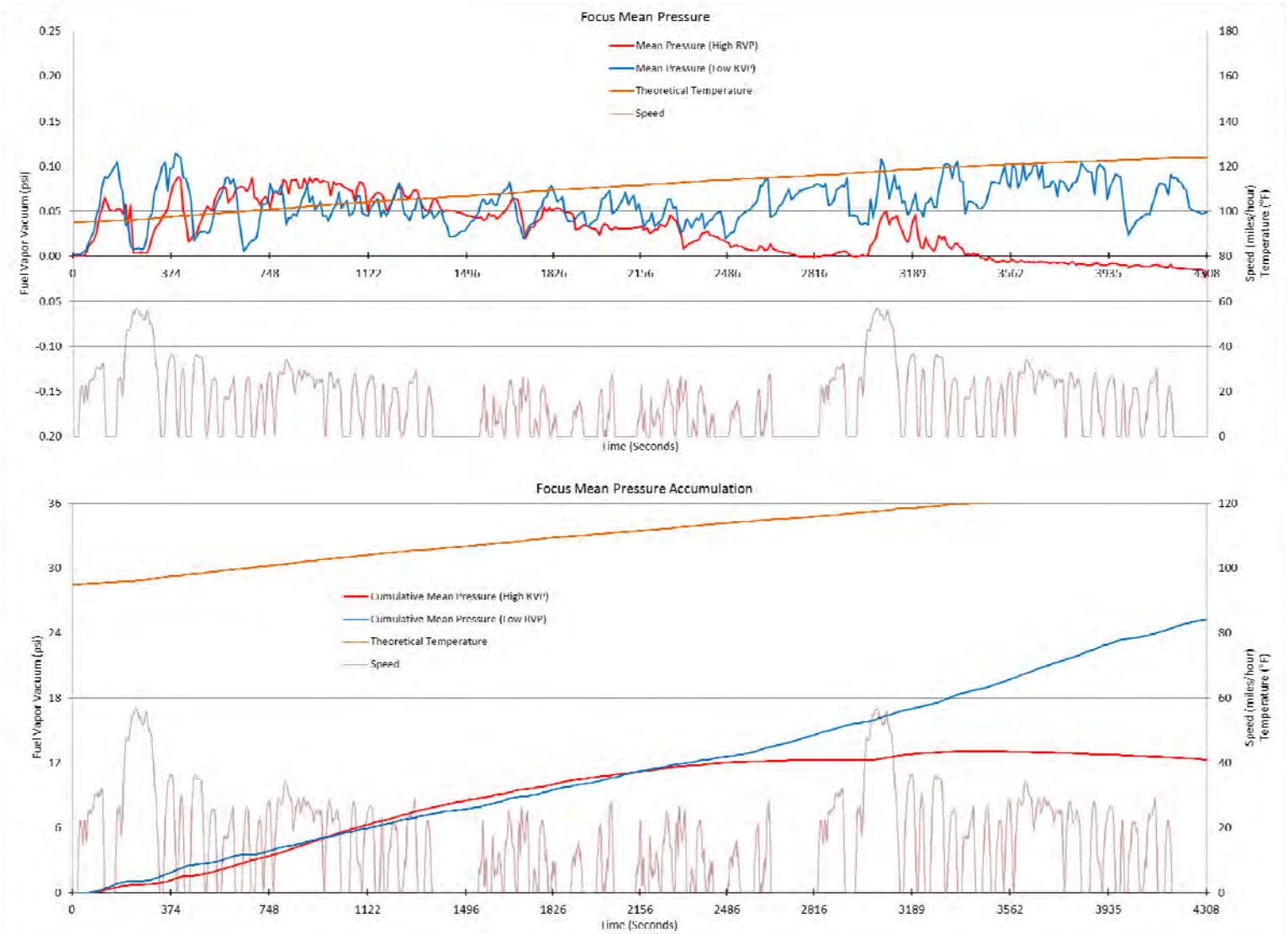
VIN:	1FAHP3FN8AW272304
ENGINE FAMILY:	AFMXV02.0VZX
EVAPORATIVE FAMILY:	AFMXR0110GCX
EMISSIONS STANDARD:	SULEV II PZEV
ENGINE DISPLACEMENT:	2.00 Liters
INERTIA WEIGHT:	3000 Pounds
Tank CAPACITY:	13.0 Gallons
ROAD LOAD A:	4.01
ROAD LOAD B:	0.5575
ROAD LOAD C:	0.01269
PEAK FUEL TEMP:	123.8 °F

Sequence:		1	2	3	4	5	6	7	8	9	10
Fuel:		High RVP Fuel (10.0 RVP)					Low RVP Fuel (7.7 RVP)				
Leak location:		No Leak	Tank	Canister	Tank	Canister	No Leak	Tank	Canister	Tank	Canister
Leak Size:		No Leak	0.040	0.040	0.020	0.020	No Leak	0.040	0.040	0.020	0.020
Purge Flow LA-4 Precon.											
Purge Flow LA-92 Precon.											
Results in Grams:											
Running Loss	P1	0.002	0.317	0.165	0.012	0.213	0.003	0.132	0.637	0.325	0.121
	P2	0.001	1.349	0.822	0.530	0.510	0.002	0.179	0.517	0.235	0.126
	P3	0.005	6.250	12.471	11.927	11.777	0.002	0.018	0.481	0.010	0.105
	TOTAL	0.008	7.916	13.458	12.469	12.500	0.007	0.329	1.635	0.570	0.352
Hot Soak		1.154	0.589	0.952	0.945	0.558	0.216	0.481	0.164	0.250	0.210
Static Test	P1	0.040	0.156	0.060	0.107	0.202	0.056	0.240	0.053	0.393	0.063
	P2	0.040	9.130	8.563	2.407	2.525	0.043	5.849	6.895	2.574	1.773
	TOTAL	0.080	9.286	8.624	2.514	2.727	0.099	6.089	6.948	2.967	1.836
RL + HS + ST		1.242	17.791	23.034	15.928	15.785	0.322	6.899	8.747	3.787	2.398

B.5.1 Running Loss Fuel Vapor Pressure Comparisons

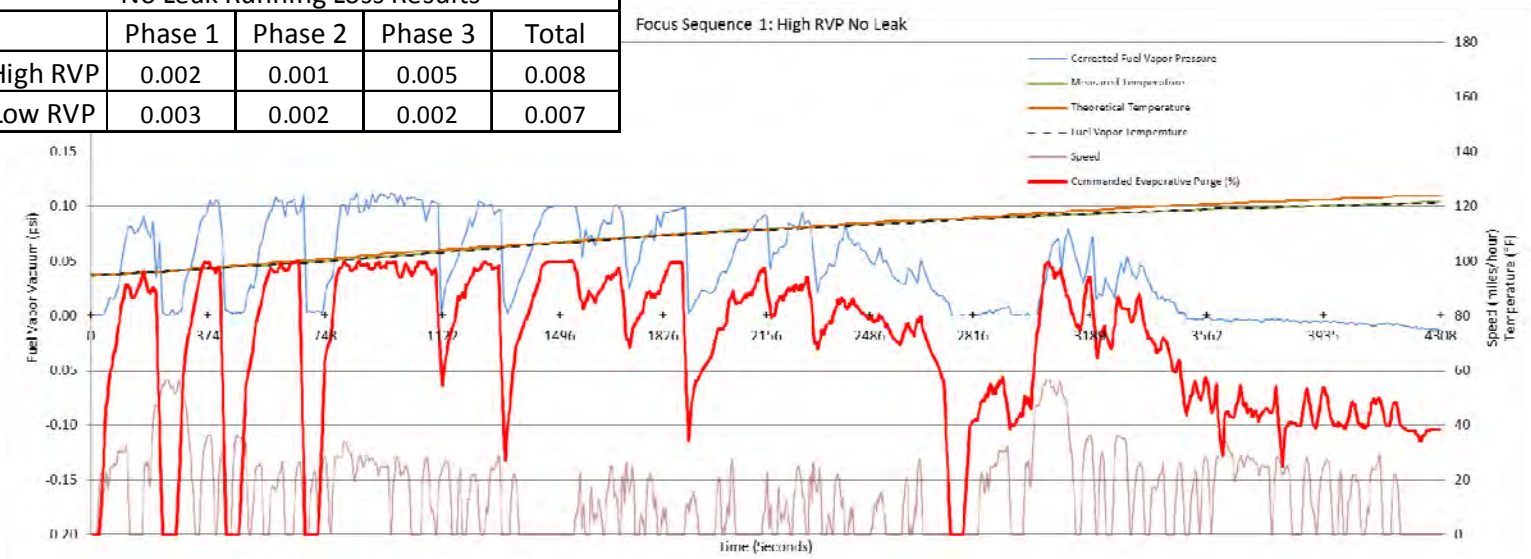


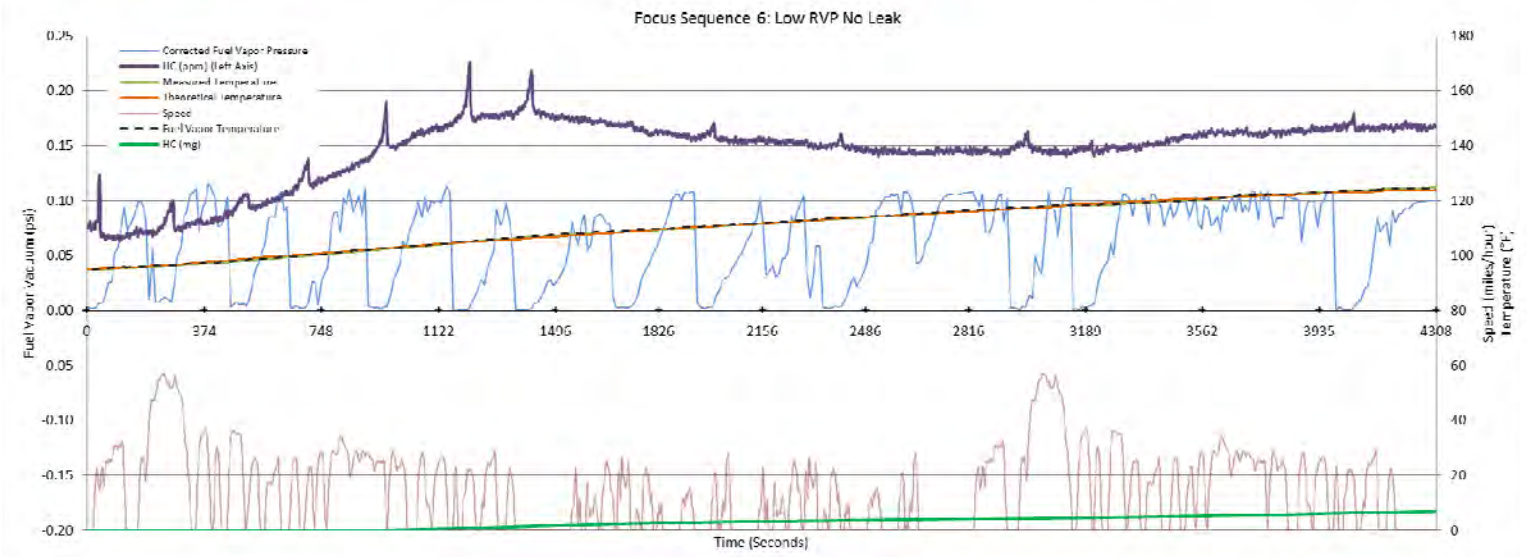


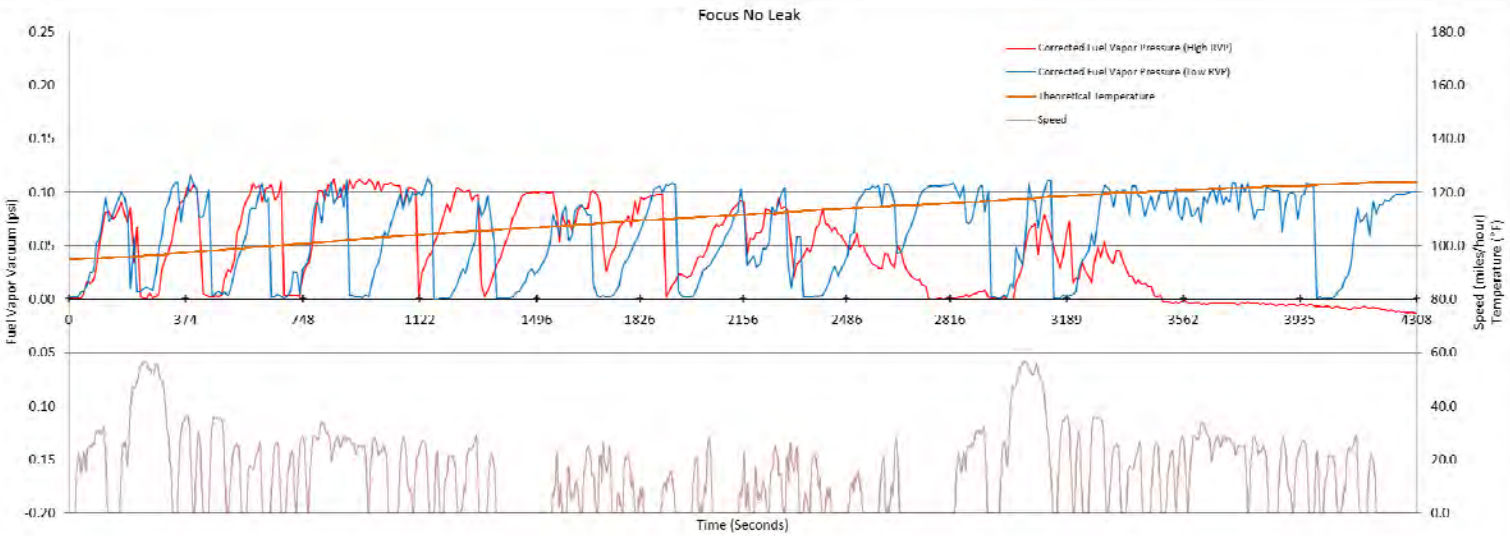

Focus Mean Pressure
Mean Pressure (High RVP)
Mean Pressure (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)
Focus Mean Pressure Accumulation
Cumulative Mean Pressure (High RVP)
Cumulative Mean Pressure (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)

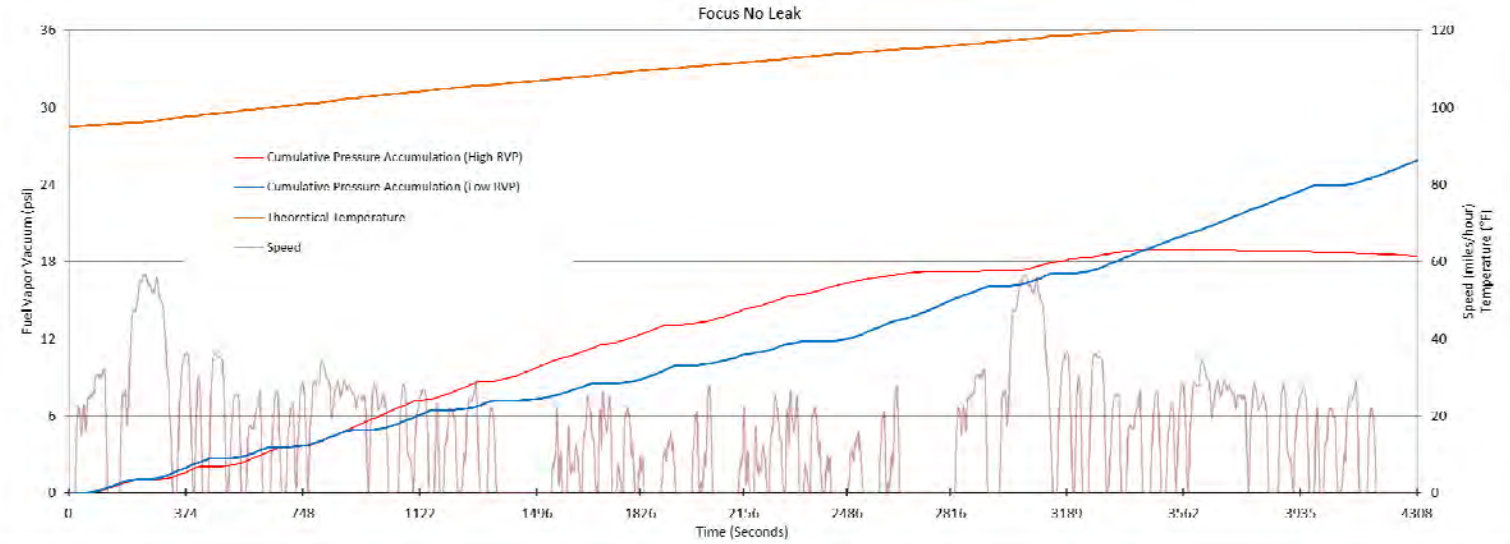
B.5.2 No Leak

No Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.002	0.001	0.005	0.008
Low RVP	0.003	0.002	0.002	0.007

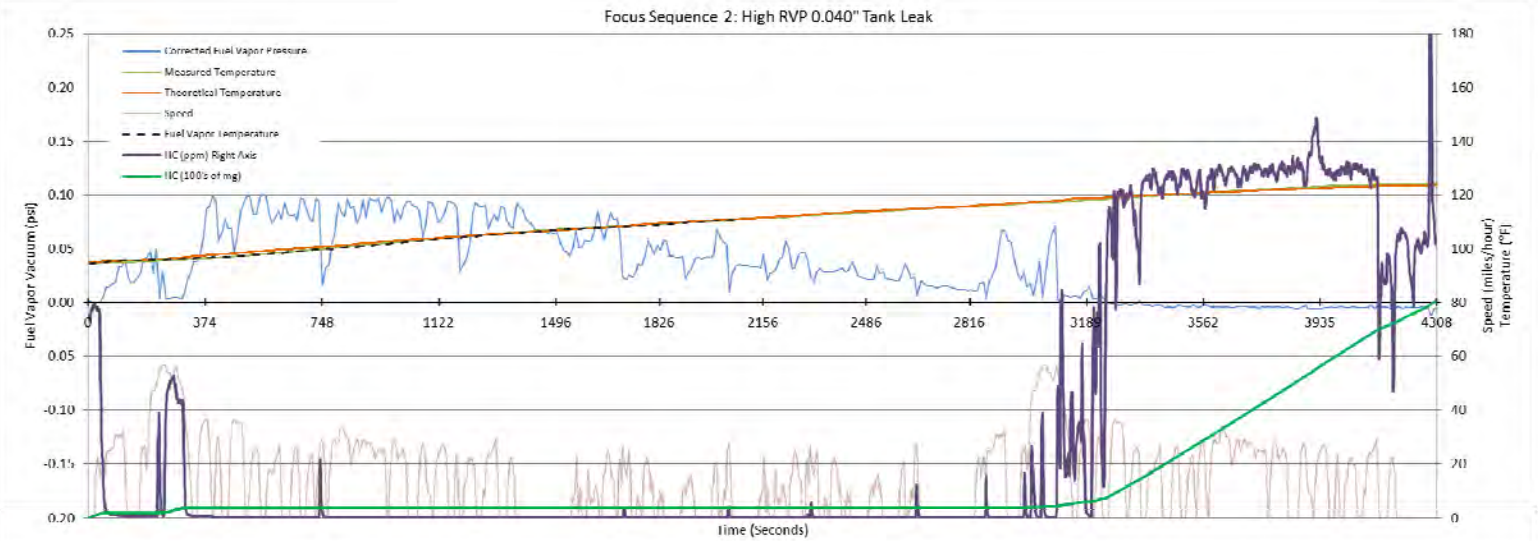


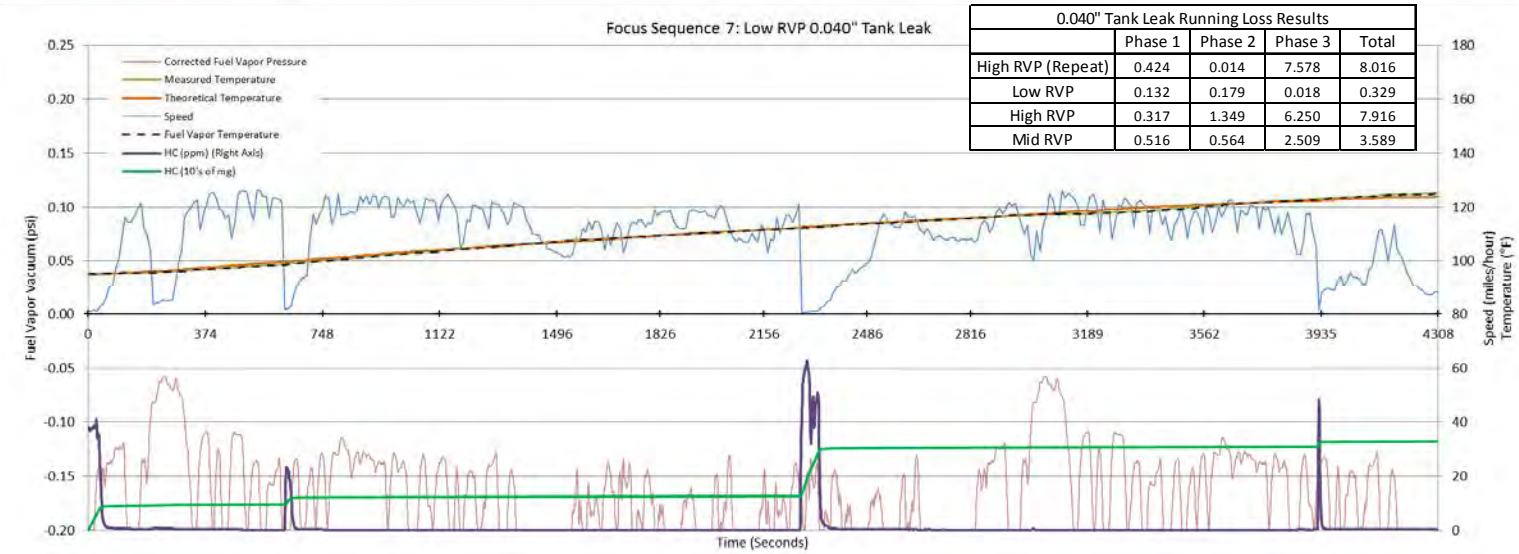



Focus No Leak
Corrected Fuel Vapor Pressure (High RVP)
Corrected Fuel Vapor Pressure (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)


Focus No Leak
Cumulative Pressure Accumulation (High RVP)
Cumulative Pressure Accumulation (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)

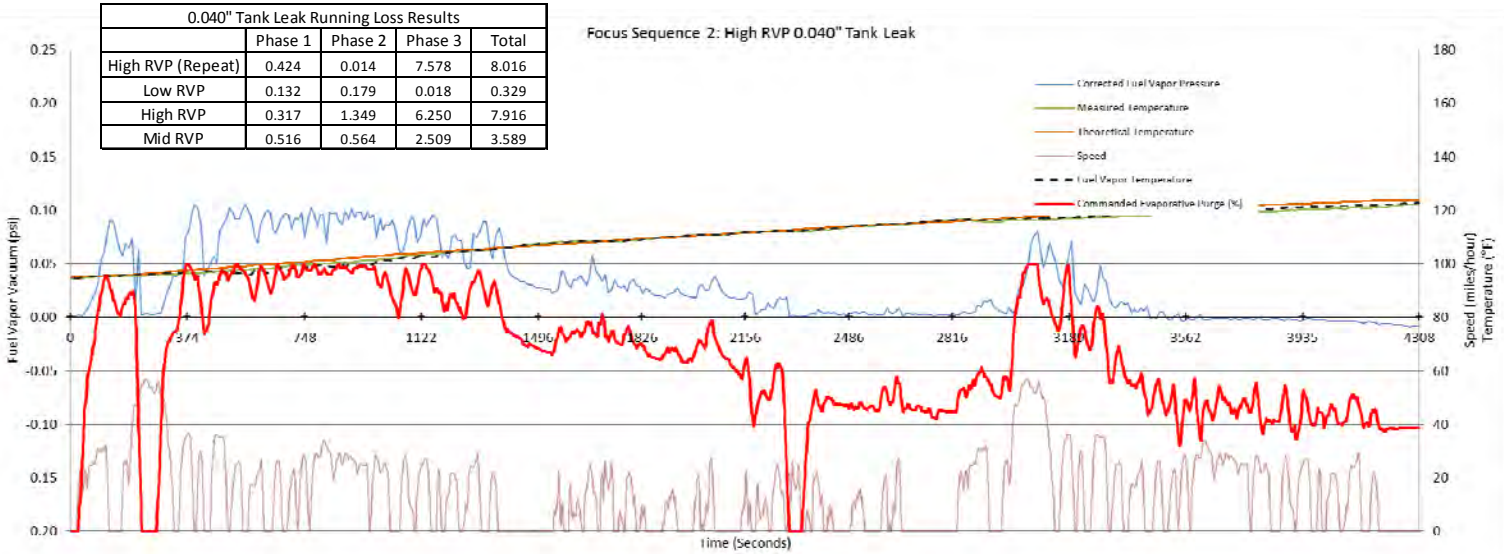
B.5.3 0.040” Tank Leak

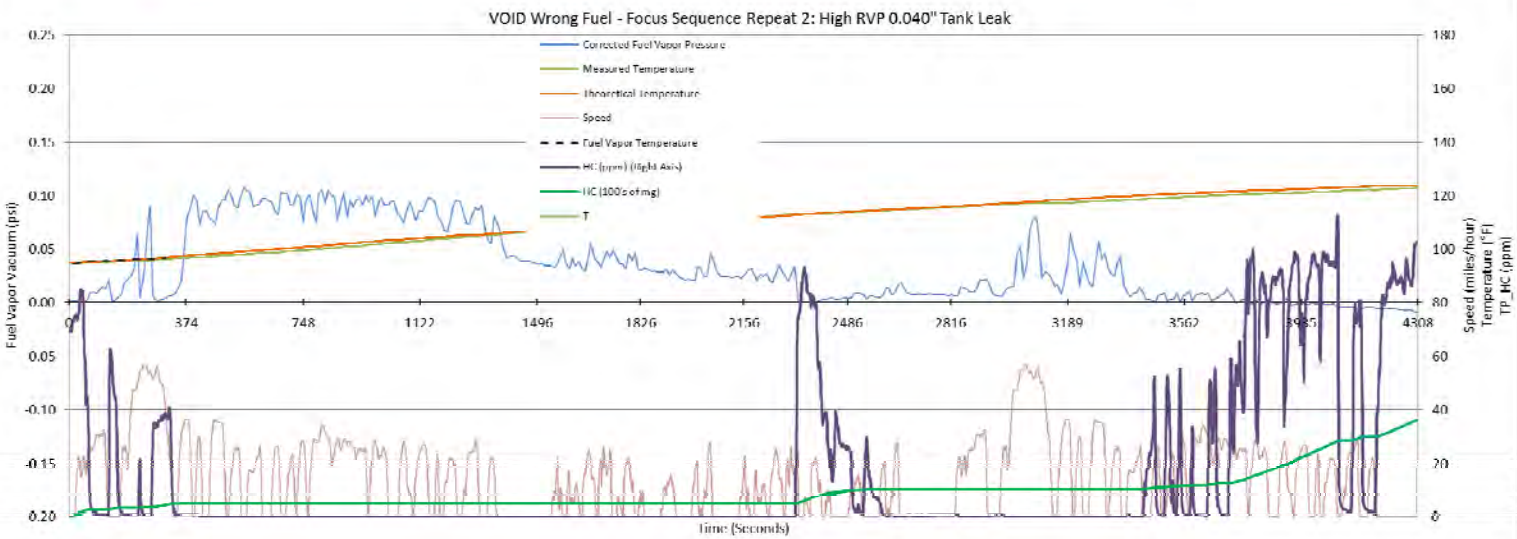




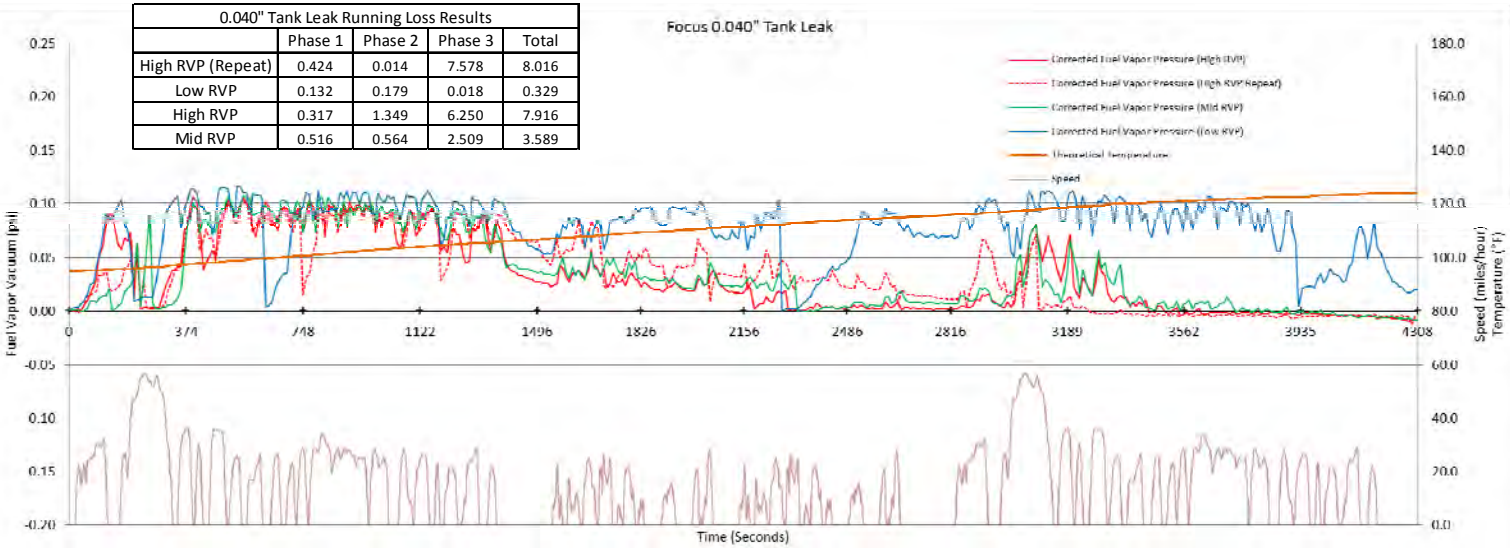
0.040" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP (Repeat)	0.424	0.014	7.578	8.016
Low RVP	0.132	0.179	0.018	0.329
High RVP	0.317	1.349	6.250	7.916
Mid RVP	0.516	0.564	2.509	3.589

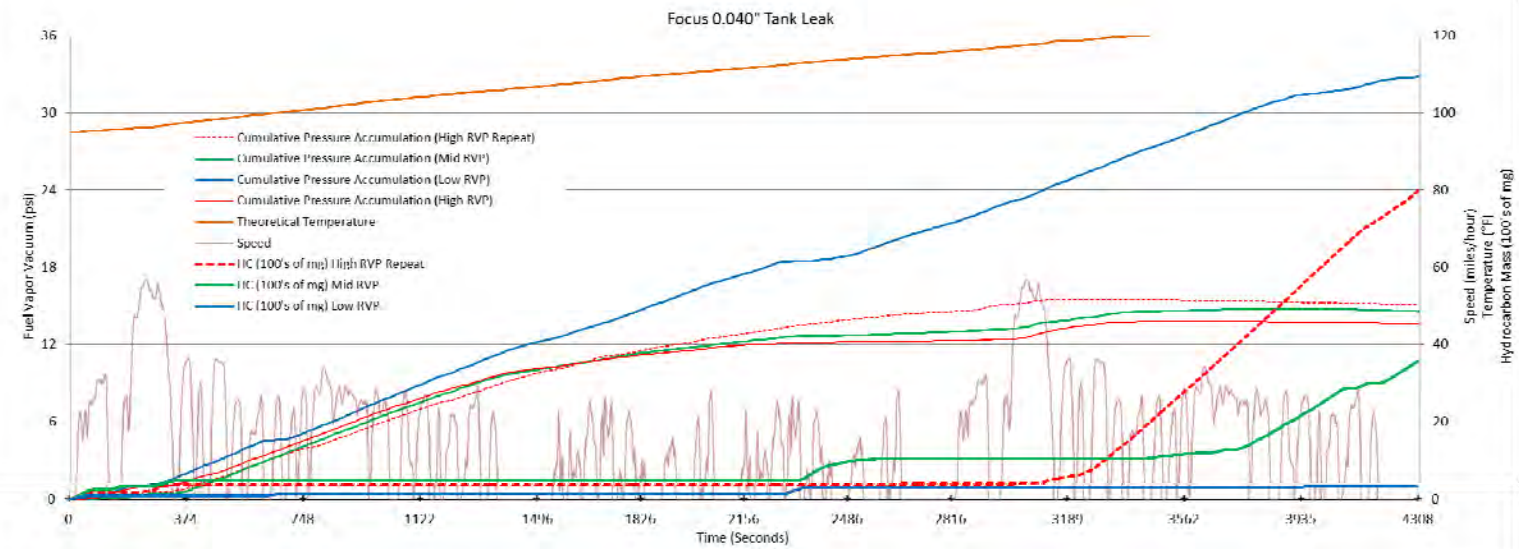
0.040" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP (Repeat)	0.424	0.014	7.578	8.016
Low RVP	0.132	0.179	0.018	0.329
High RVP	0.317	1.349	6.250	7.916
Mid RVP	0.516	0.564	2.509	3.589





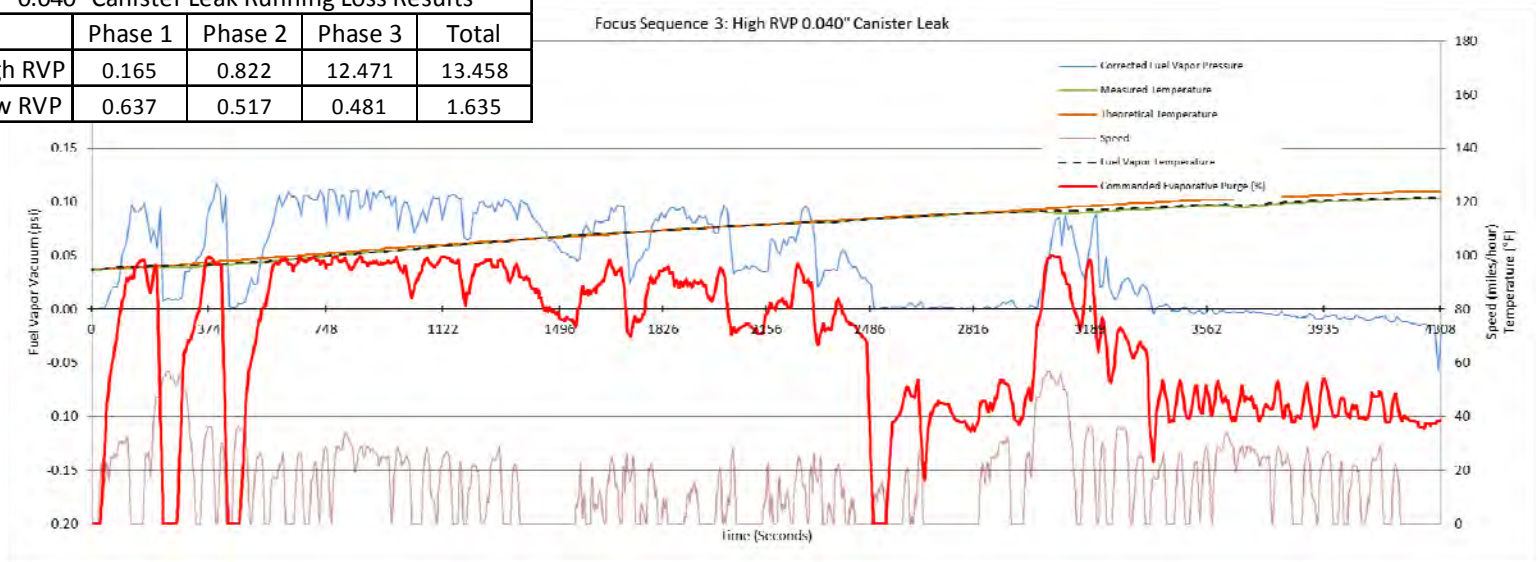
0.040" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP (Repeat)	0.424	0.014	7.578	8.016
Low RVP	0.132	0.179	0.018	0.329
High RVP	0.317	1.349	6.250	7.916
Mid RVP	0.516	0.564	2.509	3.589

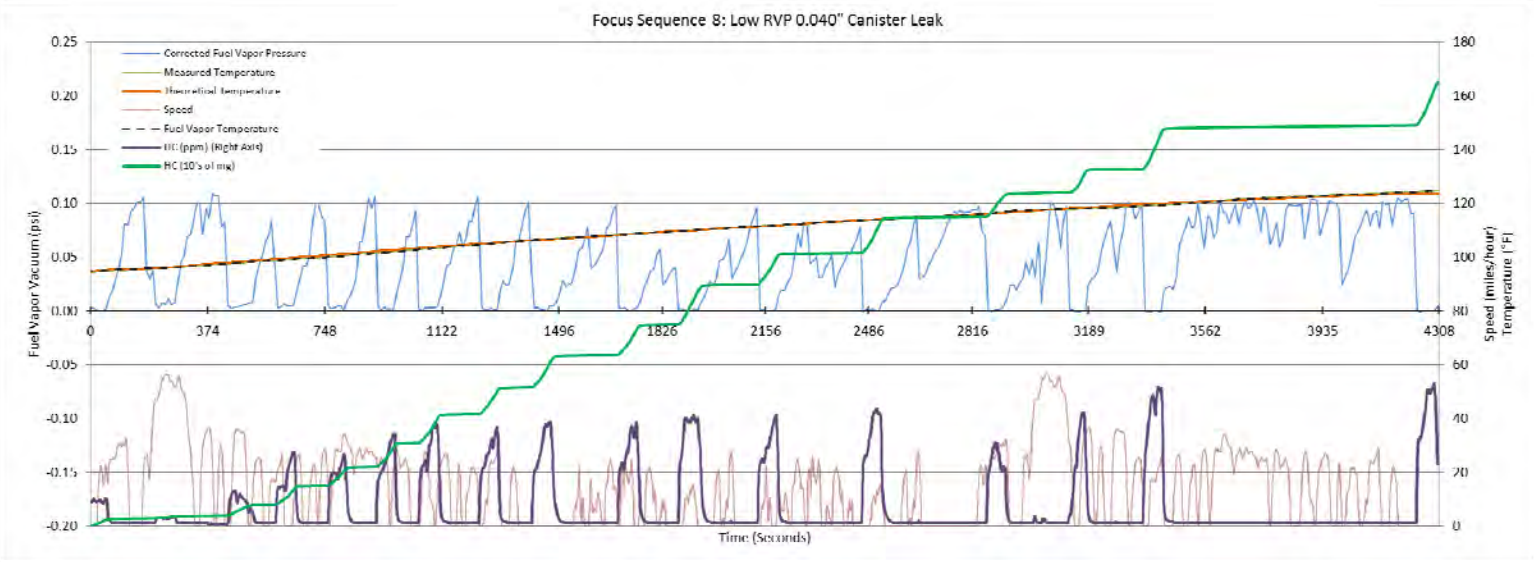


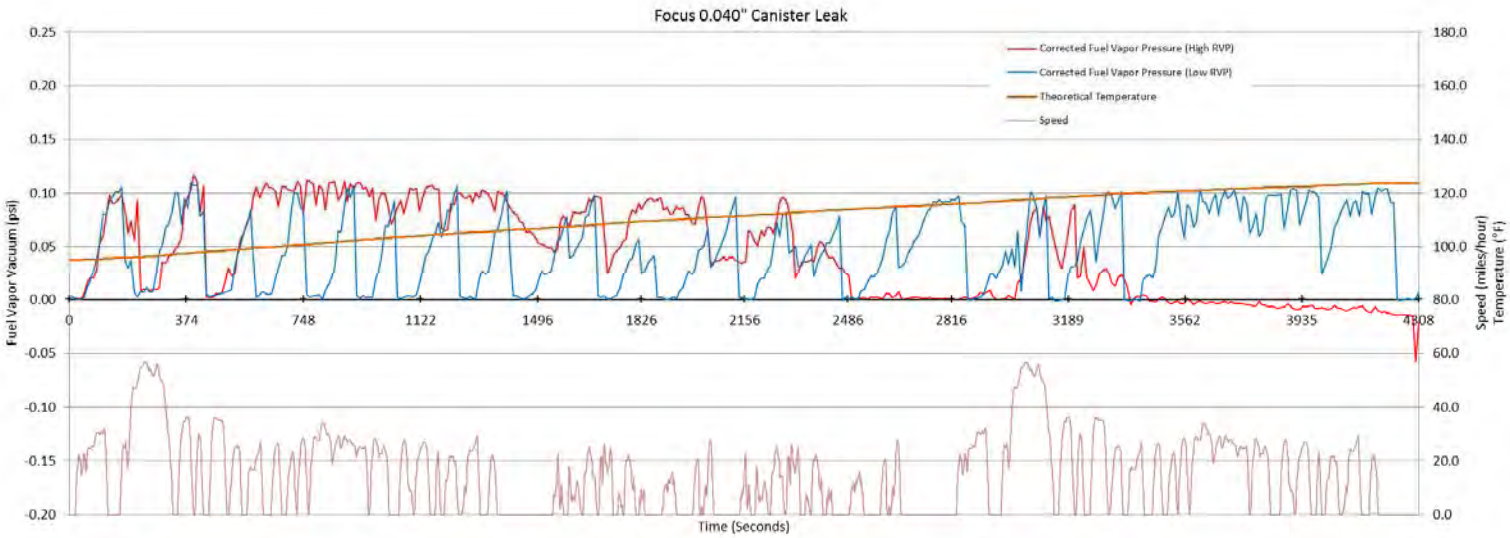


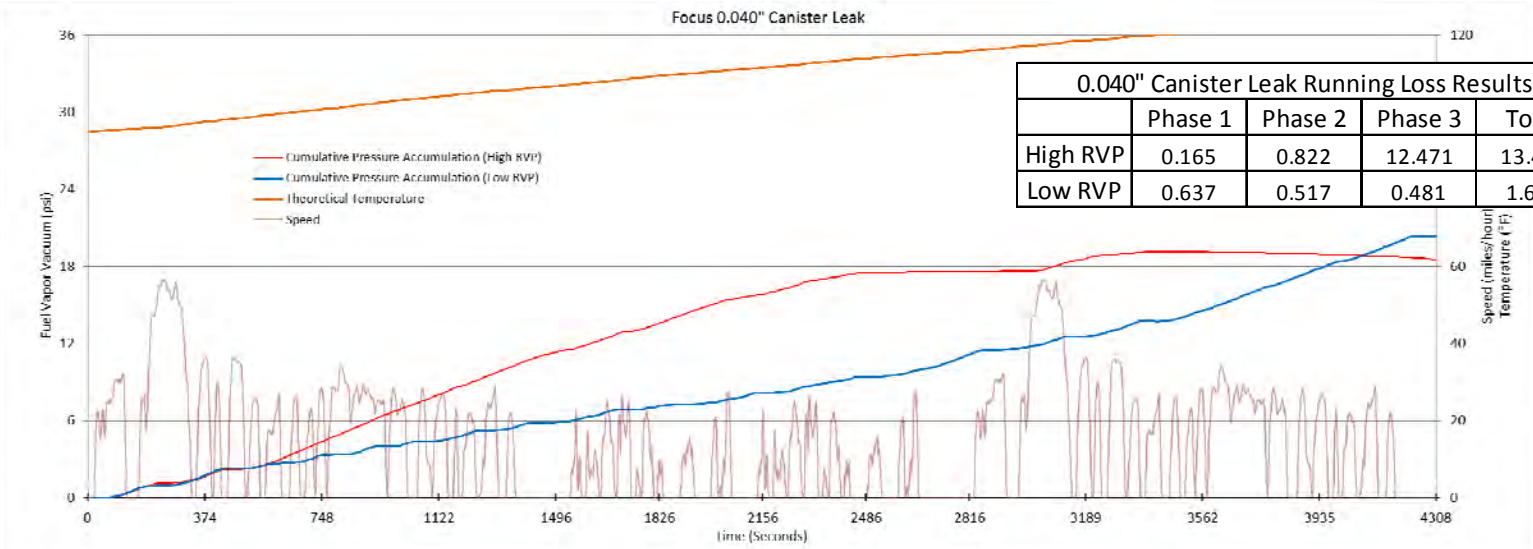
B.5.4 0.040” Canister Leak

0.040" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.165	0.822	12.471	13.458
Low RVP	0.637	0.517	0.481	1.635





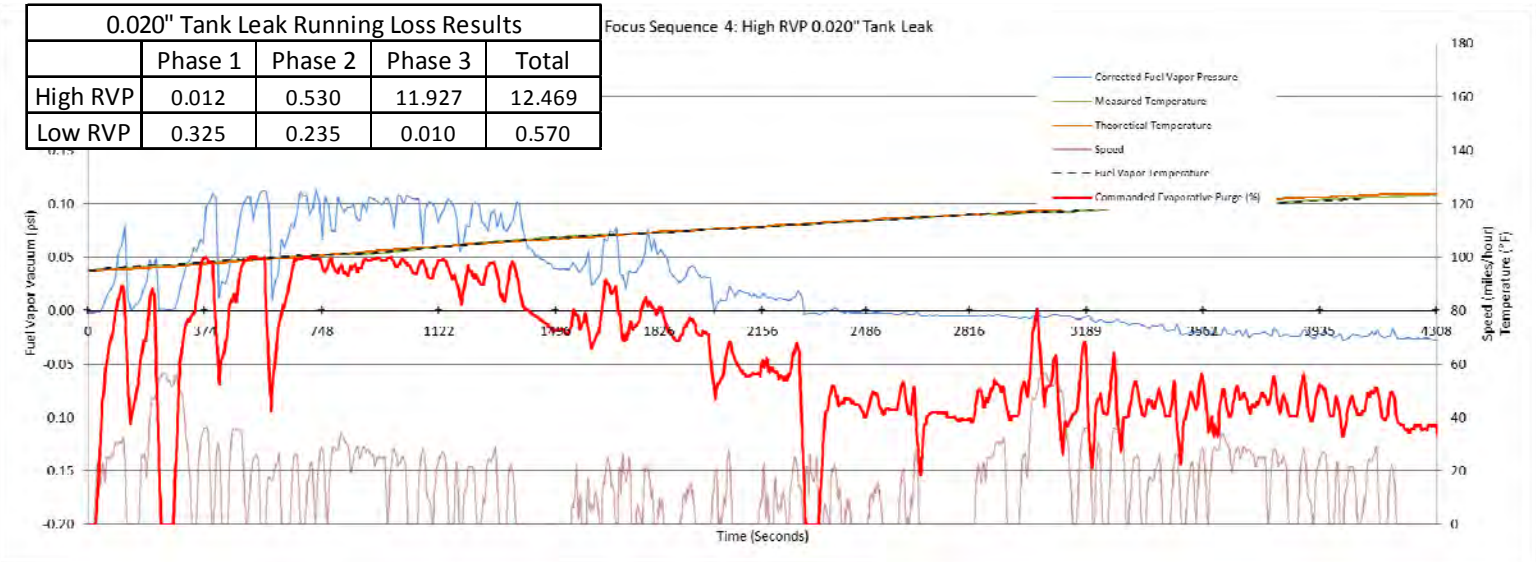


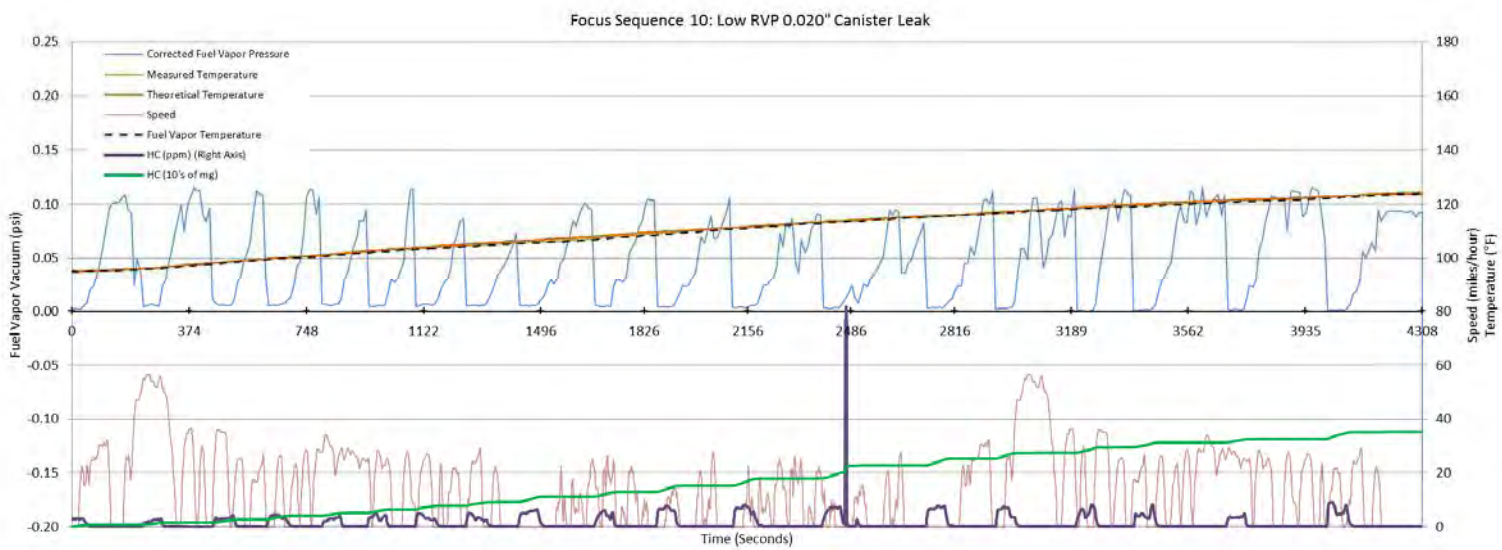


0.040" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.165	0.822	12.471	13.458
Low RVP	0.637	0.517	0.481	1.635

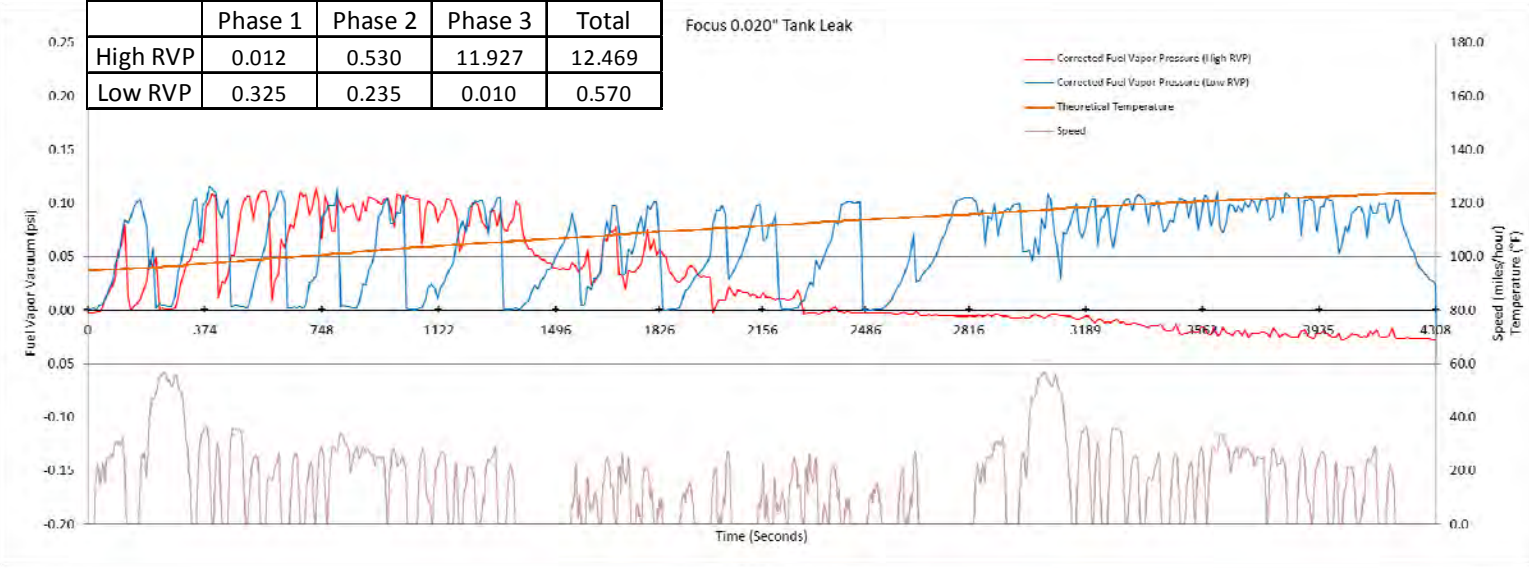
B.5.5 0.020” Tank Leak

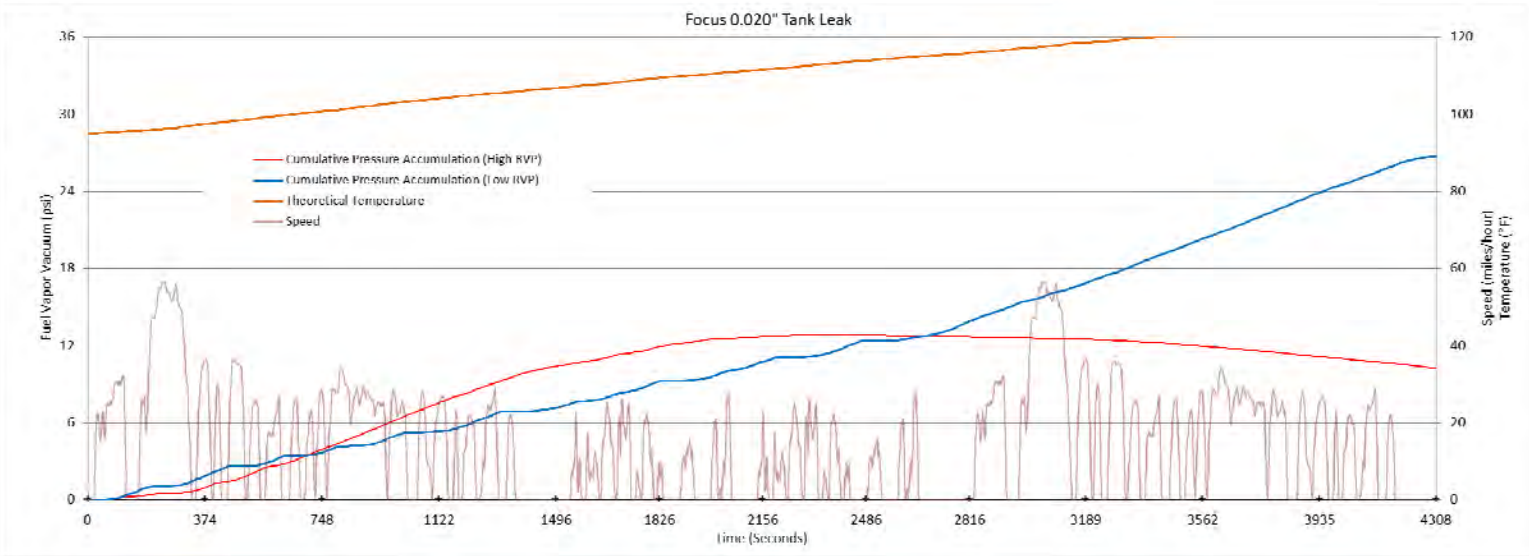
0.020" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.012	0.530	11.927	12.469
Low RVP	0.325	0.235	0.010	0.570





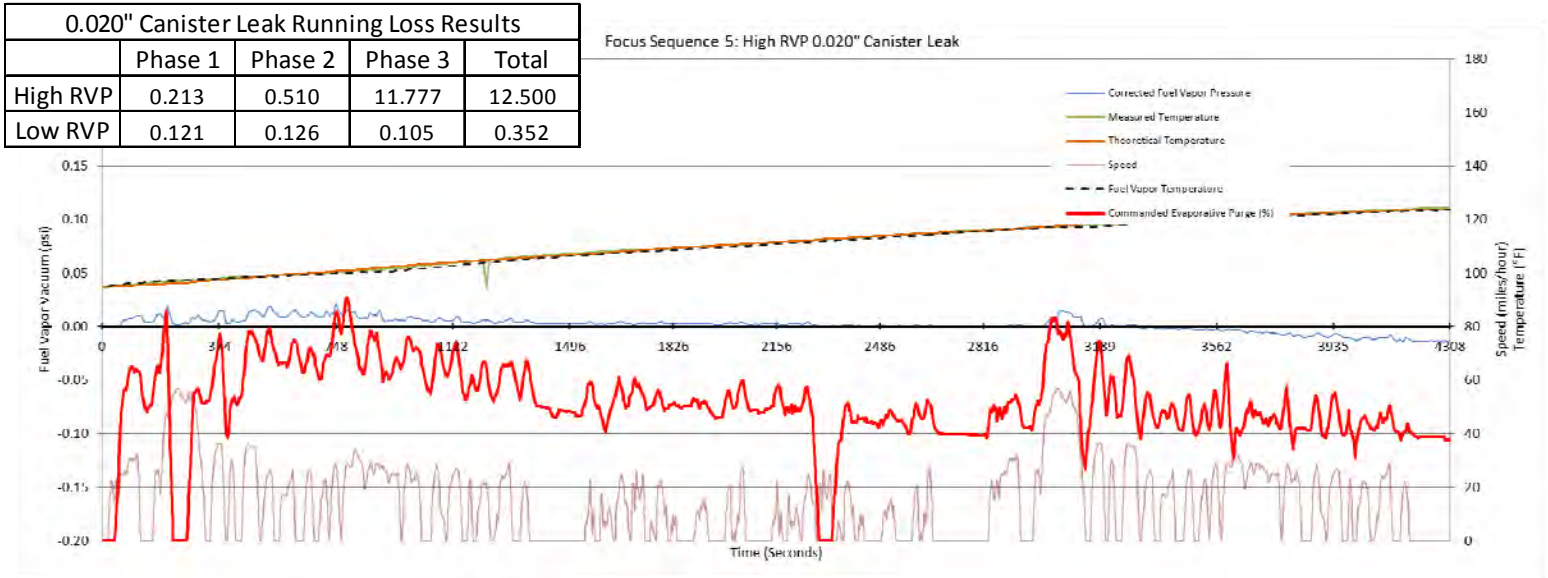
0.020" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.012	0.530	11.927	12.469
Low RVP	0.325	0.235	0.010	0.570

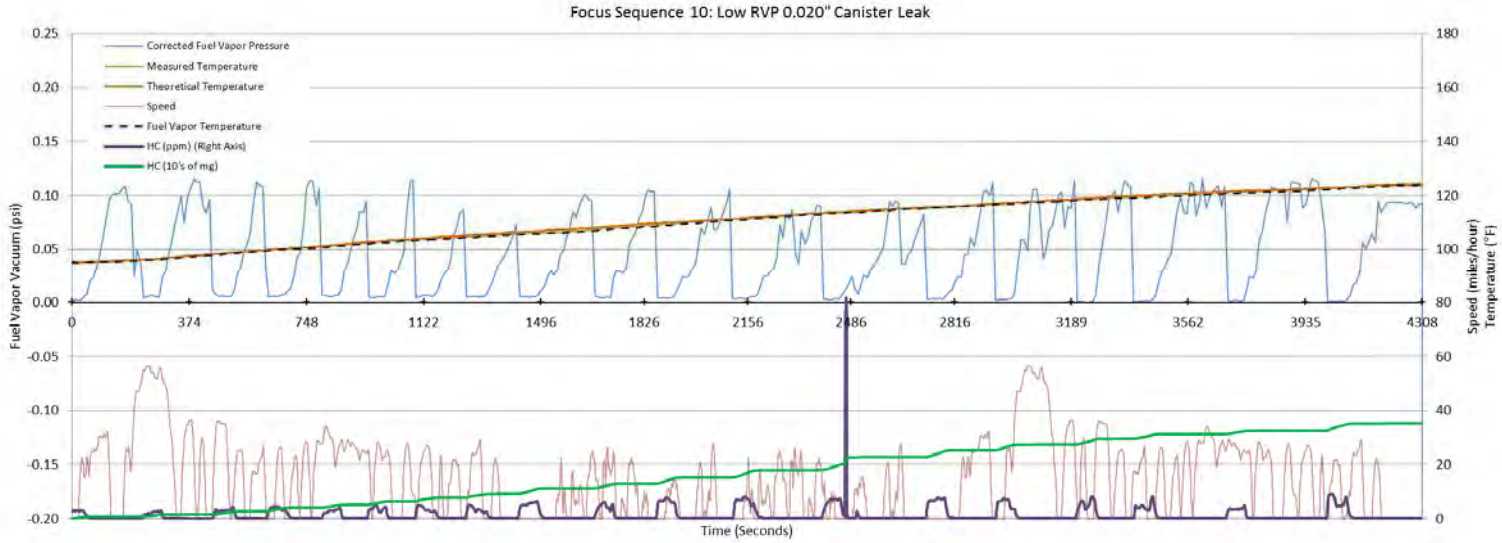




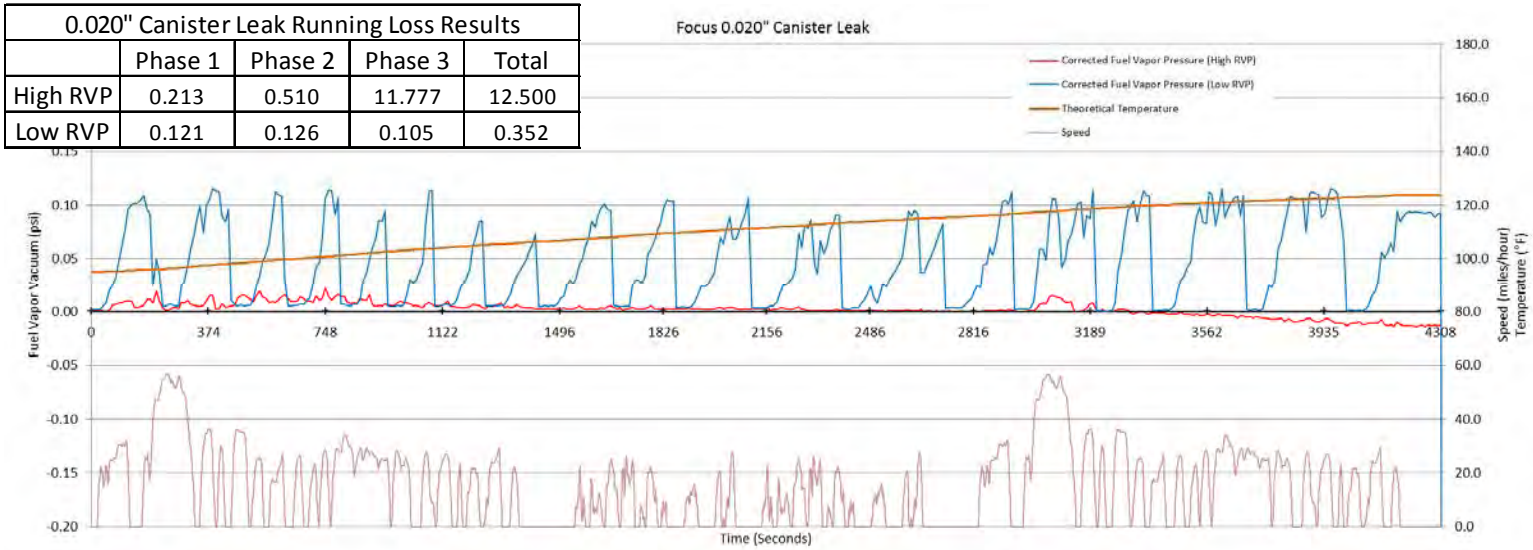
B.5.6 0.020” Canister Leak

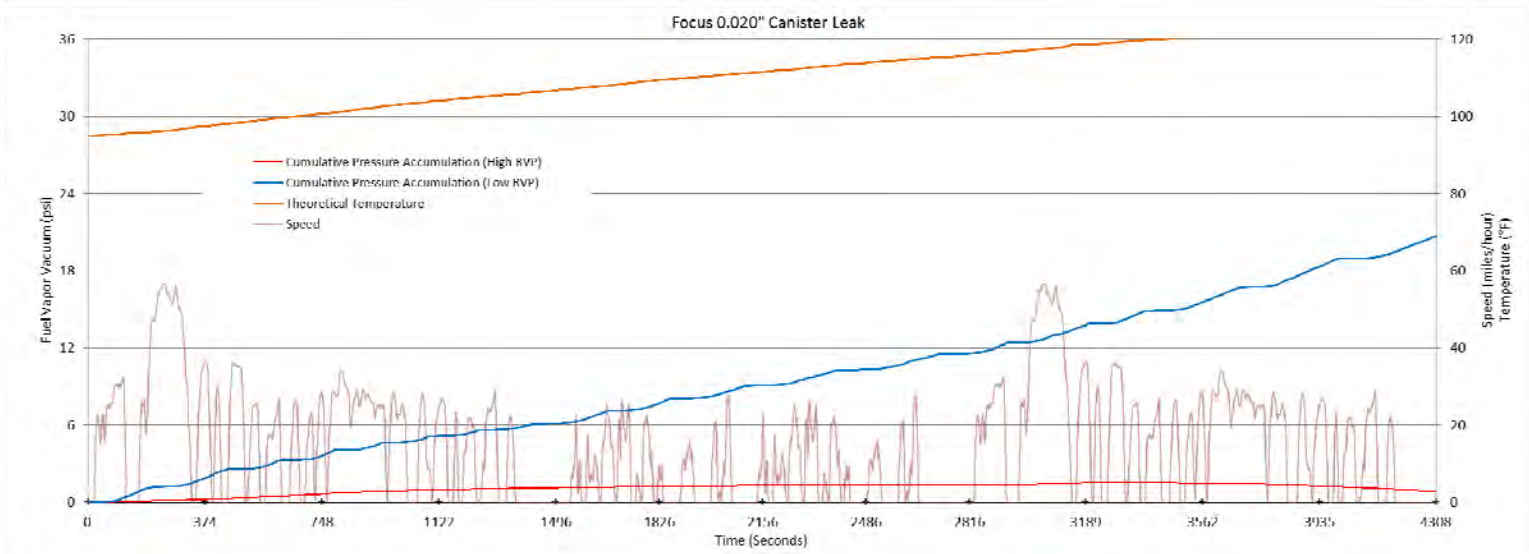
0.020" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.213	0.510	11.777	12.500
Low RVP	0.121	0.126	0.105	0.352





0.020" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.213	0.510	11.777	12.500
Low RVP	0.121	0.126	0.105	0.352



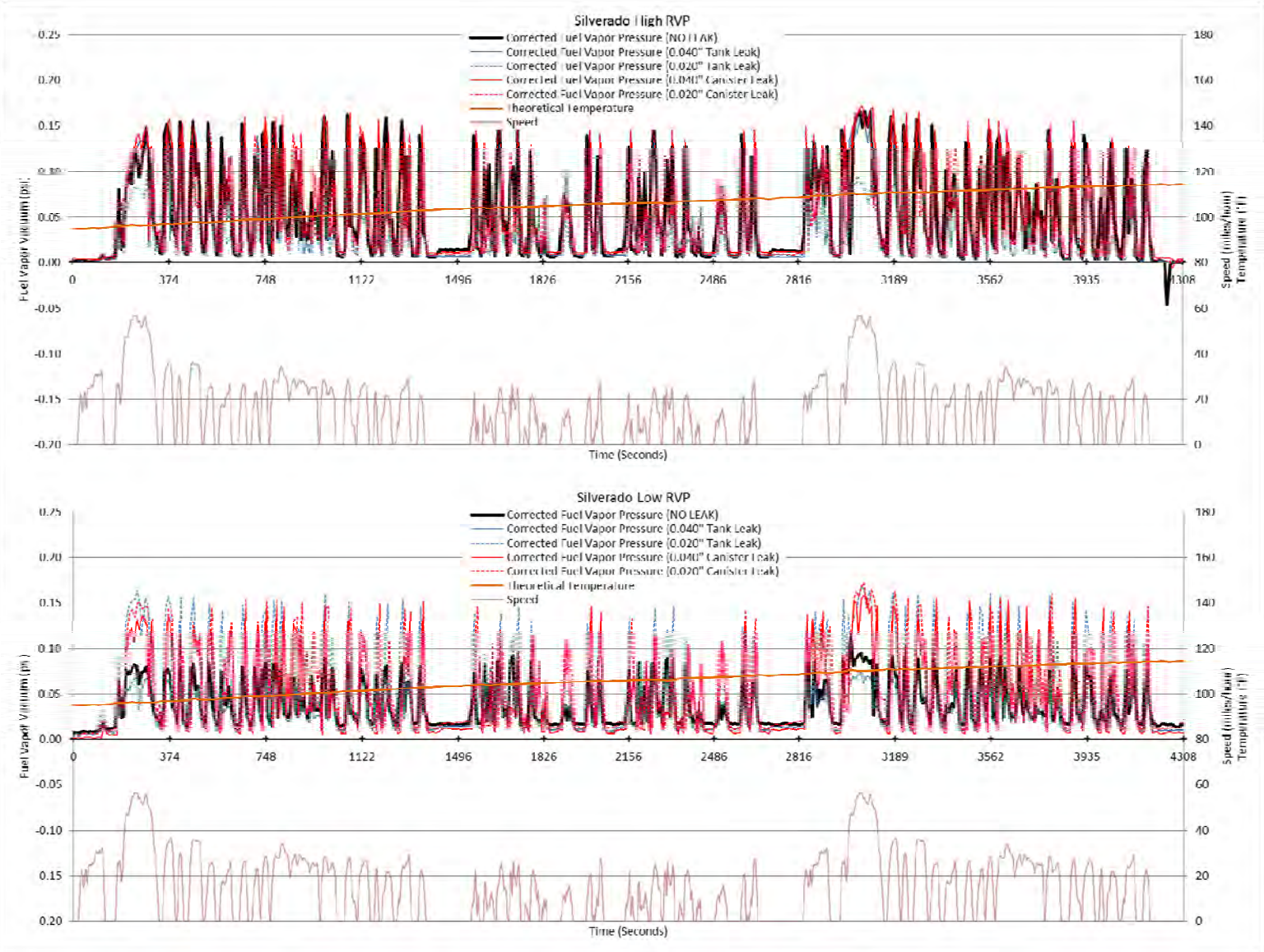


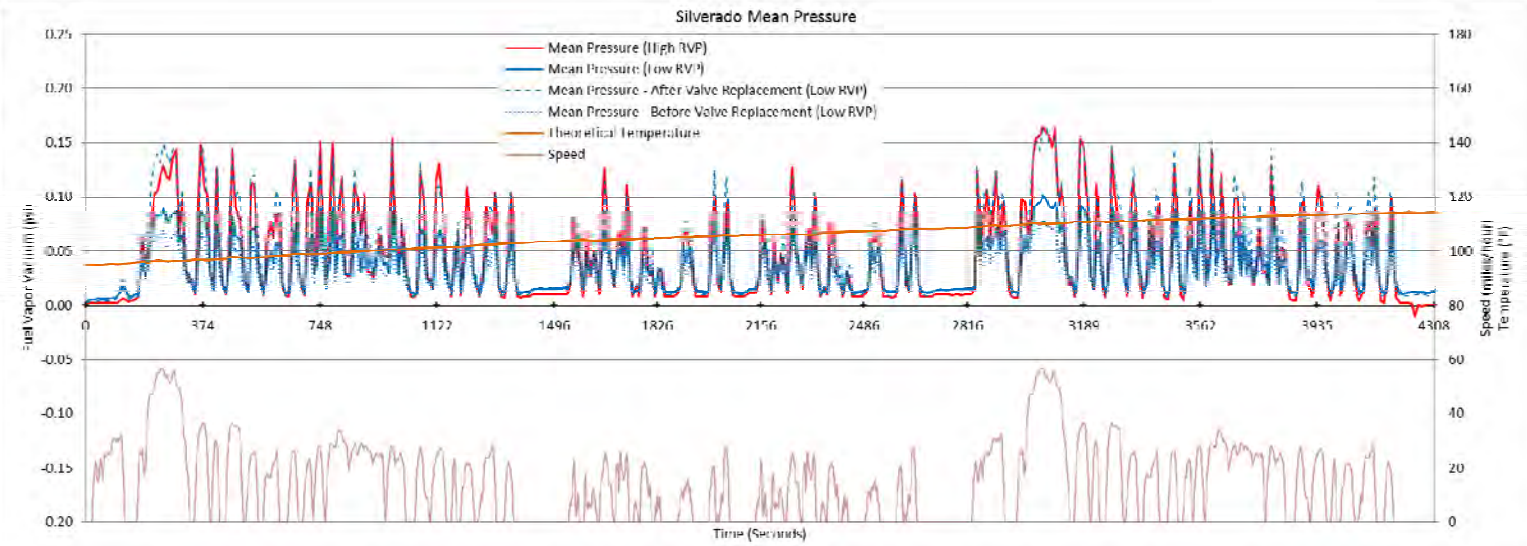
B.6 2006 Chevrolet Silverado

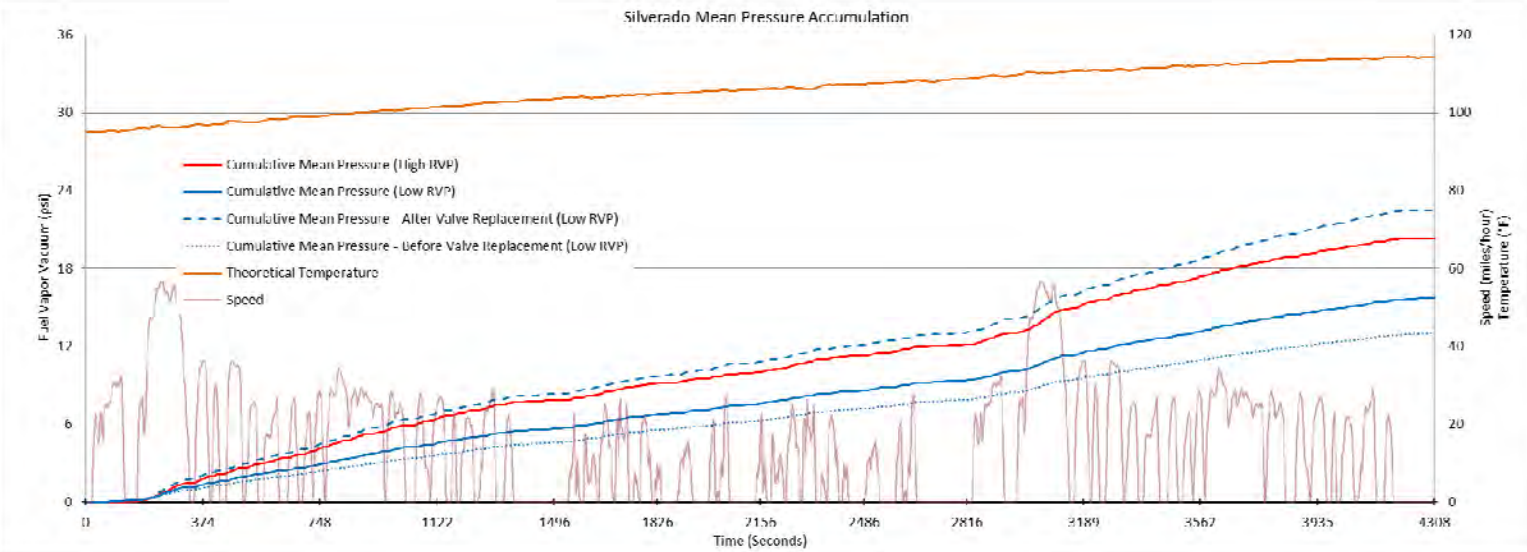
VIN:	1GCEK19B66Z154114
ENGINE FAMILY:	6GMXT05.3379
EVAPORATIVE FAMILY:	6GMXR0176820
EMISSIONS STANDARD:	Tier 2 Bin 8
ENGINE DISPLACEMENT:	5.30 Liters
INERTIA WEIGHT:	5500 Pounds
Tank CAPACITY:	26.0 Gallons
ROAD LOAD A:	1.44
ROAD LOAD B:	1.2678
ROAD LOAD C:	0.002258
PEAK FUEL TEMP:	114.3 °F

Sequence:		1	2	3	4	5	6	7	8	9	10
Fuel:		High RVP Fuel (10.0 RVP)					Low RVP Fuel (7.7 RVP)				
Leak location:		No Leak	Tank	Canister	Tank	Canister	No Leak	Tank	Canister	Tank	Canister
Leak Size:		No Leak	0.040	0.040	0.020	0.020	No Leak	0.040	0.040	0.020	0.020
Purge Flow LA-4 Precon.											
Purge Flow LA-92 Precon.											
Results in Grams:											
Running Loss	P1	0.002	0.057	0.023	0.042	0.108	0.001	0.018	0.062	0.012	0.064
	P2	0.000	0.012	0.021	0.003	0.097	0.001	0.000	0.065	0.002	0.078
	P3	0.000	0.361	0.040	0.082	0.109	0.001	0.002	0.052	0.001	0.062
	TOTAL	0.002	0.430	0.084	0.127	0.314	0.003	0.020	0.179	0.015	0.204
Hot Soak		0.063	0.749	1.435	0.206	0.254	0.061	0.841	1.165	0.225	0.364
Static Test	P1	0.010	0.371	0.010	0.015	0.008	0.013	0.230	0.010	0.303	0.071
	P2	0.007	8.796	8.483	3.441	2.691	0.008	4.862	6.156	2.330	2.830
	TOTAL	0.017	9.168	8.493	3.456	2.699	0.021	5.092	6.167	2.633	2.901
RL + HS + ST		0.082	10.347	10.012	3.789	3.267	0.085	5.953	7.511	2.873	3.469

B.6.1 Running Loss Fuel Vapor Pressure Comparisons

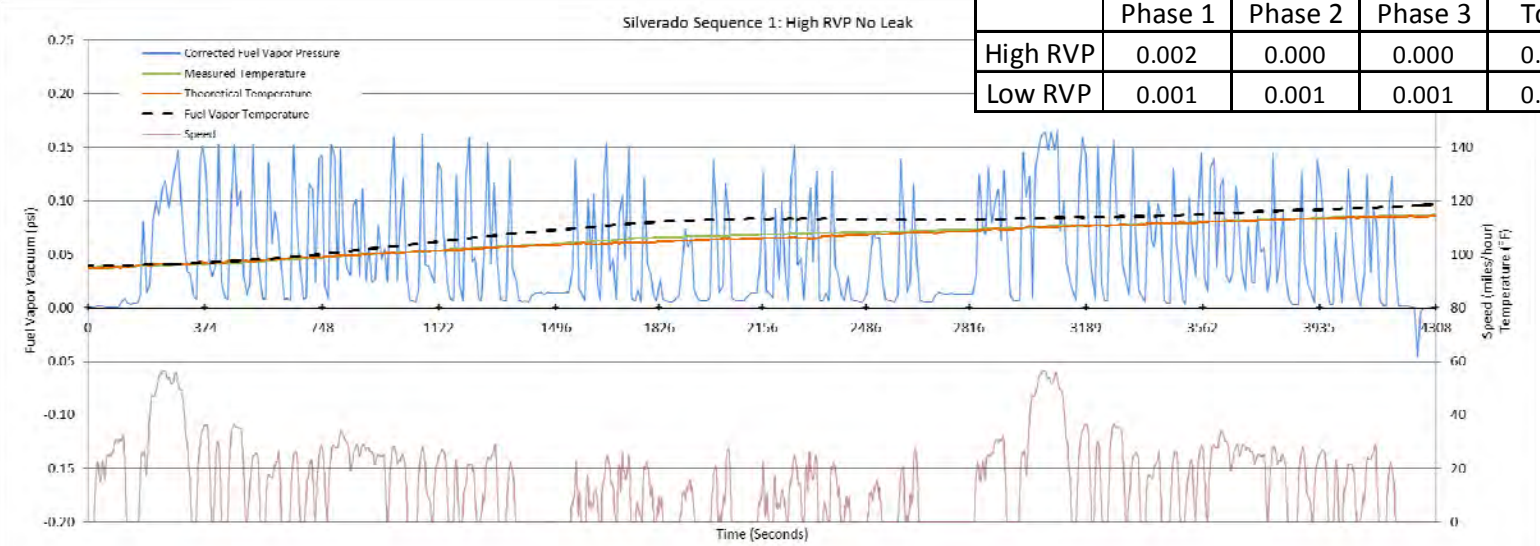


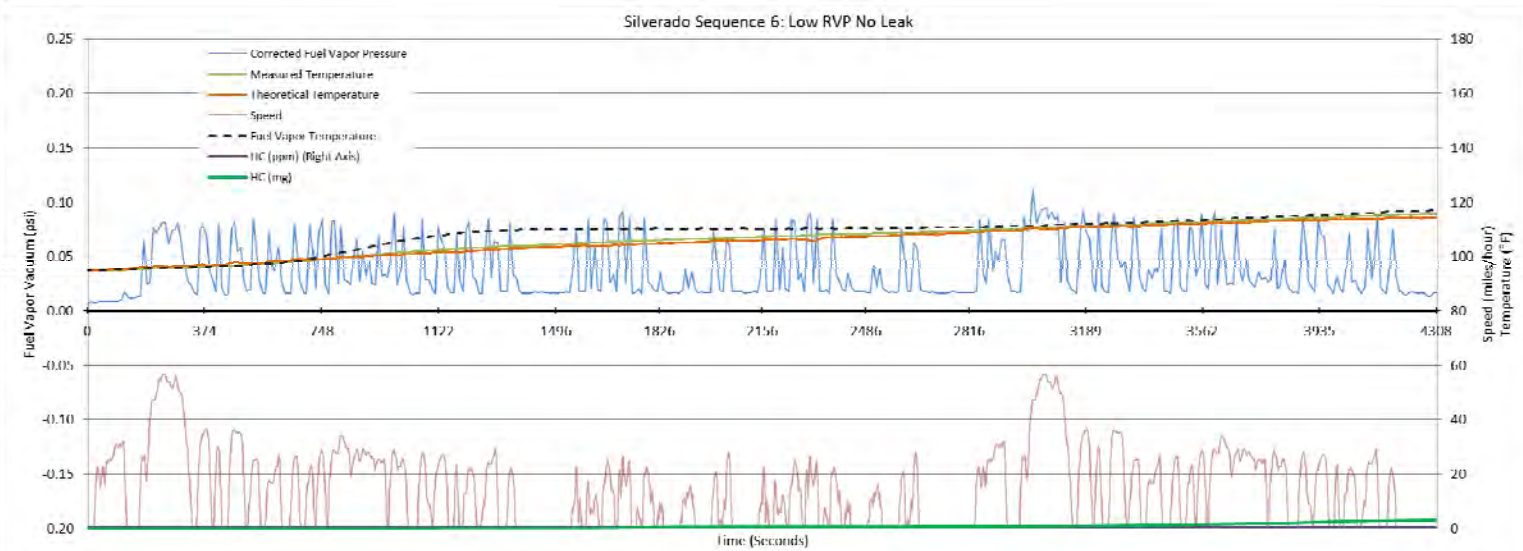

Silverado Mean Pressure
Mean Pressure (High RVP)
Mean Pressure (Low RVP)
Mean Pressure - After Valve Replacement (Low RVP)
Mean Pressure - Before Valve Replacement (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)


Silverado Mean Pressure Accumulation
Cumulative Mean Pressure (High RVP)
Cumulative Mean Pressure (Low RVP)
Cumulative Mean Pressure - After Valve Replacement (Low RVP)
Cumulative Mean Pressure - Before Valve Replacement (Low RVP)
Theoretical Temperature
Speed
Fuel Vapor Vacuum (psi)
Speed (miles/hour)
Temperature (°F)
Time (Seconds)

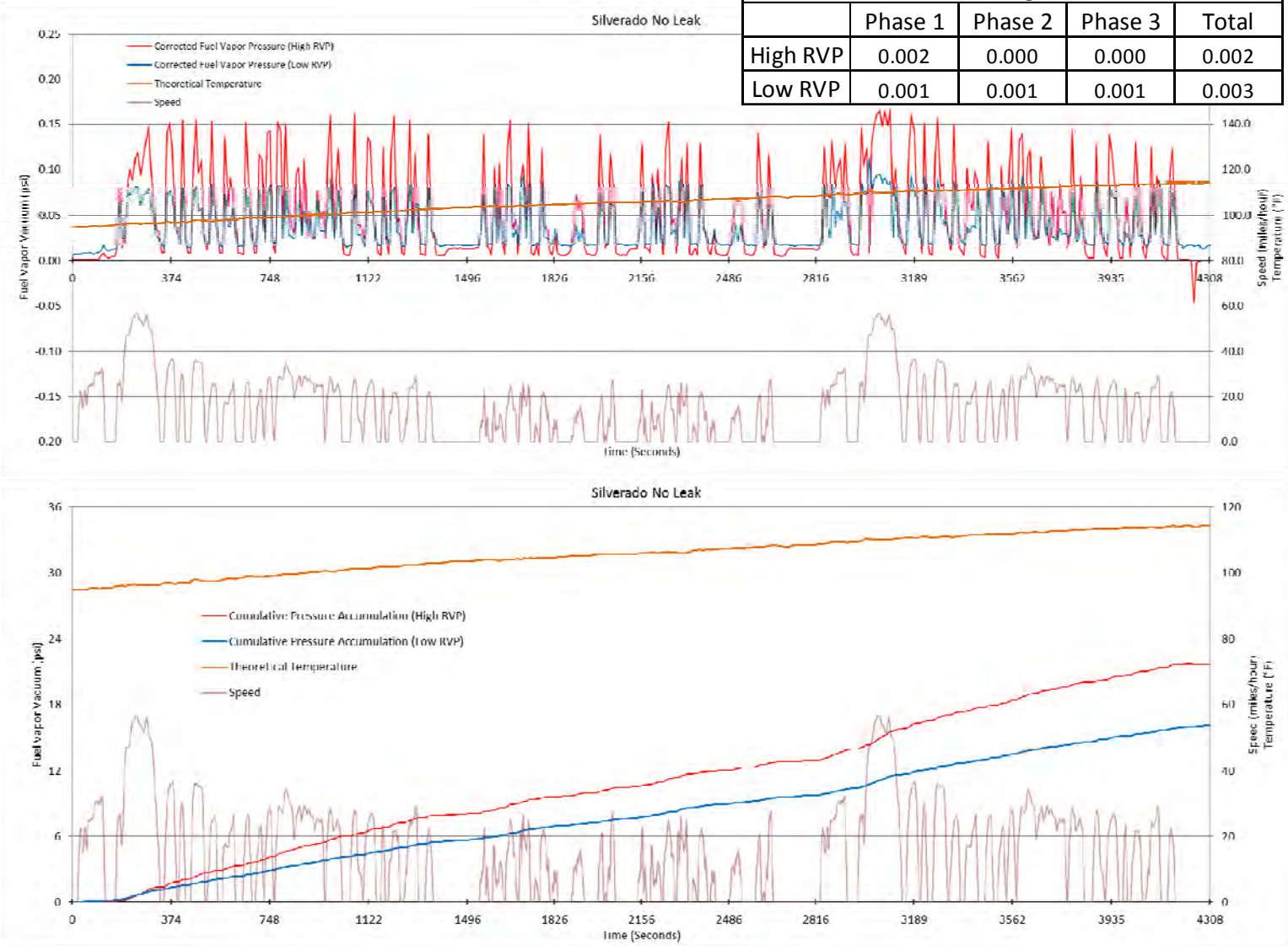
B.6.2 No Leak

No Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.002	0.000	0.000	0.002
Low RVP	0.001	0.001	0.001	0.003

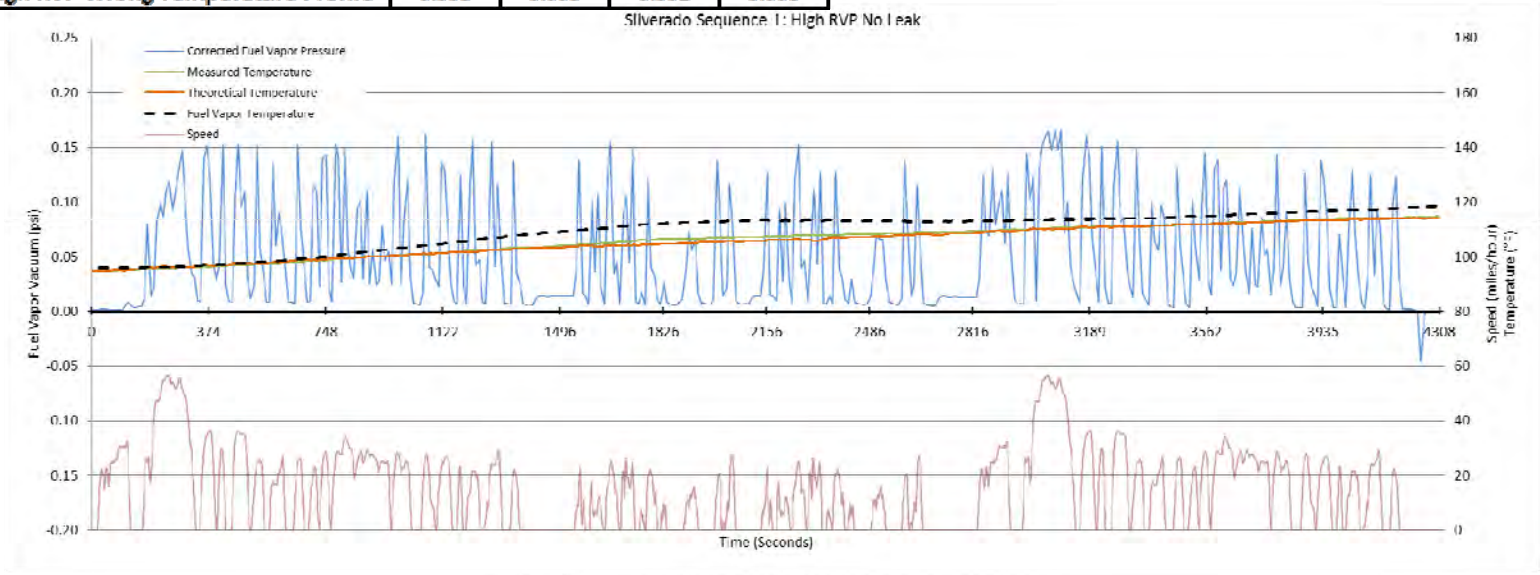


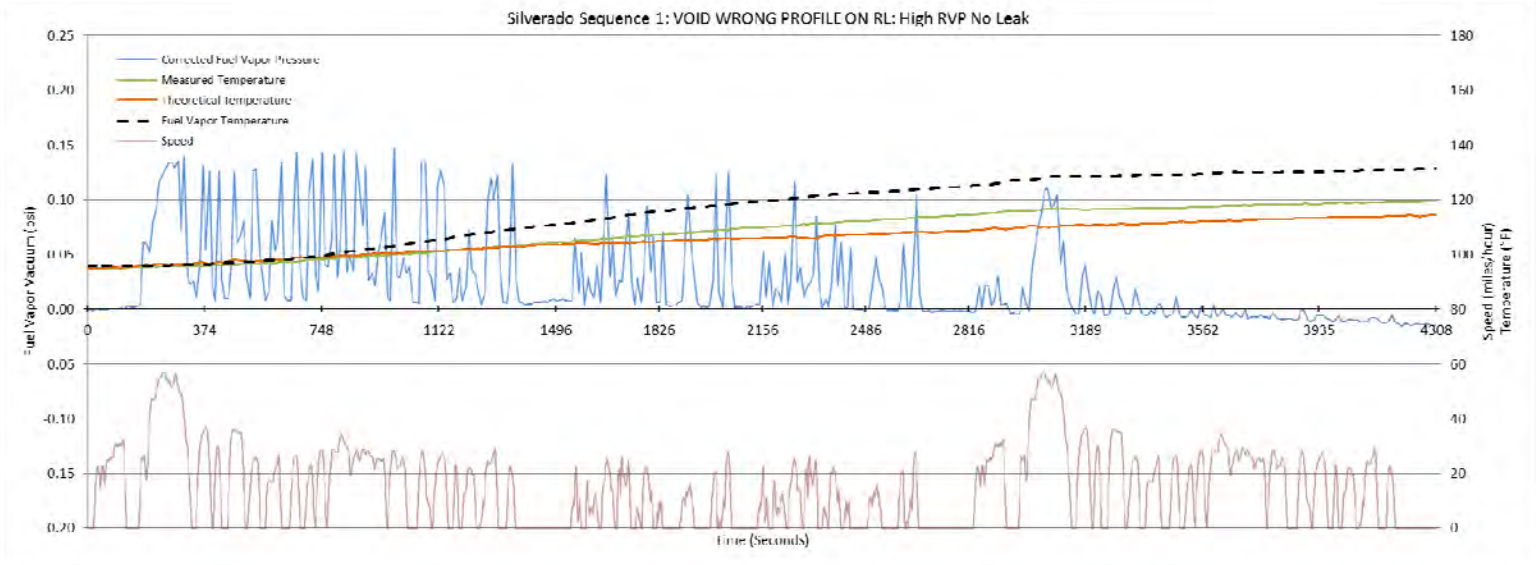


No Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.002	0.000	0.000	0.002
Low RVP	0.001	0.001	0.001	0.003

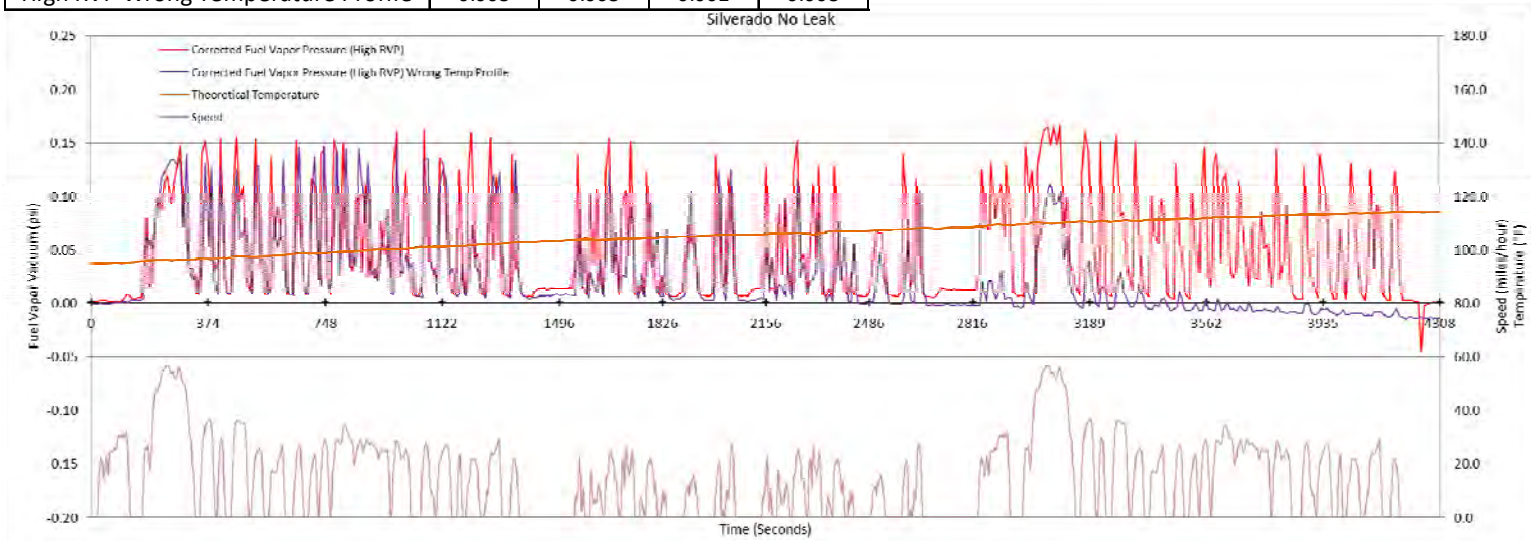


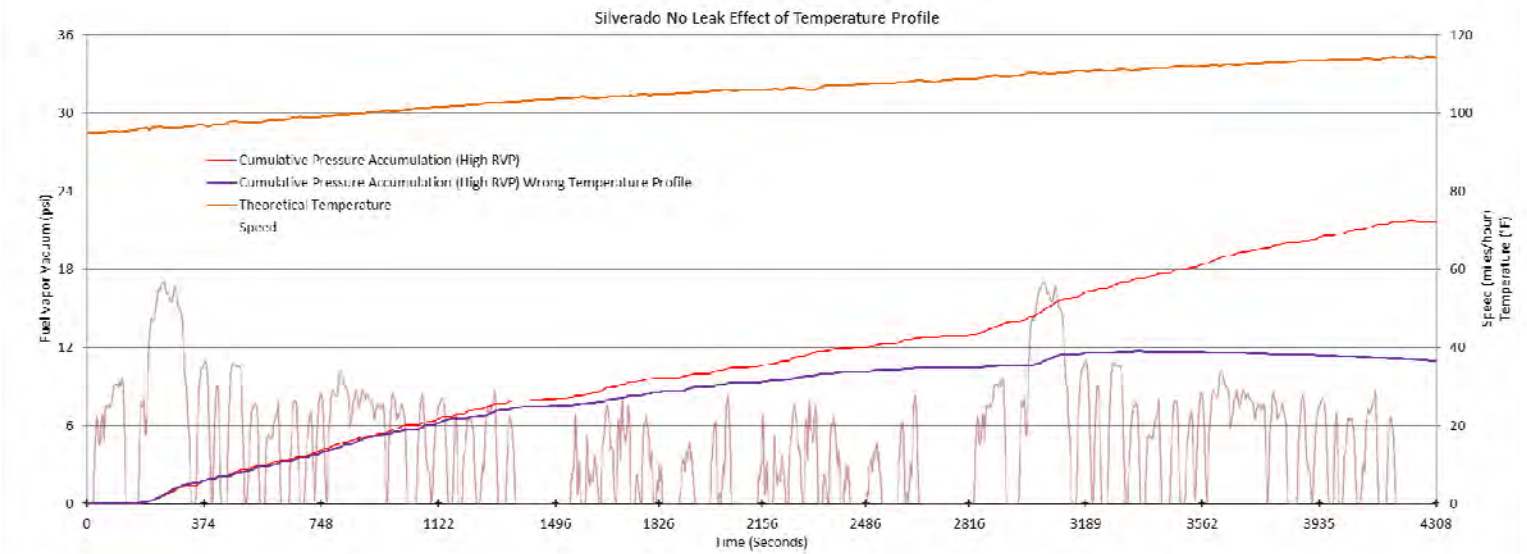
No Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.002	0.000	0.000	0.002
High RVP Wrong Temperature Profile	0.003	0.003	0.002	0.008





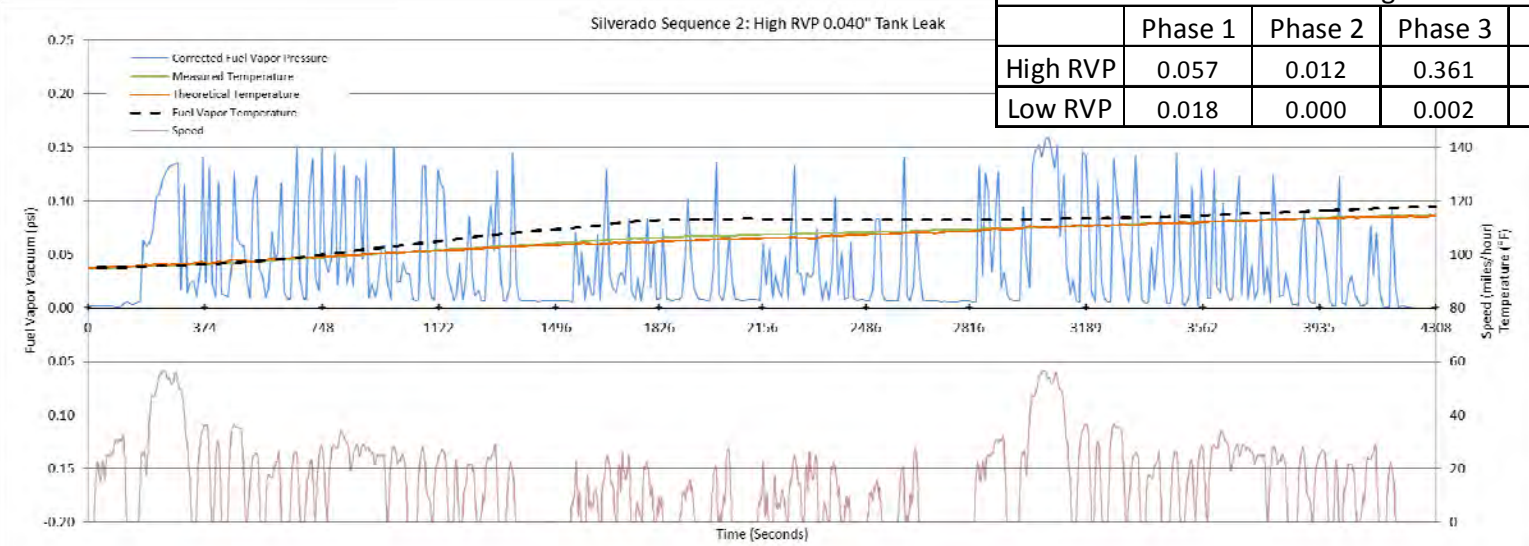
No Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.002	0.000	0.000	0.002
High RVP Wrong Temperature Profile	0.003	0.003	0.002	0.008

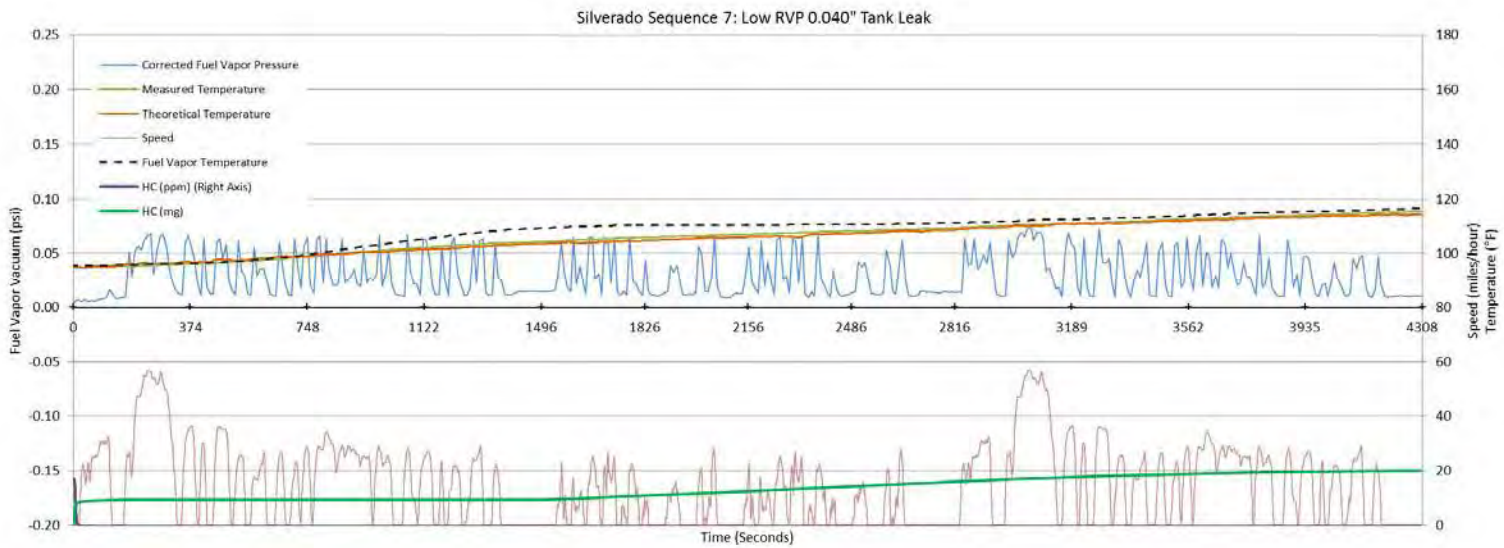




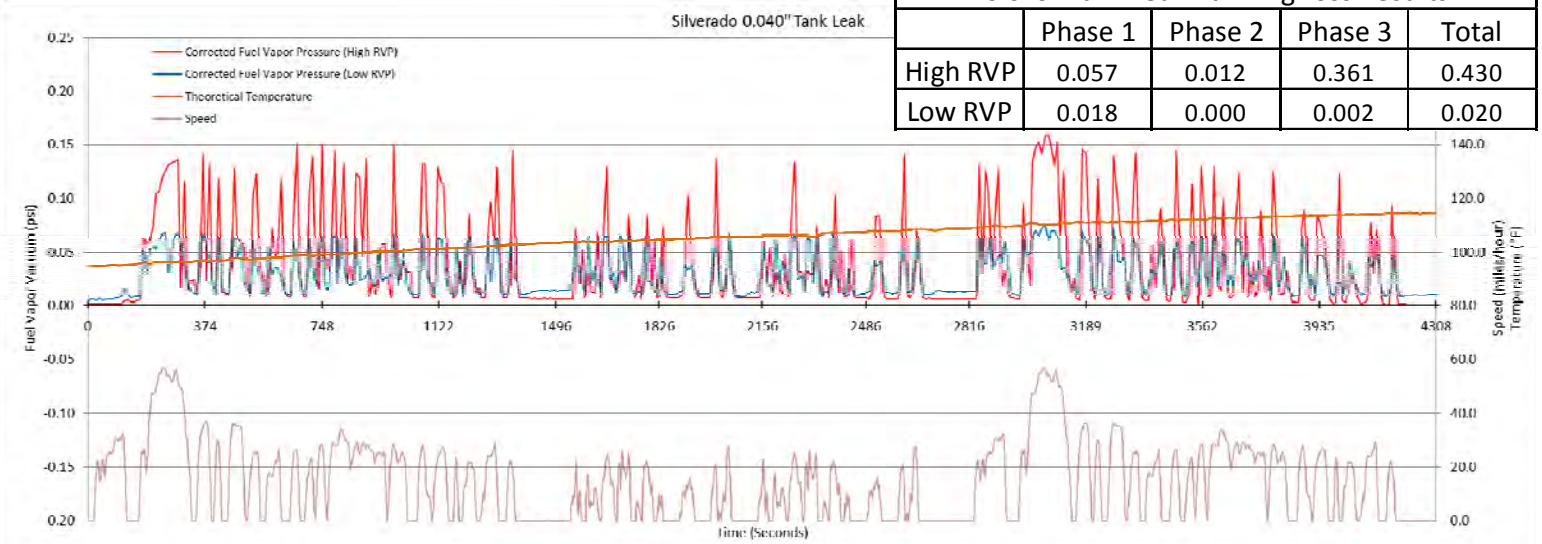
B.6.3 0.040” Tank Leak

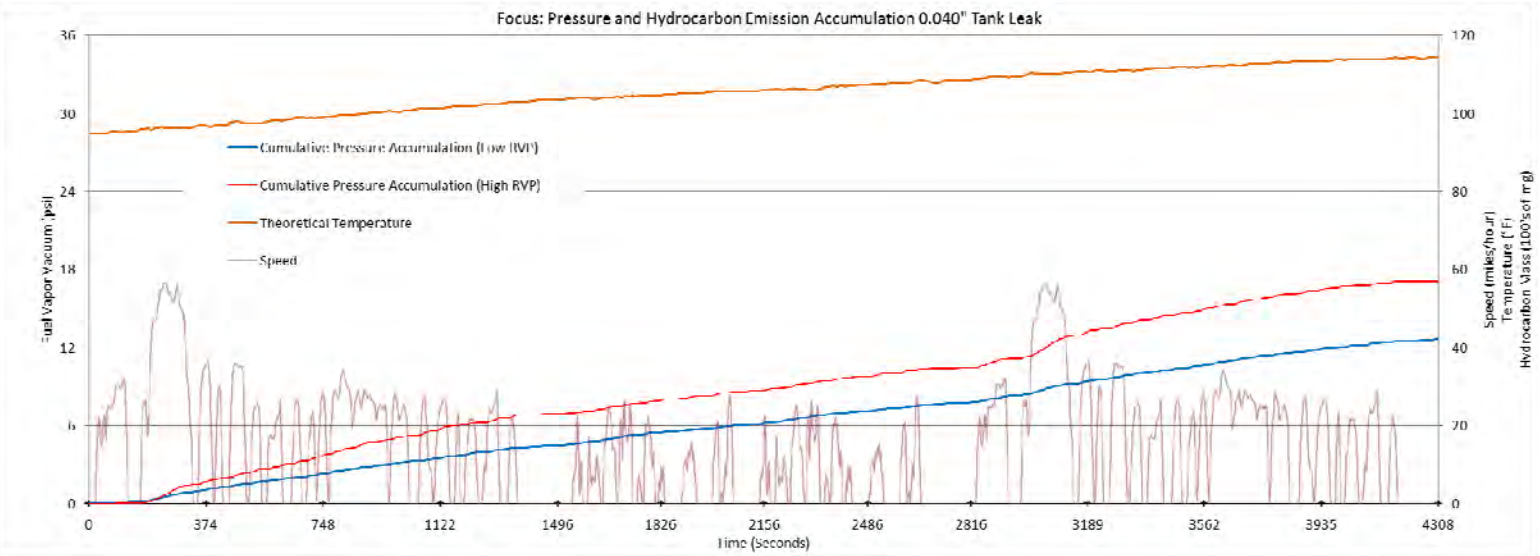
0.040" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.057	0.012	0.361	0.430
Low RVP	0.018	0.000	0.002	0.020





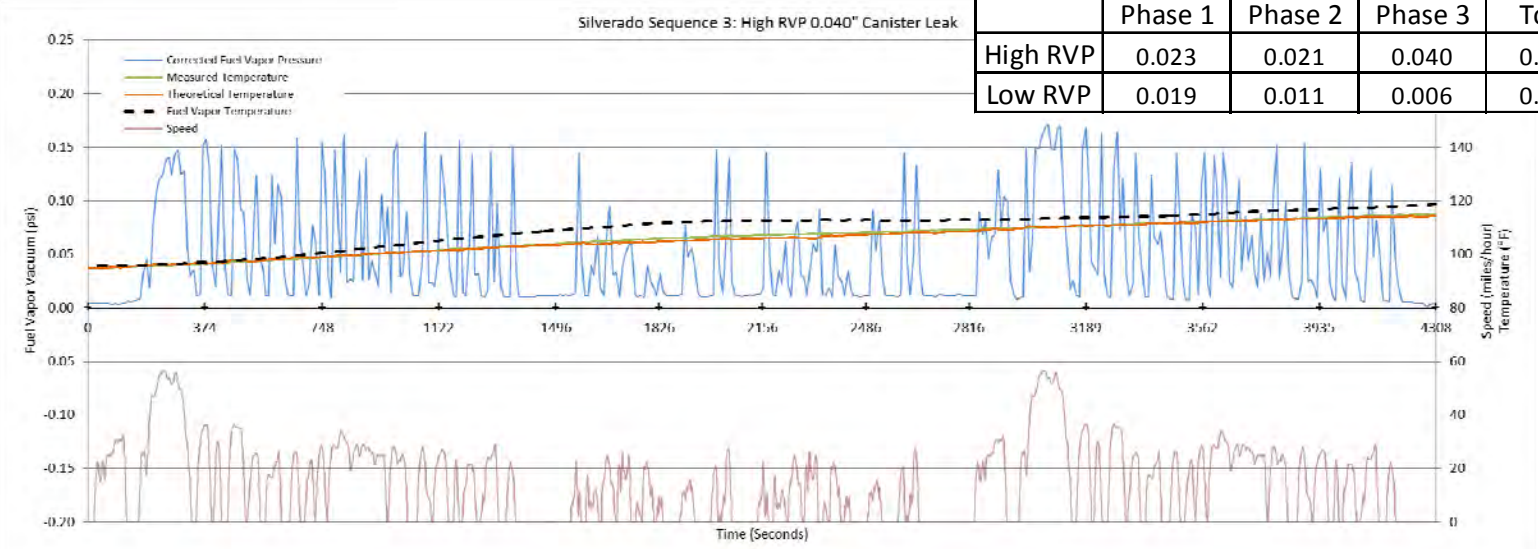
0.040" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.057	0.012	0.361	0.430
Low RVP	0.018	0.000	0.002	0.020

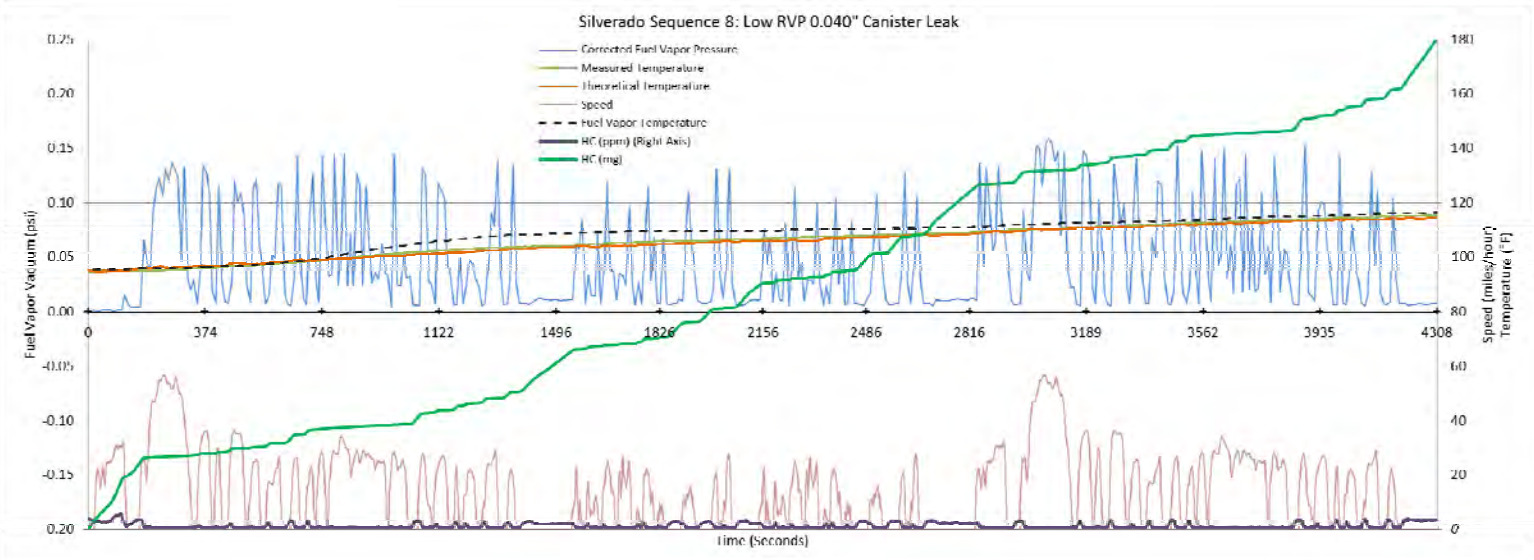




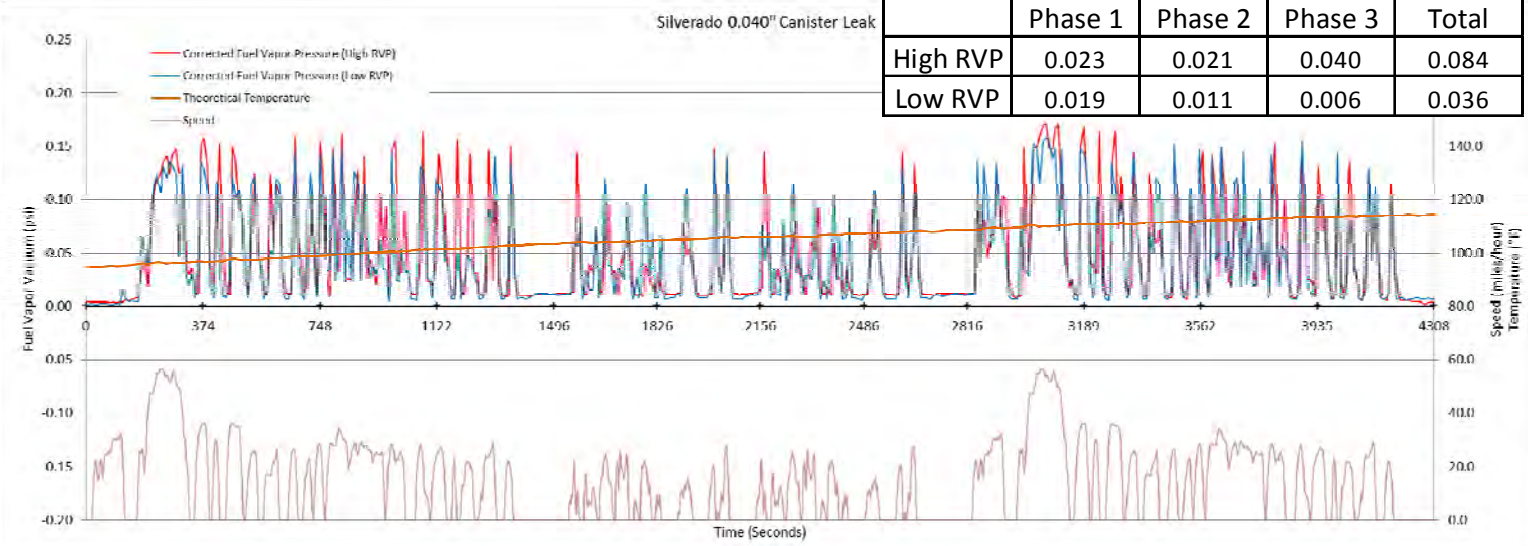
B.6.4 0.040” Canister Leak

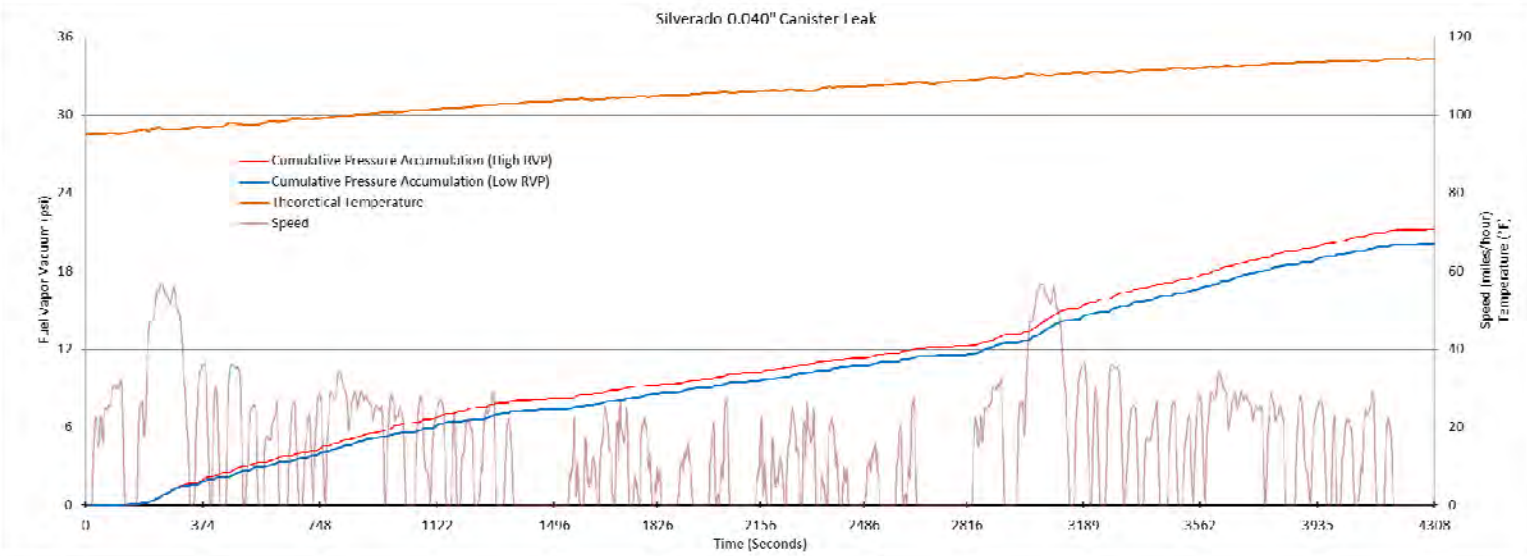
0.040" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.023	0.021	0.040	0.084
Low RVP	0.019	0.011	0.006	0.036

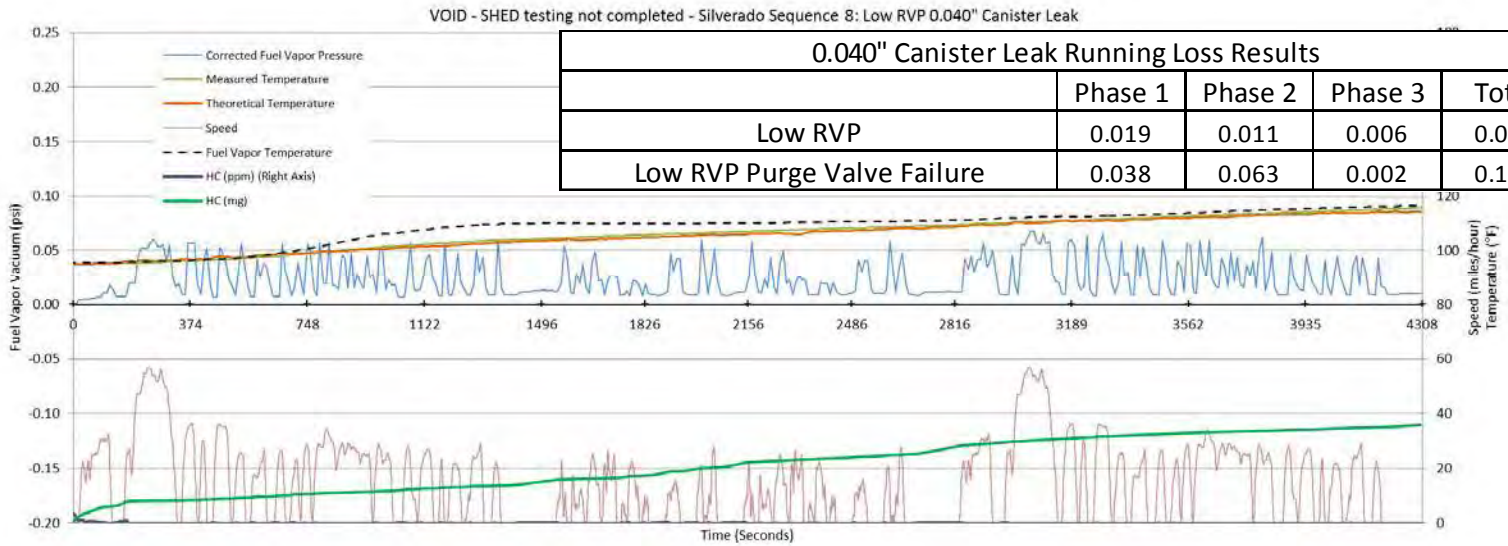




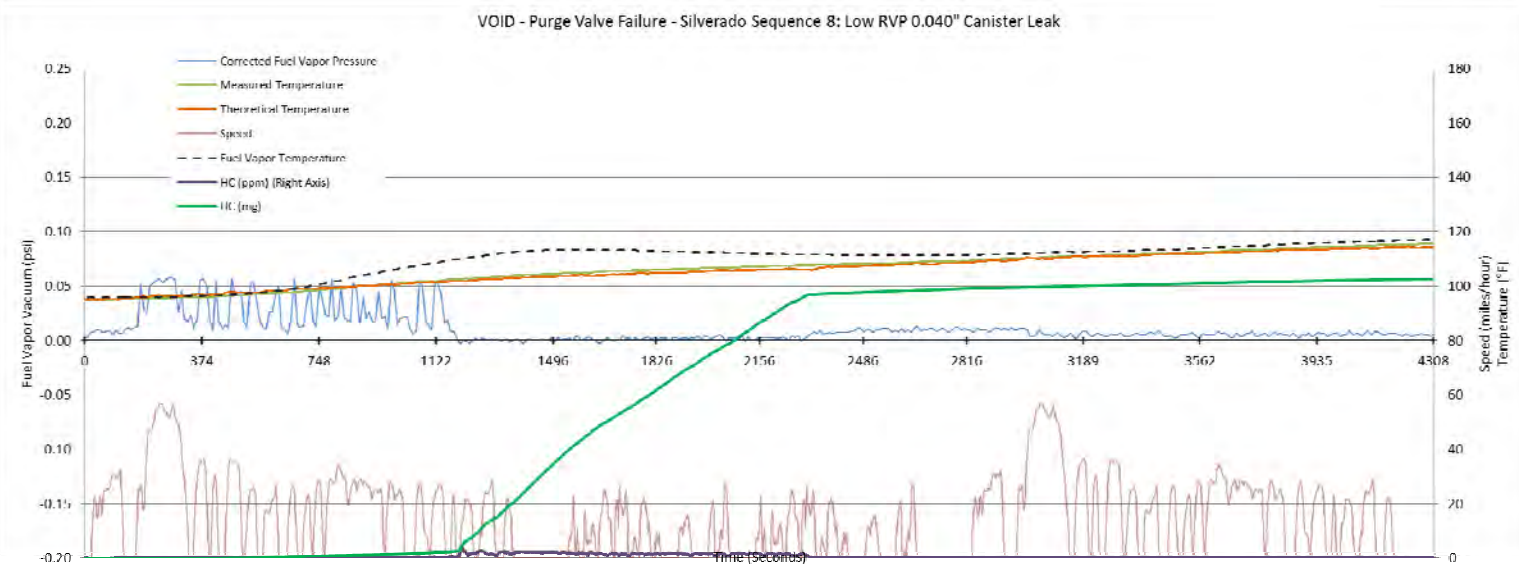
0.040" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.023	0.021	0.040	0.084
Low RVP	0.019	0.011	0.006	0.036



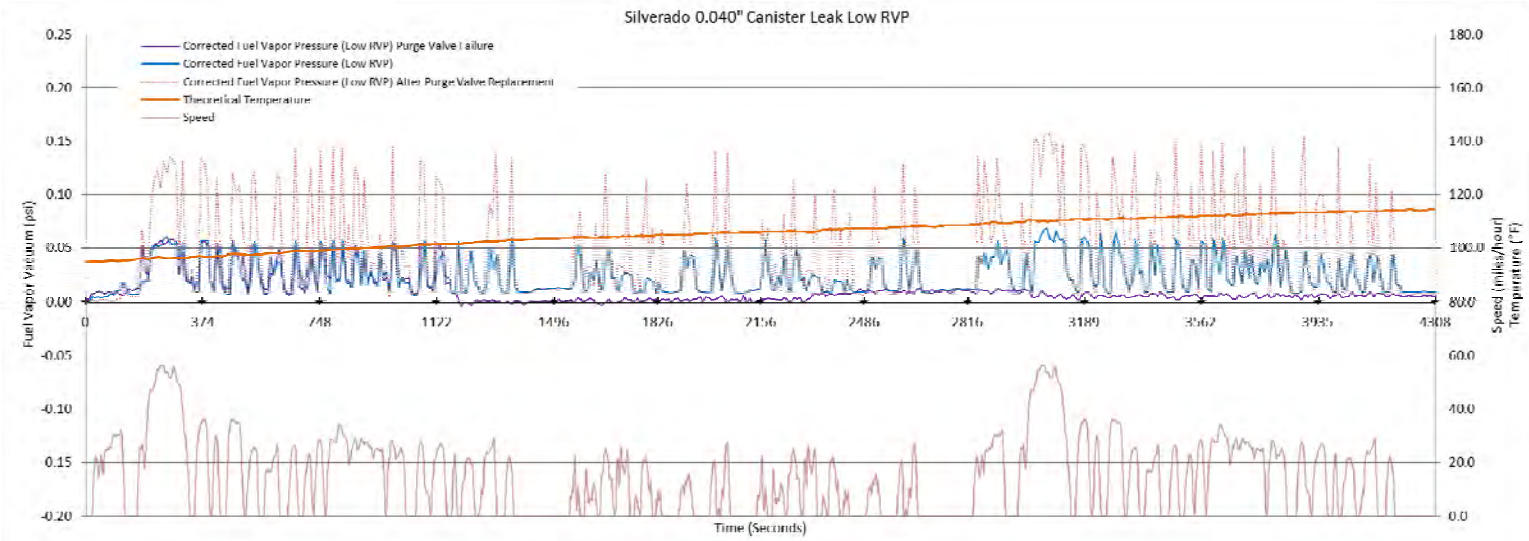


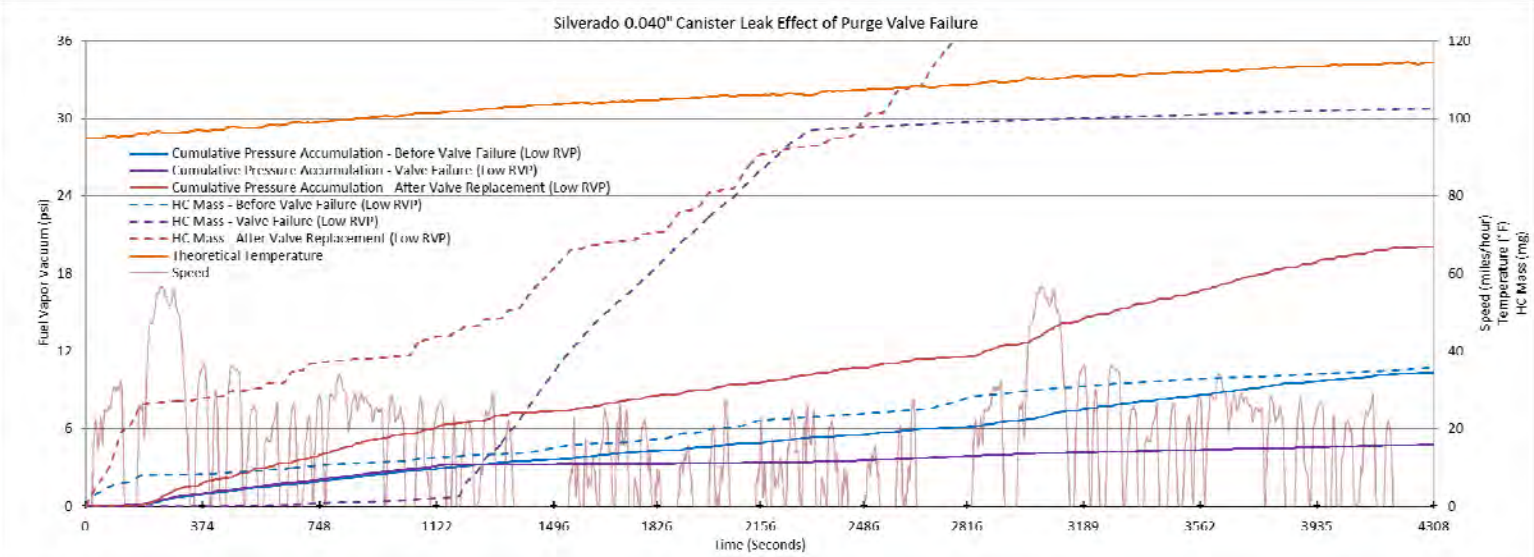


0.040" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
Low RVP	0.019	0.011	0.006	0.036
Low RVP Purge Valve Failure	0.038	0.063	0.002	0.103



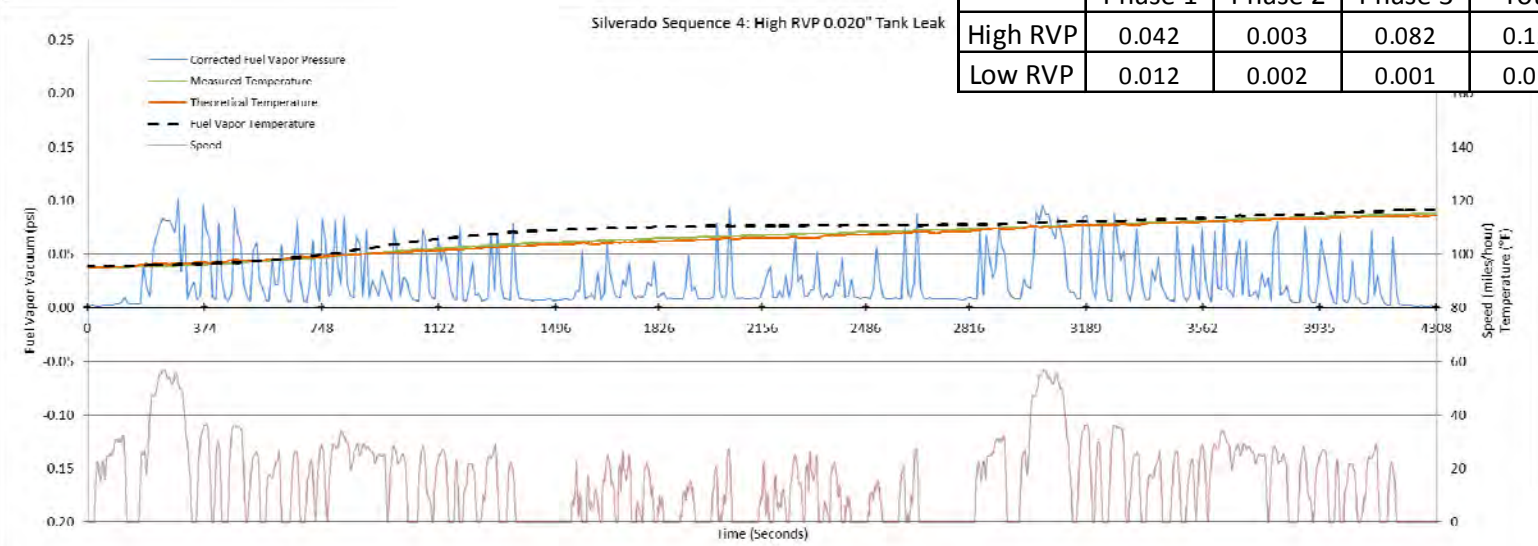
0.040" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
Low RVP	0.019	0.011	0.006	0.036
Low RVP Purge Valve Failure	0.038	0.063	0.002	0.103

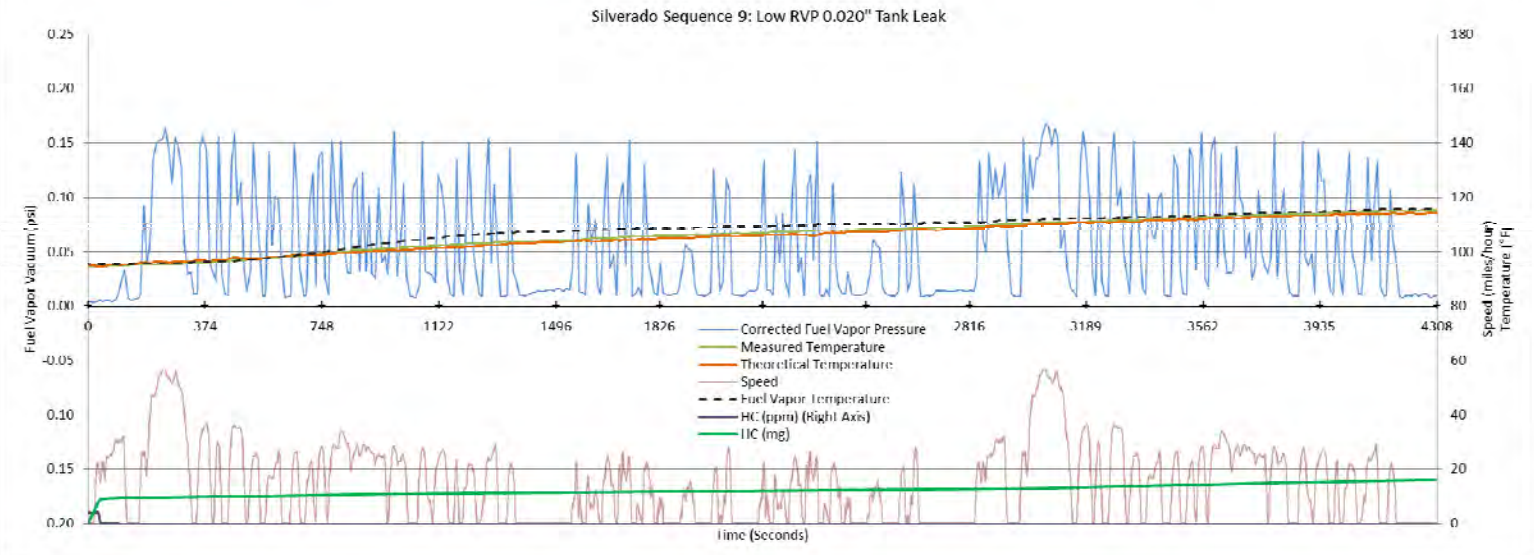


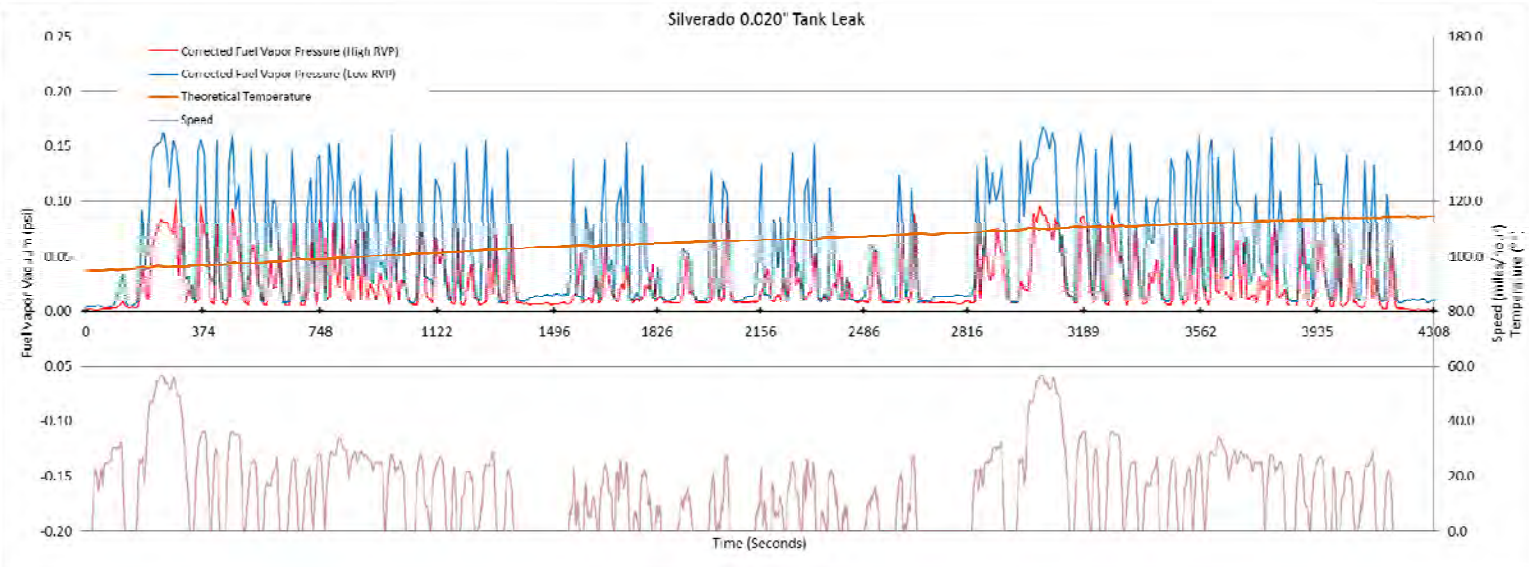


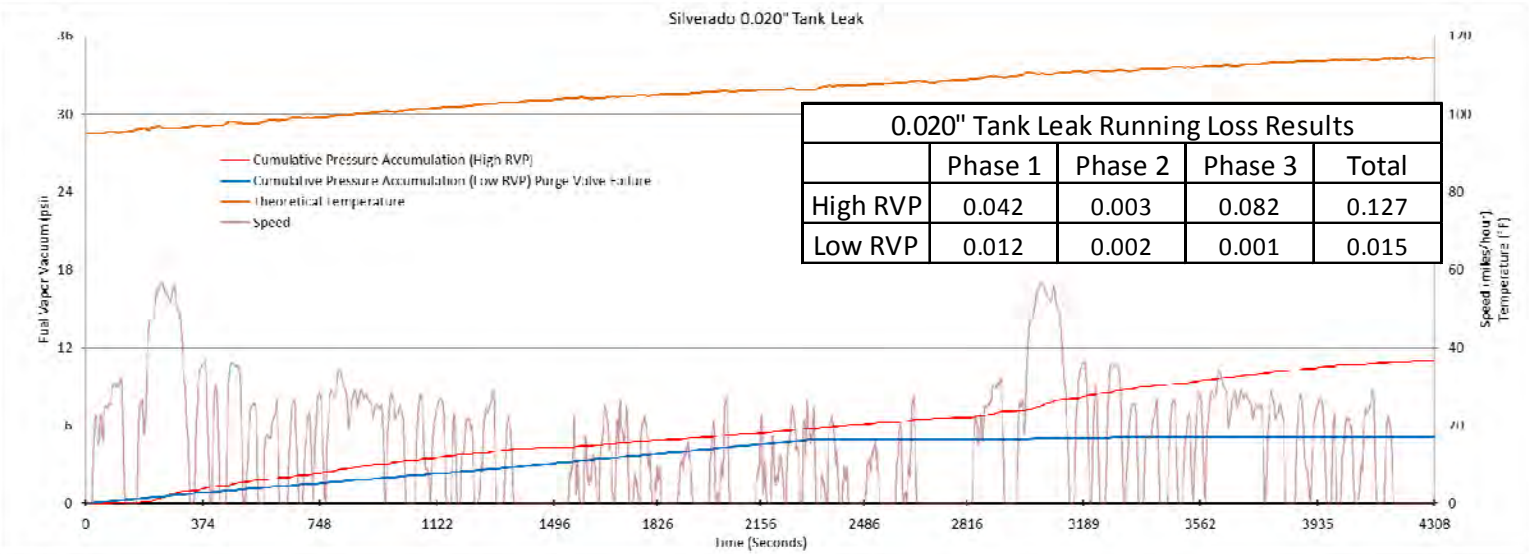
B.6.5 0.020” Tank Leak

0.020" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.042	0.003	0.082	0.127
Low RVP	0.012	0.002	0.001	0.015





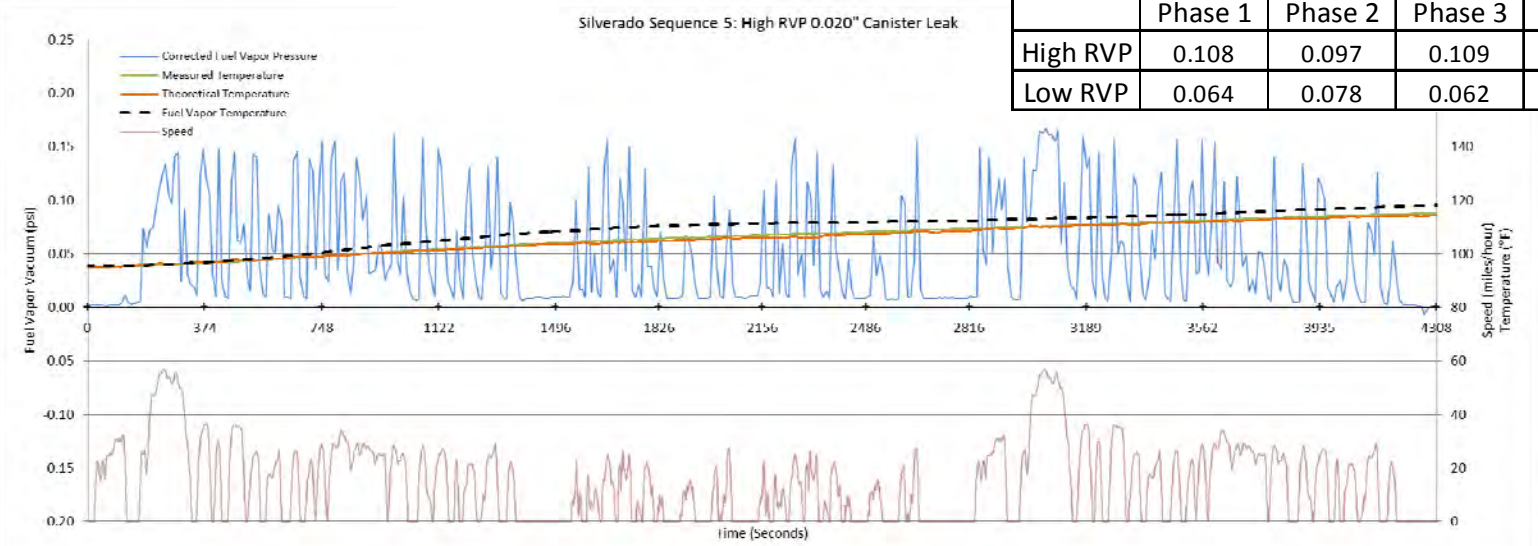


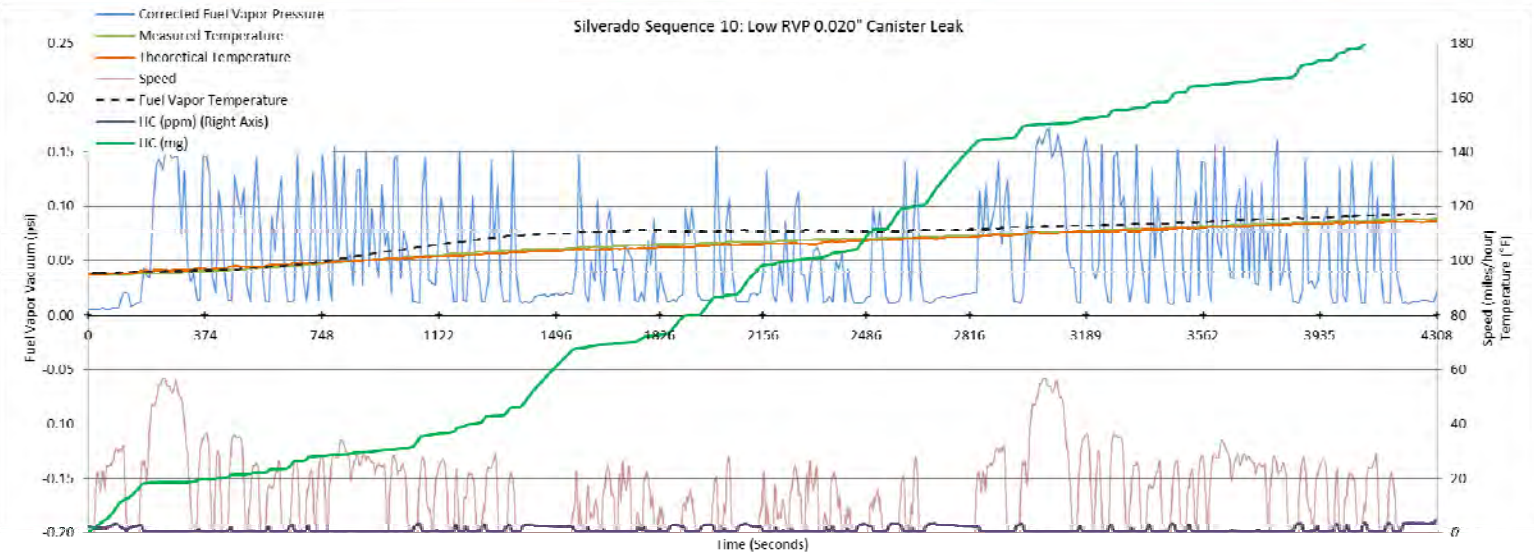


0.020" Tank Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.042	0.003	0.082	0.127
Low RVP	0.012	0.002	0.001	0.015

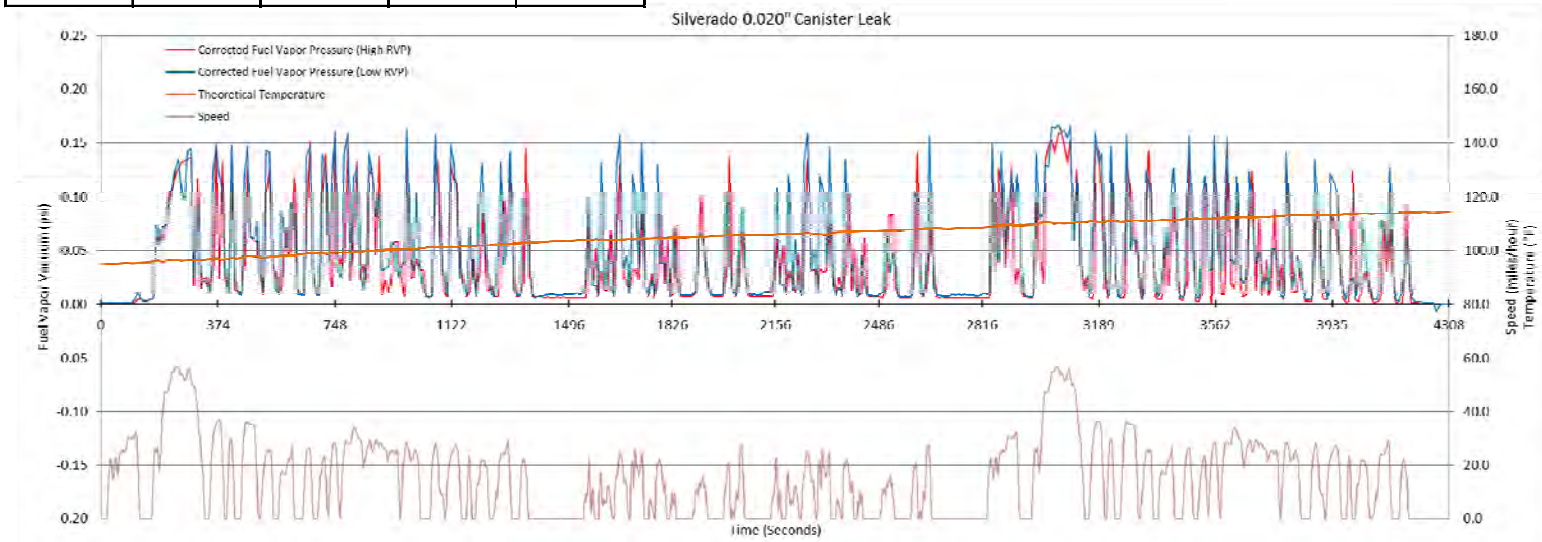
B.6.6 0.020” Canister Leak

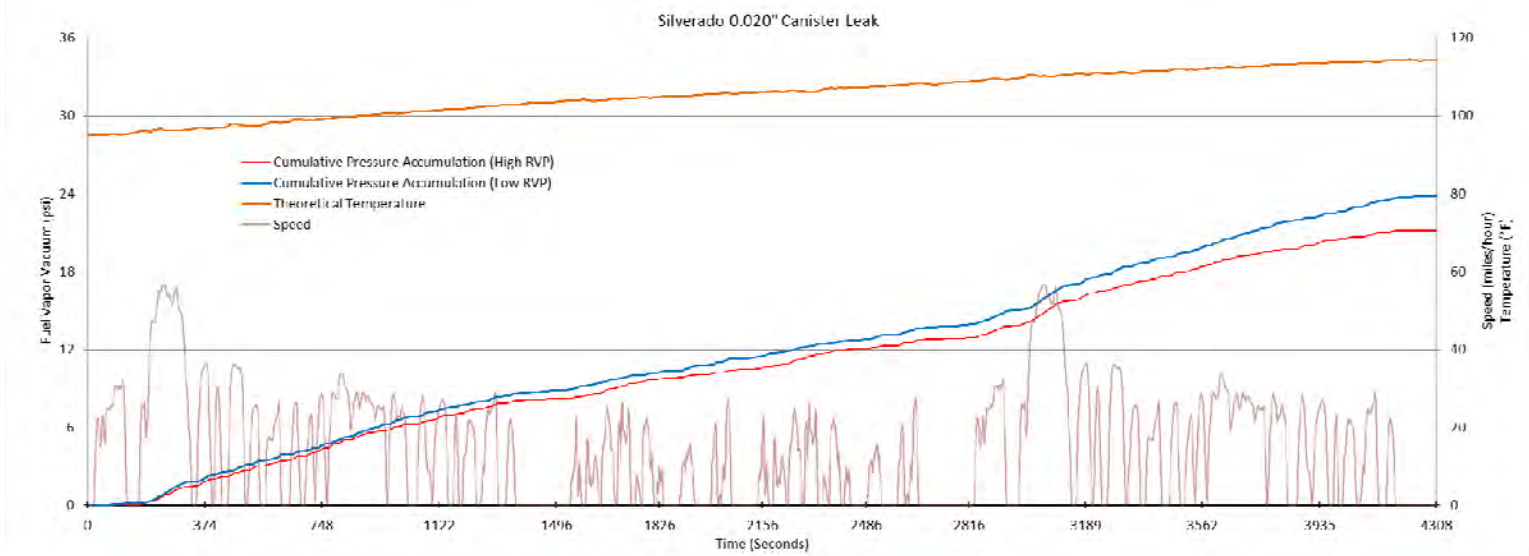
0.020" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.108	0.097	0.109	0.314
Low RVP	0.064	0.078	0.062	0.204





0.020" Canister Leak Running Loss Results				
	Phase 1	Phase 2	Phase 3	Total
High RVP	0.108	0.097	0.109	0.314
Low RVP	0.064	0.078	0.062	0.204





Appendix C
Descriptions of Study Data

Each of the tests performed for this study produced data in different formats, the following section discusses the data acquired in each report. This data will be provided in folders organized by vehicle.

FTP 72 Report (*_74.pdf)[1]

Test Start: When the drive cycle began

Test Finish: When the drive cycle ended

Time Elapsed: Duration of the drive cycle in seconds

Distance: Distance driven over the cycle in miles

Driver: The technician responsible for driving the vehicle for the cycle

Road Load Parameters: A, B, and C Road Load Coefficients and Vehicle Inertia

Fuel Parameters: Fuel name, specific gravity, weight fraction of Carbon, Hydrogen and Oxygen, and net heating value

Environmental Conditions: Barometric pressure in inHg, site temperature in °F, site humidity in grains/pound dry air

FTP 75 Report (*.pdf)

Test Start: When the drive cycle began

Test Finish: When the drive cycle ended

Time Elapsed: Duration of the drive cycle in seconds

Distance: Distance driven over the cycle in miles

Driver: The technician responsible for driving the vehicle for the cycle

[1] "*_74.pdf" was the naming convention used by APTL for the FTP-72 tests performed for this study.

Road Load Parameters: A, B, and C Road Load Coefficients and Vehicle Inertia

Fuel Parameters: Fuel name, specific gravity, weight fraction of Carbon, Hydrogen and Oxygen, and net heating value

Environmental Conditions: Barometric pressure in inHg, site temperature in °F, site humidity in grains/pound dry air

Running Loss Report (*.pdf)

Test Start: When the drive cycle began

Test Finish: When the drive cycle ended

Time Elapsed: Duration of the drive cycle in seconds

Distance: Distance driven over the cycle in miles

Driver: The technician responsible for driving the vehicle for the cycle

Road Load Parameters: A, B, and C Road Load Coefficients and Vehicle Inertia

Fuel Parameters: Fuel name, specific gravity, weight fraction of Carbon, Hydrogen and Oxygen, and net heating value

Environmental Conditions: Barometric pressure in inHg, site temperature in °F, site humidity in grains/pound dry air

Emissions Sampling System: For each phase of the running loss test the hydrocarbon FID analyzer (calibrated using propane) reports the range, the ambient bag concentration, the sample bag concentration, the net concentration, the hydrocarbon mass, and the CVS volume

Running Loss Data File (*.csv)

Data was recorded at 0.1 Hz (once every 10 seconds) during the preheat and the driven portions of the running loss test.

Time: Seconds from the beginning of recording

Fuel Temperature: Measured in °F

Fuel Temperature Set Point: From manufacturer fuel tank temperature profile, in °F

Fuel Vapor Temperature: Measured in °F

Fuel Vapor Pressure: Measured in psi, all but the very last tests demonstrate a zero bias which was corrected out in subsequent analysis (this is discussed further in the Issues Encountered and Solutions section above)

Discharge Air Temperature: Measured in °F

Discharge Air Temperature Set Point: As controlled by APTL software so that the fuel temperature measured matches the fuel temperature set point, in °F

Running Loss Continuous Hydrocarbon File (*.csv)

Ford APTL continuously recorded data during the second half of testing for all tests run with the 7 psi RVP fuel. The data is recorded at 1 Hz during the drive portion of the running loss test.

Time: Seconds from the beginning of recording

Hydrocarbon Concentration: Measured in ppm (analyzer calibrated using propane)

OBD2 Data (*.csv)

OBDII data was collected using a HEM Data mini logger provided by the EPA during the three driving portions (the FTP 72, the FTP 75, and the running loss test) of the test sequence. The OBDII data collection system was problematic and didn't consistently record data for all tests (as discussed above in the Issues Encountered and Solutions section). Data is stored in a binary file that is processed using the HEM Data's DawnEdit software. The data available varies for each vehicle as some vehicles use different communication standards and don't broadcast the same types of data. The data description in below describes only the data that was used during analysis. Also, per the discussion above in the Issues Encountered and Solutions section – OBDII data is not available for all driving tests.

Time: When the drive cycle began

VIN: The vehicle identification number for the unit under test

Vehicle Speed: The vehicle speed measured in miles per hour

Commanded Evaporative Purge: Measured in percent, this is how much purge was commanded by the vehicle while the vehicle was in operation

Hot Soak Data (*.xls)

The hot soak data is contained on Sheet1 in the workbook. Sheet4 contains analyzer zero span results. The other sheets contained in the workbook are extraneous sheets used by Ford for performing SHED leak calculations and error estimates. The data presented in Sheet1 is broken into several boxes of data.

Technician: Technician that initiated the test sequence

SHED Number: Identifies which SHED was used for the particular test.

Start Date/Time: The time the test began

End Date/Time: The time the test ended

Initial/Final Barometer: Atmospheric pressure at the beginning and end of the test, measured in inHg, located in the SHED Post Volume Information Box

Initial/Final Temperature: SHED temperature at beginning and end of the test, measured in °F, located in the SHED Post Volume Information Box

Initial/Final SHED Volume: SHED volume at the beginning and end of the test, measured in °F, located in the SHED Post Volume Information Box

Fuel Temperature: The fuel temperature at the beginning and the end of the test, measured in °F using J-Type thermocouples, located in the Fuel Temperature J Box (NB the measurements in the Fuel Temperature K Box are not the correct temperature measurements)

Emissions Sampling System: Reports, in the Hotsoak Emission Results Box, the concentration and mass of hydrocarbons in the SHED at the beginning of the test, and

at the end of the test; in the HC Summary Box, the change in the hydrocarbon mass and concentration from the beginning of the test to the end

Static Test Data (*.xls)

The static test data is contained on Sheet1 in the workbook. Sheet4 contains analyzer zero span results. The other sheets contained in the workbook are extraneous sheets used by Ford for performing SHED leak calculations and error estimates. The data presented in Sheet1 is broken into several boxes of data.

Technician: Technician that initiated the test sequence

SHED Number: Identifies which SHED was used for the particular test.

Start Date/Time: The time the test began

End Date/Time: The time the test ended

Initial/Final Barometer: Atmospheric pressure at the beginning and end of the test, measured in inHg, located in the SHED Post Volume Information Box

Initial/Final Temperature: SHED temperature at beginning and end of the test, measured in °F, located in the SHED Post Volume Information Box

Initial/Final SHED Volume: SHED volume at the beginning and end of the test, measured in °F, located in the SHED Post Volume Information Box

Fuel Temperature: The fuel temperature at the beginning and the end of the test, measured in °F using J-Type thermocouples, located in the Fuel Temperature J Box (NB the measurements in the Fuel Temperature K Box are not the correct temperature measurements)

Emissions Sampling System: Because of the modal nature of the results of these tests the data presented in this file doesn't correctly state the desired results, a separate data file was exported which contains the concentrations and the masses of hydrocarbons in the SHED at beginning of the test and at the end of each mode

Static Test Data (*.txt)

The static test data reported in the text file reports analyzer reads at set intervals during the static test sequence. The readings that should be used when considering these reports occur at 0 minutes, 15 minutes, and 30 minutes into the test. Occasionally, the analyzer reports that an analyzer read fails and reports a “SampISD Failure”. This error doesn’t affect the analyzer reading and precise timing of analyzer readings is very important during this test so it is not recommended to consider the repeat readings that are performed after the error. The following different types of data are provided in the text file

Sample Time: The exact timing of the analyzer read

Mass: The mass of the hydrocarbons in the SHED

Concentration: The concentration of hydrocarbons in the SHED

Zero/Span: Analyzers zero – span operations results

Vehicle Data (*.xls)

Data was combined into a single Microsoft Excel workbook for each vehicle to allow for improvements in data processing and analysis. There are several worksheets in each workbook which are used to present the information described here

Test Record Worksheet

This worksheet provides the time and date each particular test in every sequence started and ended. Also provided are the APTL test numbers.

Test Sequence and Results Worksheet

This worksheet gives the final mass emissions for each test in a particular sequence. The running loss is broken down into three phases. Overall emissions for a single sequence are reported.

FTTP Worksheet

This worksheet contains the tank temperature profile and the trace to be driven during the running loss test.

Data Worksheet

This worksheet contains the data recorded at 0.1 Hz (once every 10 seconds) during the running loss preheat and cycle. The data is time aligned so that 0 seconds occurs when the drive portion begins for each test. Several graphs are also produced on this worksheet. These graphs compare fuel vapor vacuum, liquid and vapor fuel temperatures, vehicle speed, commanded evaporative purge (if available), and continuous hydrocarbon emissions (if available) for each running loss test. Additional graphs are also developed which compare the vapor vacuum for all leak configurations on a particular fuel, and also comparing the vapor vacuum for both fuels given a particular leak configuration.

Average Pressures Worksheet

This spreadsheet calculates the average vapor vacuum for each fuel, and also performs numeric integration on the measured vapor vacuum. Several graphs are then produced which demonstrate differences in behavior for the different fuels.

Continuous Hydrocarbon Measurement Worksheet

This spreadsheet contains the continuous hydrocarbon measurements recorded at 1 Hz (once per second). This data is presented in the graphs produced on the Data worksheet.

OBD Data Worksheet

This spreadsheet contains the OBDII data which is available for certain tests. A moving average has been applied to the commanded evaporative purge to reduce noise. This data is recorded a 1 Hz and is presented in the graphs produced on the Data worksheet.

Appendix D
Issues Encountered and Solutions

This appendix provides a summary of issues that were encountered during this test program and a description of how each of those issues were addressed.

HEM Data OBD Mini Loggers were provided by EPA in order to collect vehicle OBDII data during the test program. However, several problems occurred during the study which prevented the successful collection of OBDII data for some of the tests. The original data loggers used in the study had a spring load mechanism which accepted a micro SD card to record data. When the recorder was installed in the vehicle, occasionally the technician would push on the micro SD card, accidentally ejecting the card and thus preventing data acquisition. An alternative data logger which used a friction mechanism to retain the micro SD card was provided by EPA at the midpoint of the study. However, this new data logger had a different pin arrangement and would only work on the newer vehicles in the study (the Corolla and Focus). An additional difficulty observed was that only the newer vehicles broadcast the commanded evaporative purge. Because of these reasons, OBDII purge data is only available for a limited number of tests. However, fuel system vapor vacuum, which is correlated to fuel system purge, is available for all tests conducted during the study.

During preliminary testing on the Caravan, it was observed that there would be little or no emissions during the first phase of the static test if the vehicle was introduced into the SHED while fuel temperatures were greater than 95 °F. The fuel and vapor were undergoing cooling during this phase of testing, resulting in a reduction of pressure and causing SHED air to be drawn into the fuel tank rather than to have hydrocarbons expelled. This behavior was prevented by adjusting procedures for all test vehicles so that the fuel temperature was cooled to 93 °F after completing the hot soak and before beginning the static test.

Several issues arose during testing of the Corolla in November and December, 2012. During a no leak test, the orifice cap split, producing a leak condition. This test was voided and another test was repeated after the cap was replaced. Then, a canister load line was left plugged during a subsequent test, causing fuel vapors to off-gas through the fuel tank. This test was voided and repeated. On the subsequent repeat, the canister was in a saturated state and did not perform in an expected manner. This test was also voided and repeated. Then, in December 2012, a retainer on a fuel line came loose and fuel was discharged into the interior of the vehicle. That test was voided, and the vehicle was transported to an SGS facility in Jackson, MI. The interior was first washed to remove as much of the fuel as possible. Then, over a four-day

process, the vehicle was heated to 130 °F until a hydrocarbon detector was unable to detect any residual hydrocarbons being emitted from the material of the vehicle. Afterwards, the vehicle was returned to Ford APTL and the test was repeated.

The high RVP fuel at the no leak setting caused the Focus to produce canister breakthrough emissions as purge was not commensurate with vapor generation. The high RVP fuel (10.0 psi) was greater than specification fuel for standard running loss testing (9.5 psi RVP) and is thought to have contributed to this unexpected result.

In December 2012, the wrong temperature profile was initially used when performing the Chevrolet Silverado's no leak test using the high RVP (10.0 psi) fuel. This test was voided and repeated.

During the first test performed on the Caravan, an SGS onsite technician observed that the fuel vapor temperature was trending in the wrong direction, a sign that the thermocouple had been incorrectly connected. The technician initially incorrectly swapped the liquid fuel temperature thermocouple, resulting in a short spike in temperature exacerbated by Ford APTL integration algorithms. However, the correct swap was made shortly thereafter. Testing continued and the results of the test were discussed with the EPA and accepted.

In January 2013, a replicate test of the Focus was performed using the 0.040" leak installed and the high RVP fuel to verify the continuous hydrocarbon measurement system that would be used for the second half of testing. Focus replicate testing results measured approximately half of the hydrocarbons measured during the original test performed in December 2012. The fuel was tested for RVP and demonstrated an 8.5 psi RVP, significantly lower than the 10.0 RVP of the fuel used during the initial round of testing. It was discovered that the incorrect fuel had been used for this replicate test. This test was voided and repeated using the original 10.0 RVP fuel that was used in the original test. This successful, repeated test showed good agreement with the original numbers and also good operation of the continuous measurement system.

In February 2013, there was concern that the Focus was behaving anomalously as the fuel vapor pressure seemed to change erratically. This behavior was a departure from what was measured during the original round of testing during which the system would show periodic vacuum during the first half of the test, and then begin building pressure in the system during the

second half of the test. This appeared to be proper system behavior in the Focus, resulting from a purge valve that is open/shut and lacking a linear operation which could provide partially opened states. This effect became more pronounced during the second half of testing when the fuel with lower RVP was used. The lower RVP fuel produced lower vapor pressures which more clearly revealed the opening and closing of the purge valve.

During the second half of the test program (low RVP fuel testing), the Silverado demonstrated a significant reduction in the amount of suction in the fuel vapor. This culminated with a purge valve failure during testing on February 14, 2013. Initially, the purge valve appeared to demonstrate a reduced operational range. Then at the end of the first phase of testing, the valve failed in a shut state, allowing vapor pressure to build and forcing hydrocarbons through the induced leak. The valve then moved to a partially opened state towards the end of the test. At this time, the cause for anomalous hydrocarbon emissions was still under investigation, and the valve had not yet been diagnosed. Another test was performed using the failed purge valve. During this test, the valve began in a partially open state and remained there until about half way through testing. After this, the valve closed, allowing fuel vapors to be emitted. The faulty valve was then diagnosed and replaced, and the two test sequences for which the valve had failed (0.040” canister leak and 0.020” tank leak) were repeated.

In March 2013, near the end of testing, Ford APTL Data Quality personnel determined that their fuel vapor pressure transducer was connected in reverse, so that a negative pressure (vacuum relative to atmospheric) resulted in a positive measurement. The vapor pressure measurement system was also found to have a small zero bias of about 0.2 psi. Ford reconnected the transducer and recalibrated it eliminating the zero bias. Only one test (Sequence 8 on the Chevrolet Silverado, 0.040” canister leak with low RVP) was performed after Ford APTL personnel adjusted the pressure transducer. However, the adjustment did not seem to affect the peak vacuum measurement. The reported vacuum signal polarity was reversed on this final test so all data are consistent in Appendix B. All Appendix B vacuum signals have been corrected for any zero offset bias, and all vacuum signals are reported as positive pressure (reversed polarity) to facilitate visual comparison with purge rates.

Some anomalies can be seen in the fuel vapor pressure plots for the Honda Accord (high and low RVP, 0.020” leak at tank, Appendix B.2.5) and the Dodge Caravan (high RVP, 0.040”

leak at canister, Appendix B.3.4). These pressure peaks appear to be data anomalies resulting from instantaneous instrument dropout (possibly from a faulty connection) and not valid data.

Continuous hydrocarbon measurements for vehicles with induced leaks demonstrate sudden increases in the measured concentration of hydrocarbons on some tests. These include data from the Honda Accord test with low RVP, 0.040" leak at canister (in Appendix B.2.4) and also for the Dodge Caravan with low RVP, 0.040" leak at tank (in Appendix B.3.3). This appears to be valid data (not a data anomaly), as the relative vacuum drawn on the evaporative system drops below zero (therefore building a positive pressure on the system) at these times and expels hydrocarbons at the end of the test. Intermittent spikes can also be seen in the test data for the Honda Accord. Several vehicles also exhibited intermittent spikes in hydrocarbon emissions due to purge behavior. In general, however, the cumulative hydrocarbon plots show that the total hydrocarbon emissions appear to be more related to an elevation in the continuous emissions rather than the transient hydrocarbon emission spikes due to purge behavior and the closing of the purge valve on these tests (i.e., the spikes produce a small overall contribution to the hydrocarbon emission totals).

Appendix E
Induced Leak Configurations

This section provides images of the vehicles tested in this program and documents how the induced leaks were installed on each vehicle. Images demonstrating the configuration of the respective evaporative emission control systems are also provided.

E.1.1 Honda Accord

Figure E-1. Honda Accord VECI Sticker

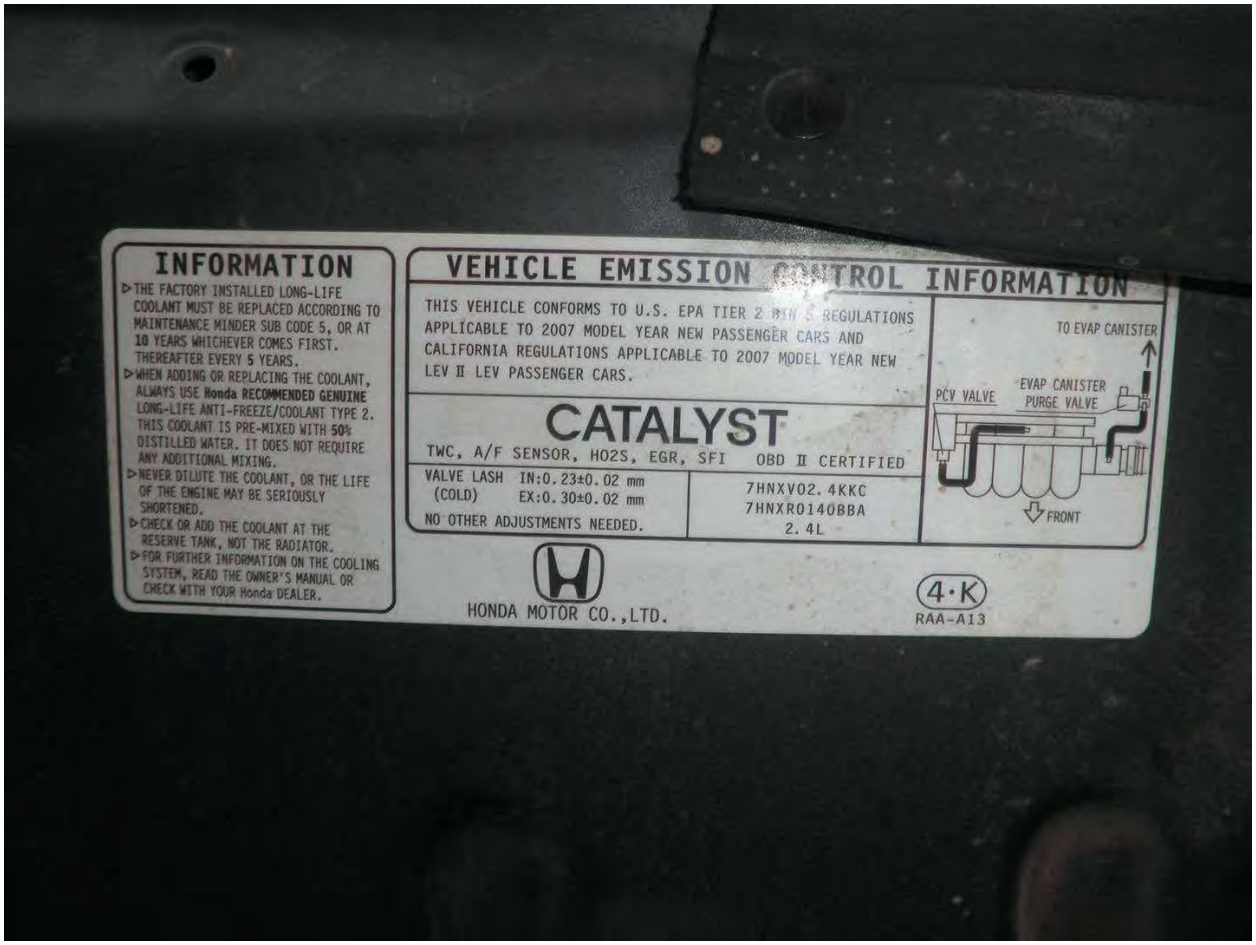


Figure E-2. Honda Accord Side of Vehicle

Figure E-3. Honda Accord Side of Vehicle

Figure E-4. Honda Accord Canister Connections

Figure E-5. Honda Accord Evaporative System Overview

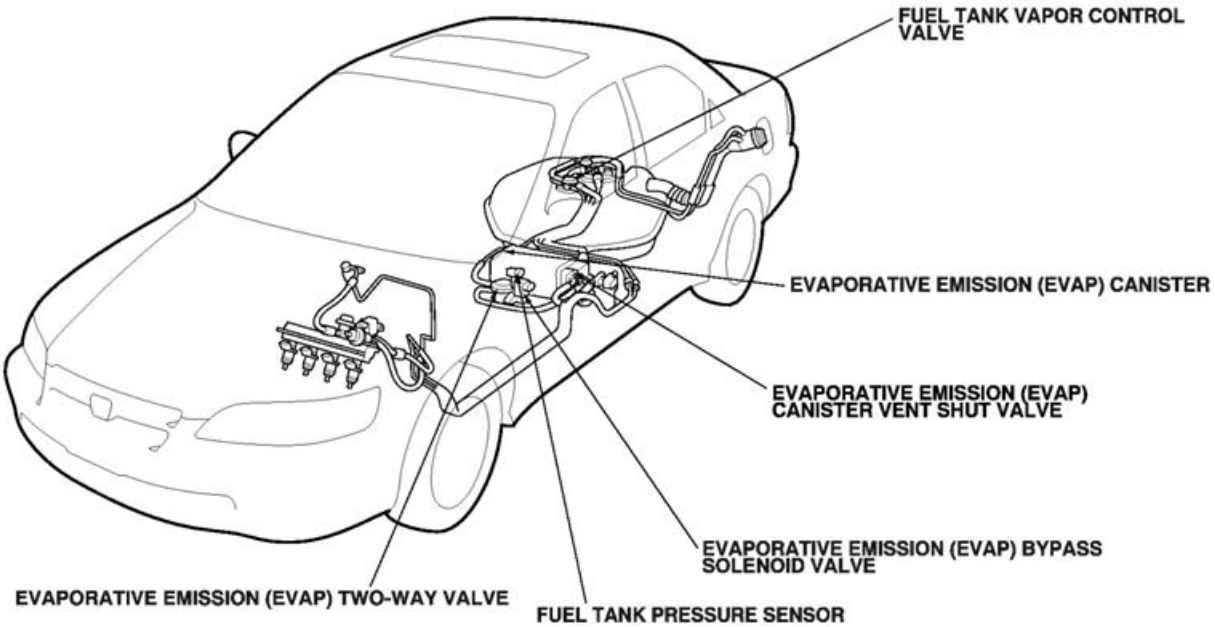


Figure E-6. Honda Accord Under Vehicle Details of Evaporative System

Figure E-7. Honda Accord Canister Details

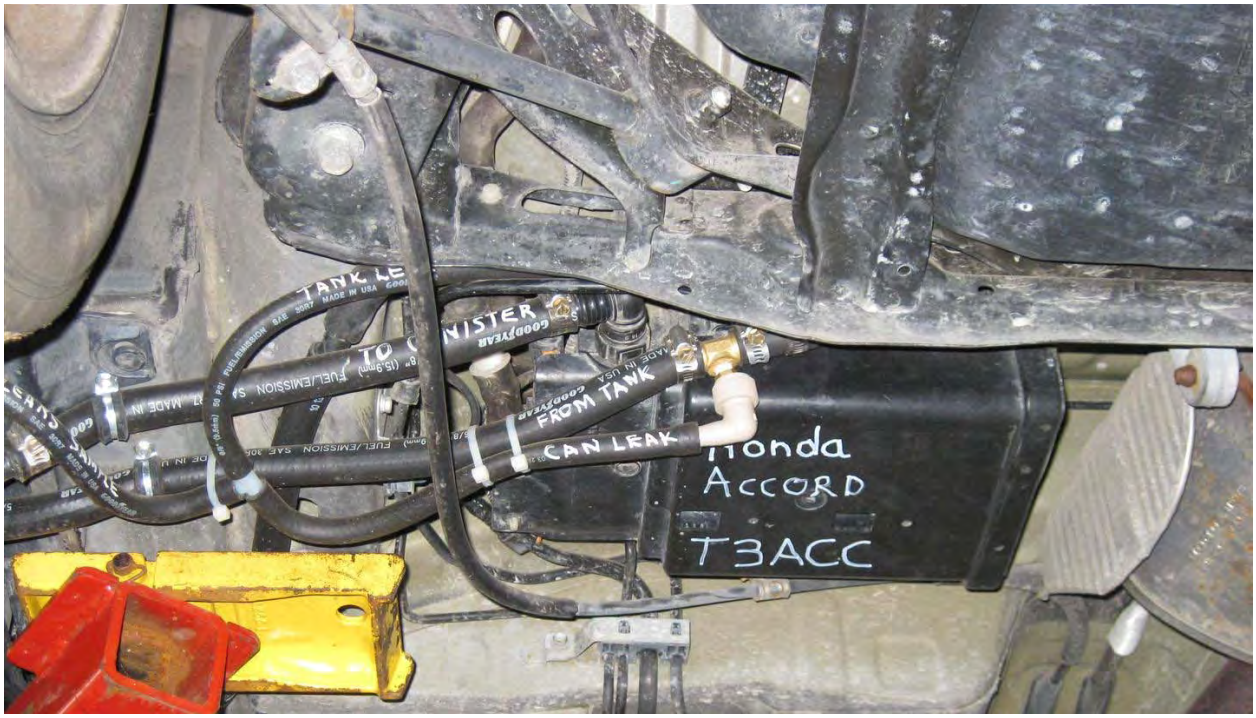
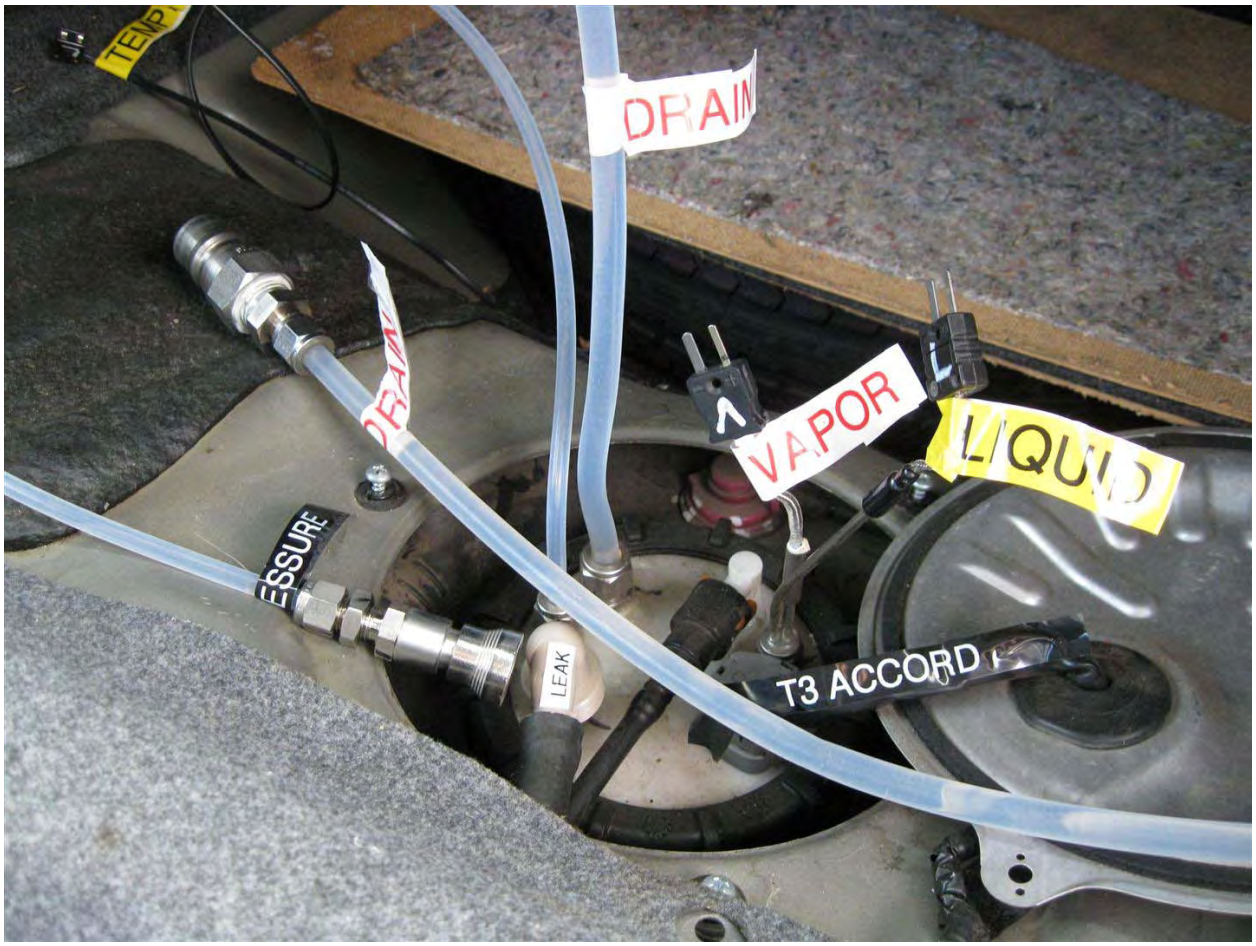


Figure E-8. Honda Accord Fuel Sending Unit

Figure E-9. Honda Accord Fuel Sending Unit as Installed



E.1.2 Dodge Caravan

Figure E-10. Dodge Caravan VECI Sticker

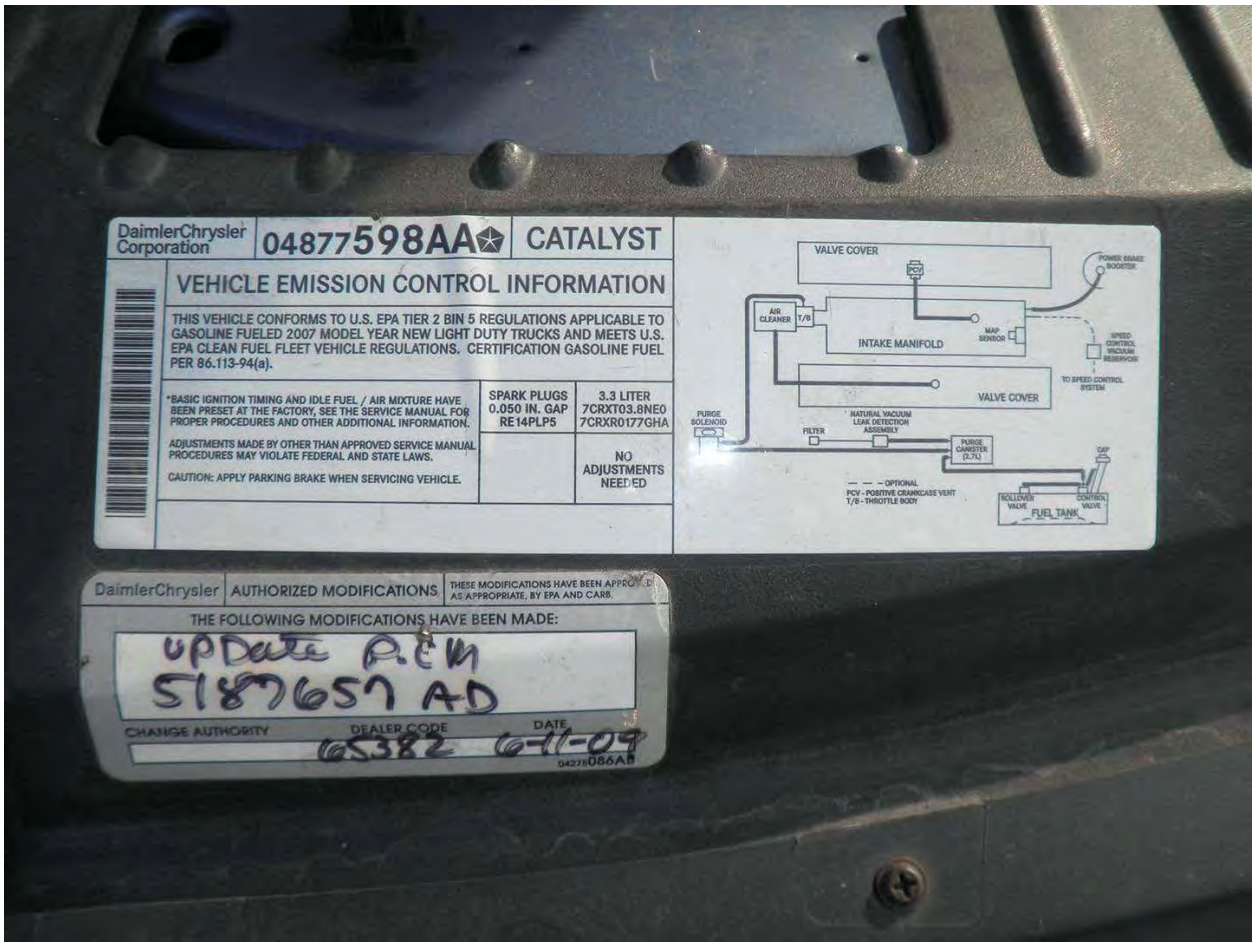


Figure E-11. Dodge Caravan Side of Vehicle

Figure E-12. Dodge Caravan Side of Vehicle

Figure E-13. Dodge Caravan Canister Connections

Figure E-14. Dodge Caravan Evaporative System Overview

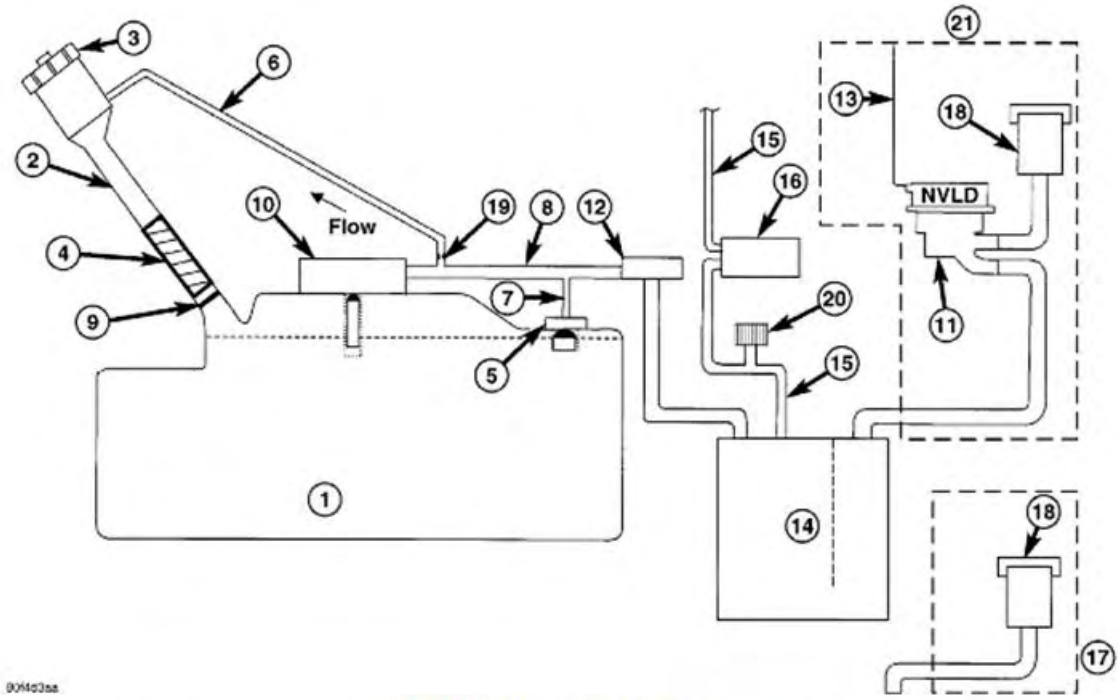


Fig. 9 ORVR System Schematic

1 - FUEL TANK (PLASTIC)
2 - FUEL FILLER TUBE
3 - FUEL CAP (PRESSURE/RELIEF)
4 - FILL TUBE TO FUEL TANK CONNECTOR (ELASTOMERIC)
5 - TANK VENT/ROLLOVER VALVE(S)
6 - VAPOR RECIRCULATION LINE
7 - TANK VAPOR LINE
8 - VAPOR LINE TO CANISTER
9 - CHECK VALVE (N/C)
10 - CONTROL VALVE
11 - NATURAL VACUUM LEAD DETECTION (NVLD)
12 - LIQUID SEPARATOR (IF EQUIPPED)
13 - ENGINE WIRING HARNESS TO NVLD
14 - VAPOR CANISTER
15 - PURGE LINE
16 - PURGE DEVICE
17 - WITHOUT NVLD
18 - BREATHER ELEMENT
19 - FLOW CONTROL ORIFICE
20 - SERVICE PORT
21 - WITH NVLD

Figure E-15. Dodge Caravan Detail Shows (1) the Canister, and (2) the Vent

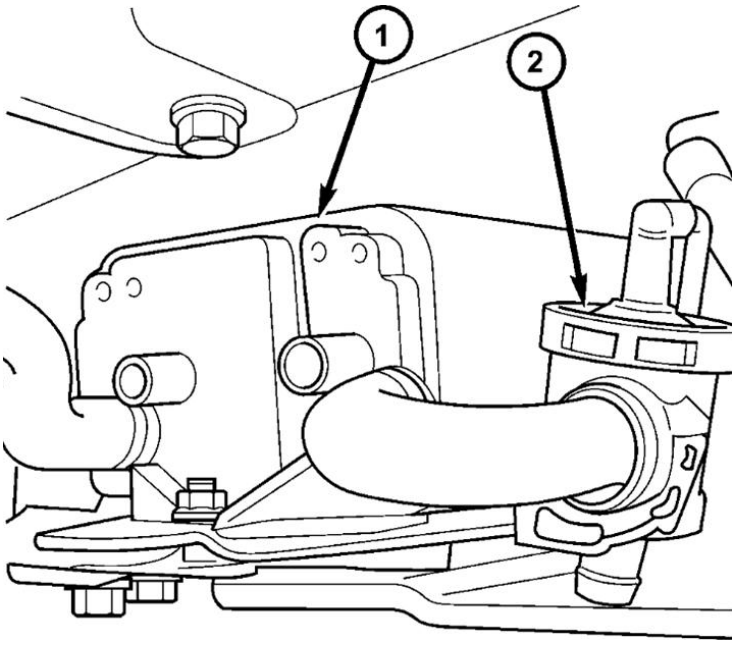
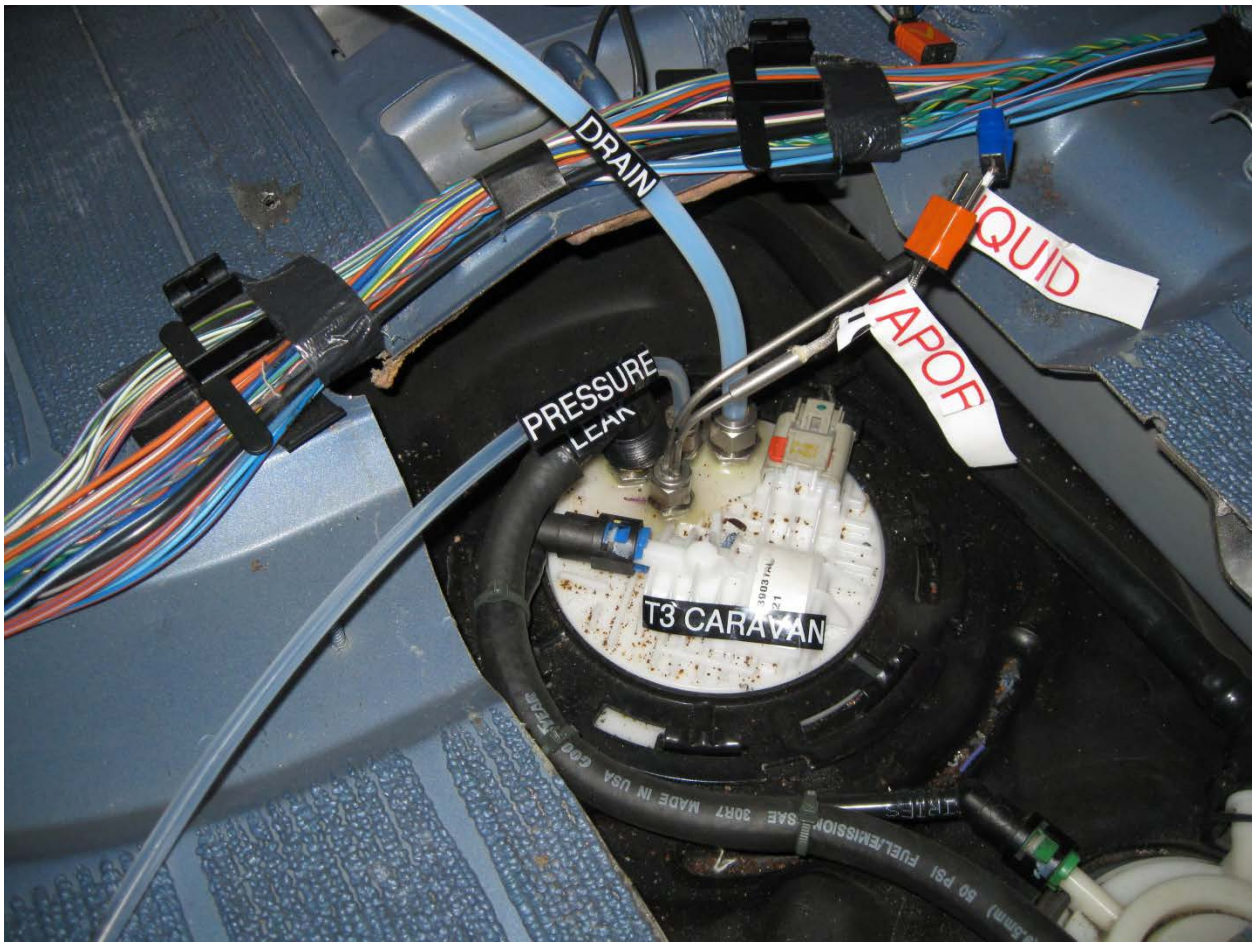


Figure E-16. Dodge Caravan Under Vehicle Details of Evaporative System

Figure E-17. Dodge Caravan Canister Details

Figure E-18. Dodge Caravan Fuel Sending Unit

Figure E-19. Dodge Caravan Fuel Sending Unit as Installed



E.1.3 Toyota Corolla

Figure E-20. Toyota Corolla VECI Label

Figure E-21. Toyota Corolla Side of Vehicle

Figure E-22. Toyota Corolla Side of Vehicle

Figure E-23. Toyota Corolla Canister Connections

Figure E-24. Toyota Corolla Evaporative System Overview

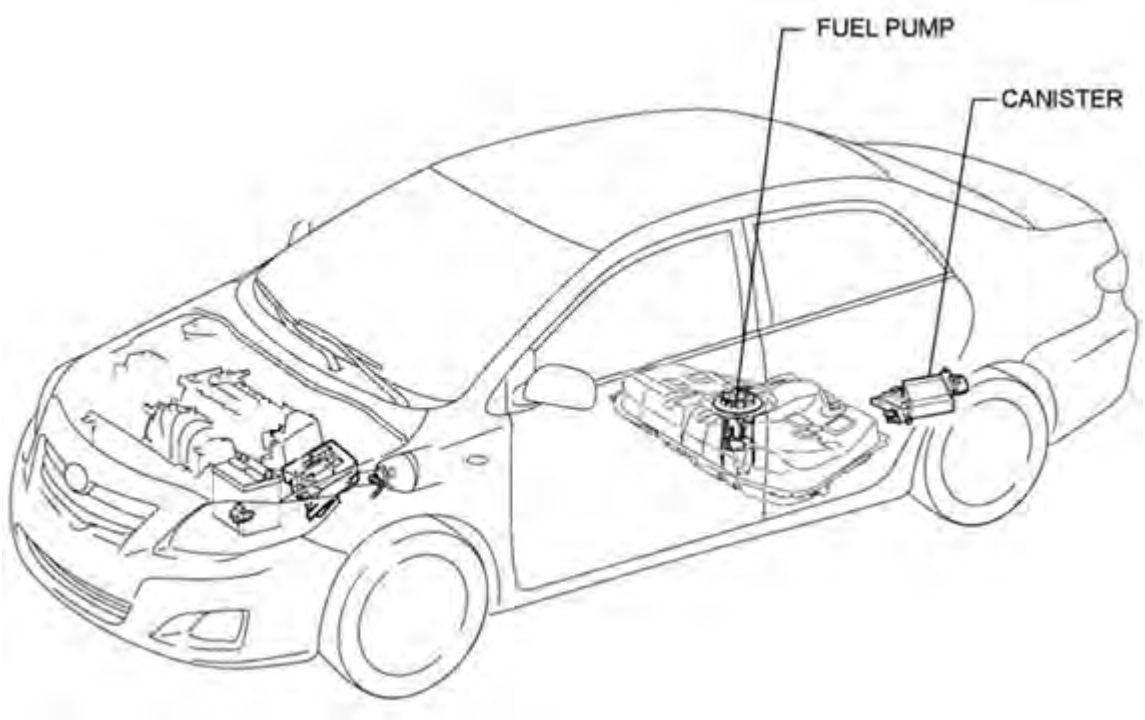


Figure E-25. Toyota Corolla Under Vehicle Details of Evaporative System

Figure E-26. Toyota Corolla Canister Details

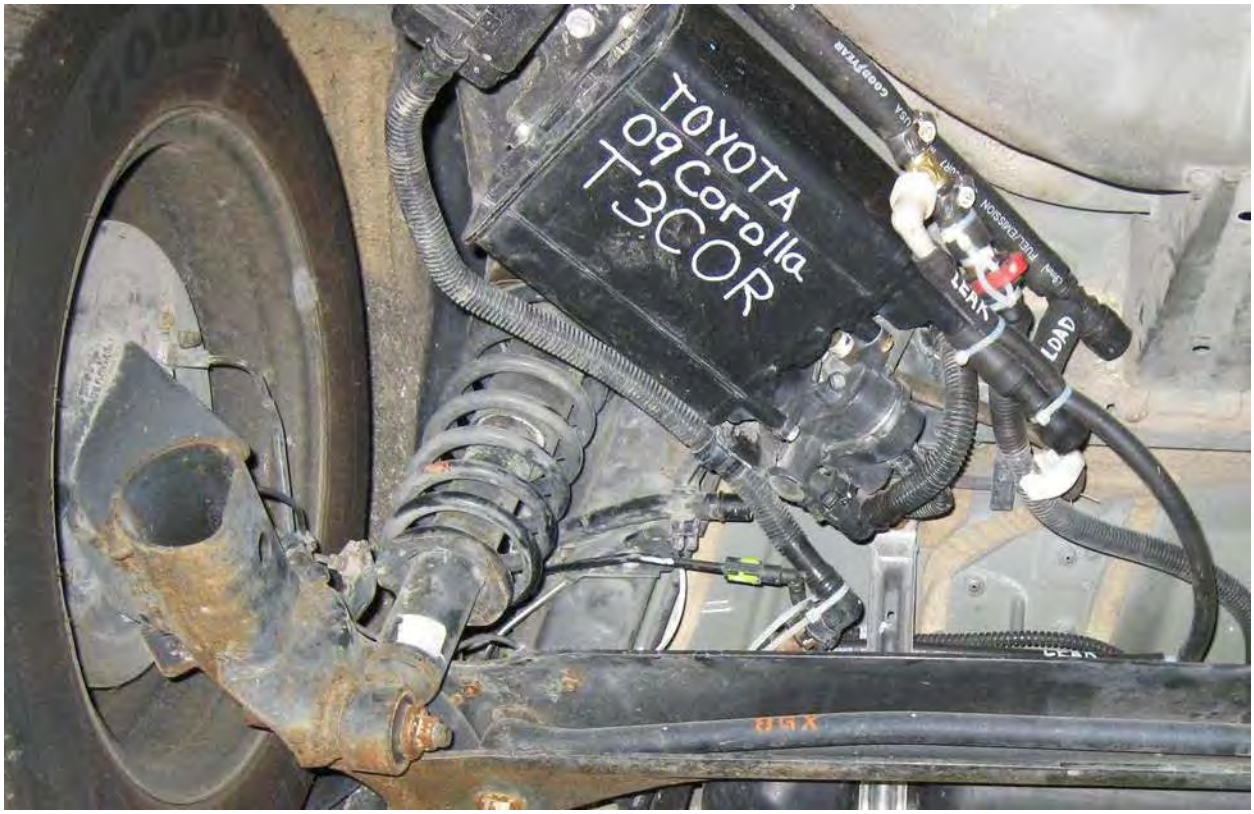
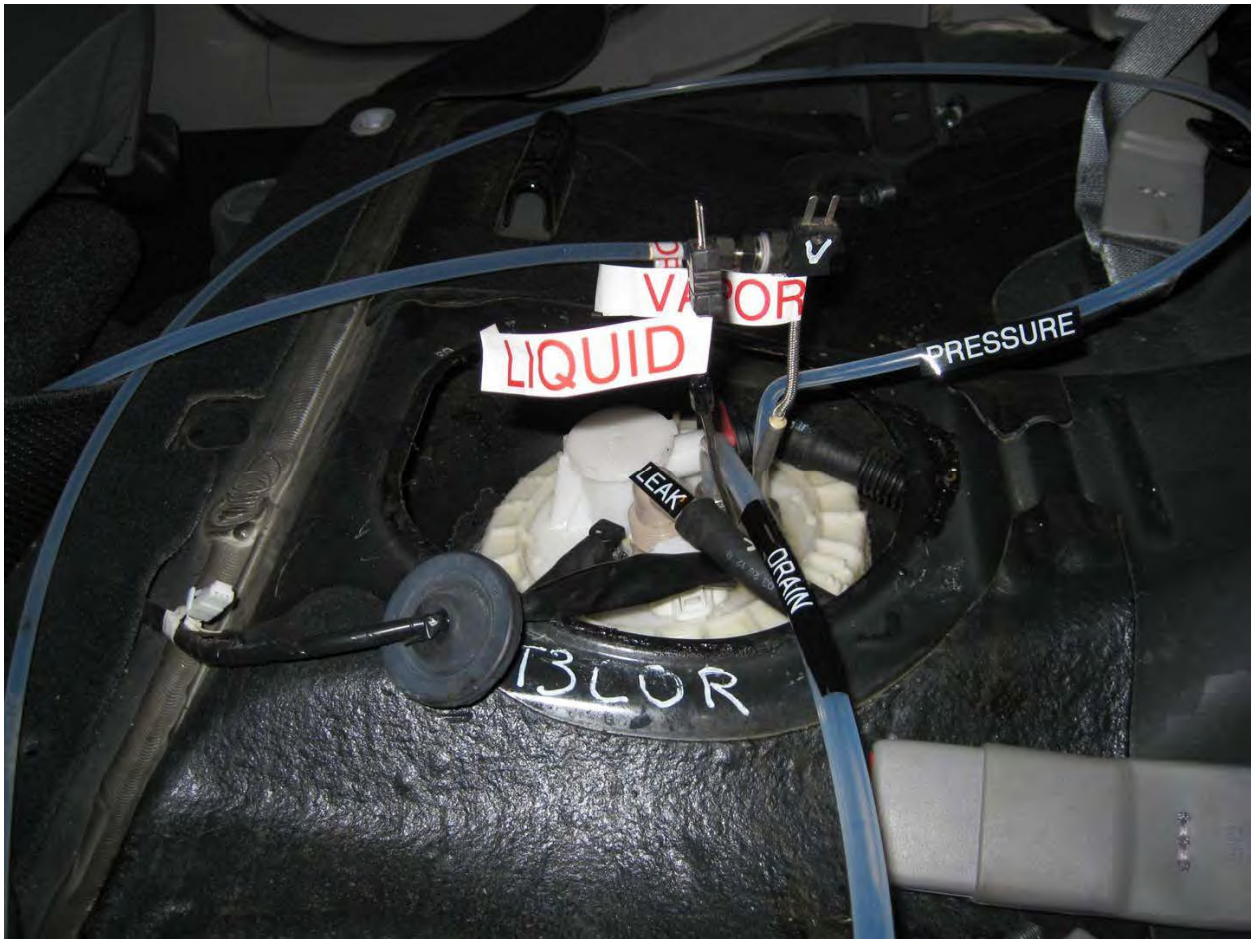


Figure E-27. Toyota Corolla Fuel Sending Unit

Figure E-28. Toyota Corolla Fuel Sending Unit as Installed



E.1.4 Ford Focus

Figure E-29. Ford Focus VECI Label

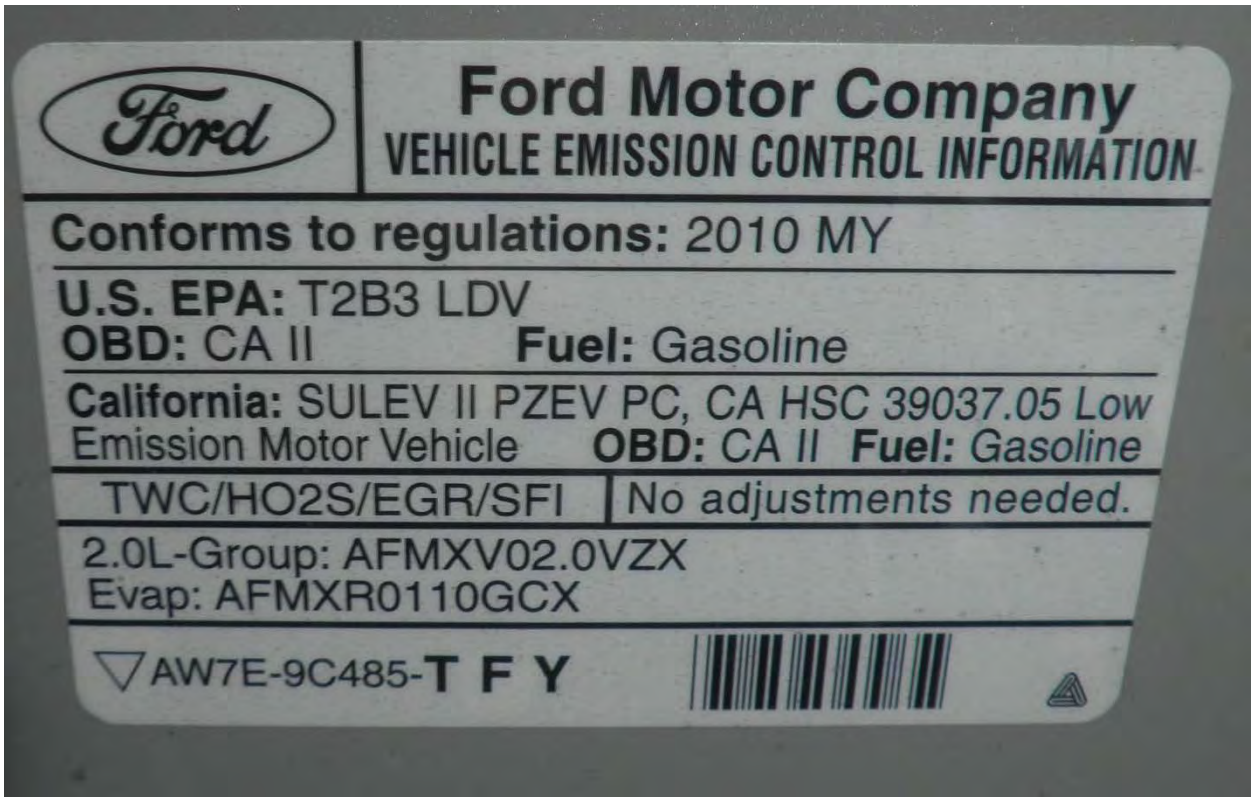


Figure E-30. Ford Focus Side of Vehicle

Figure E-31. Ford Focus Side of Vehicle

Figure E-32. Ford Focus Canister Connections

Figure E-33. Ford Focus Evaporative System Overview

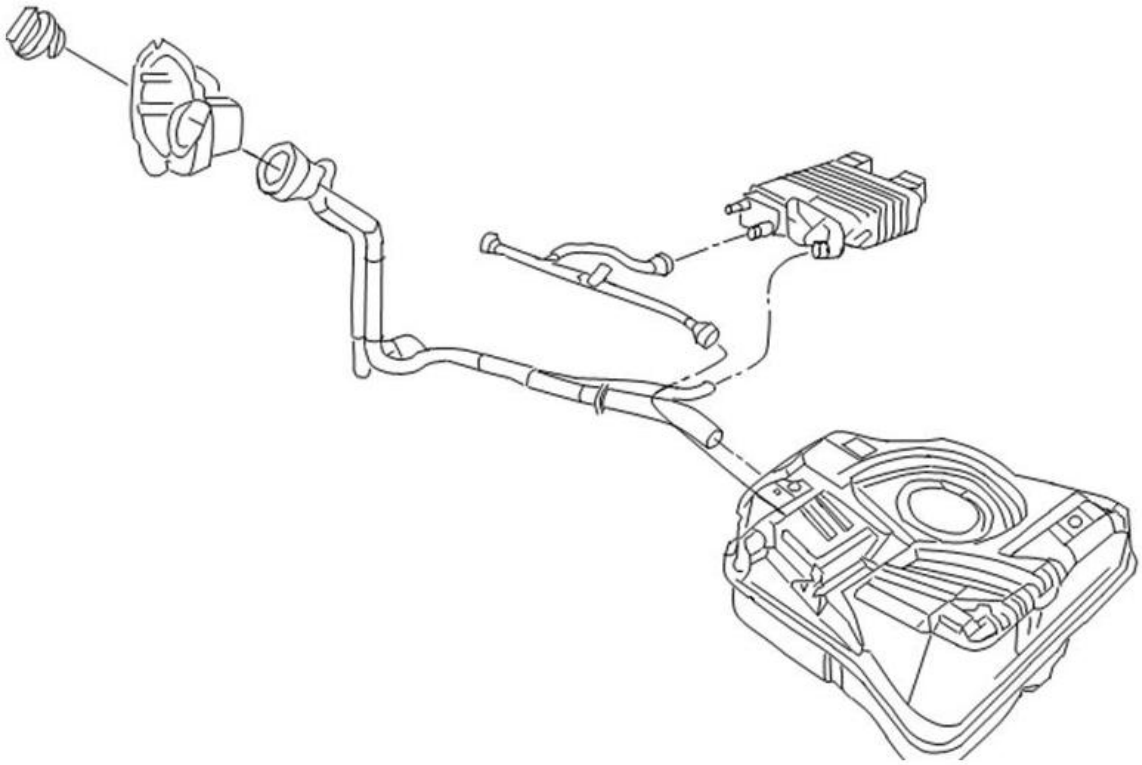


Figure E-34. Ford Focus Evaporative System Detail; (Orange) Filler Neck, (Red) Canister Load, (Green) Canister Purge, (Blue) Canister Vent

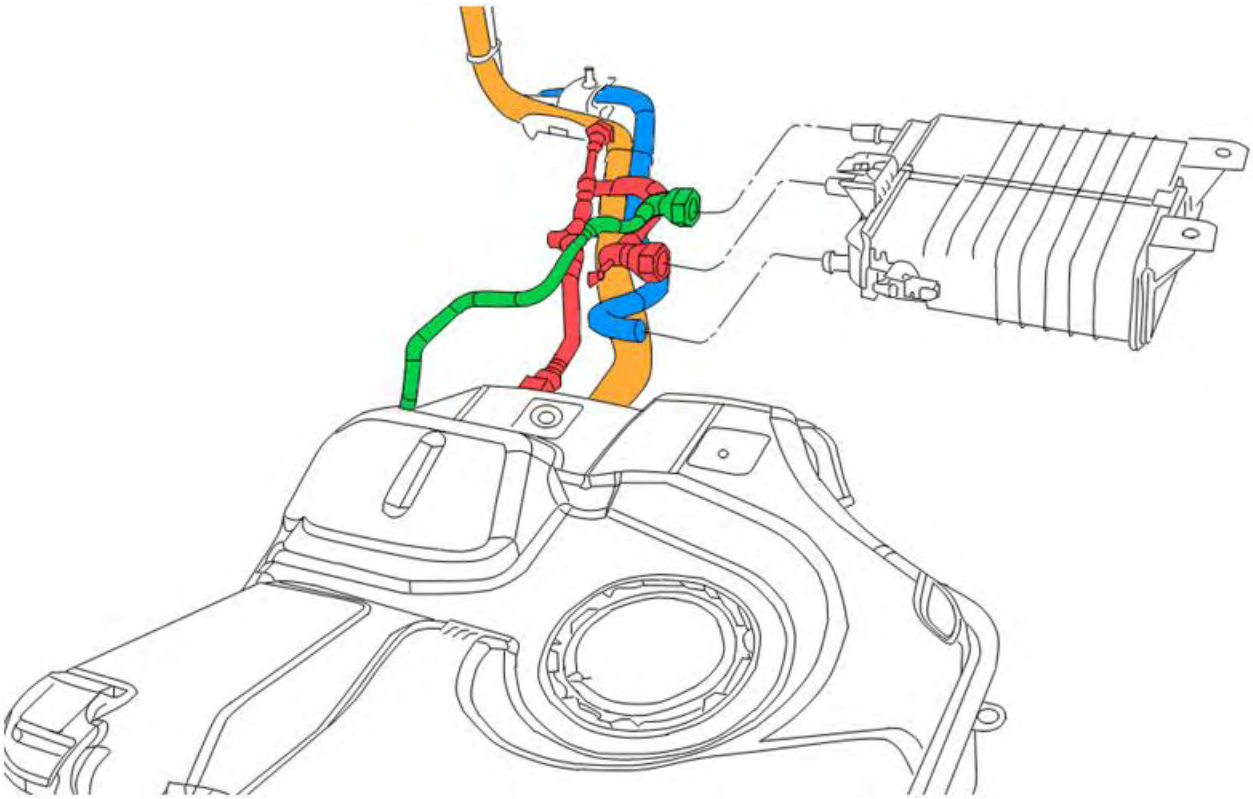
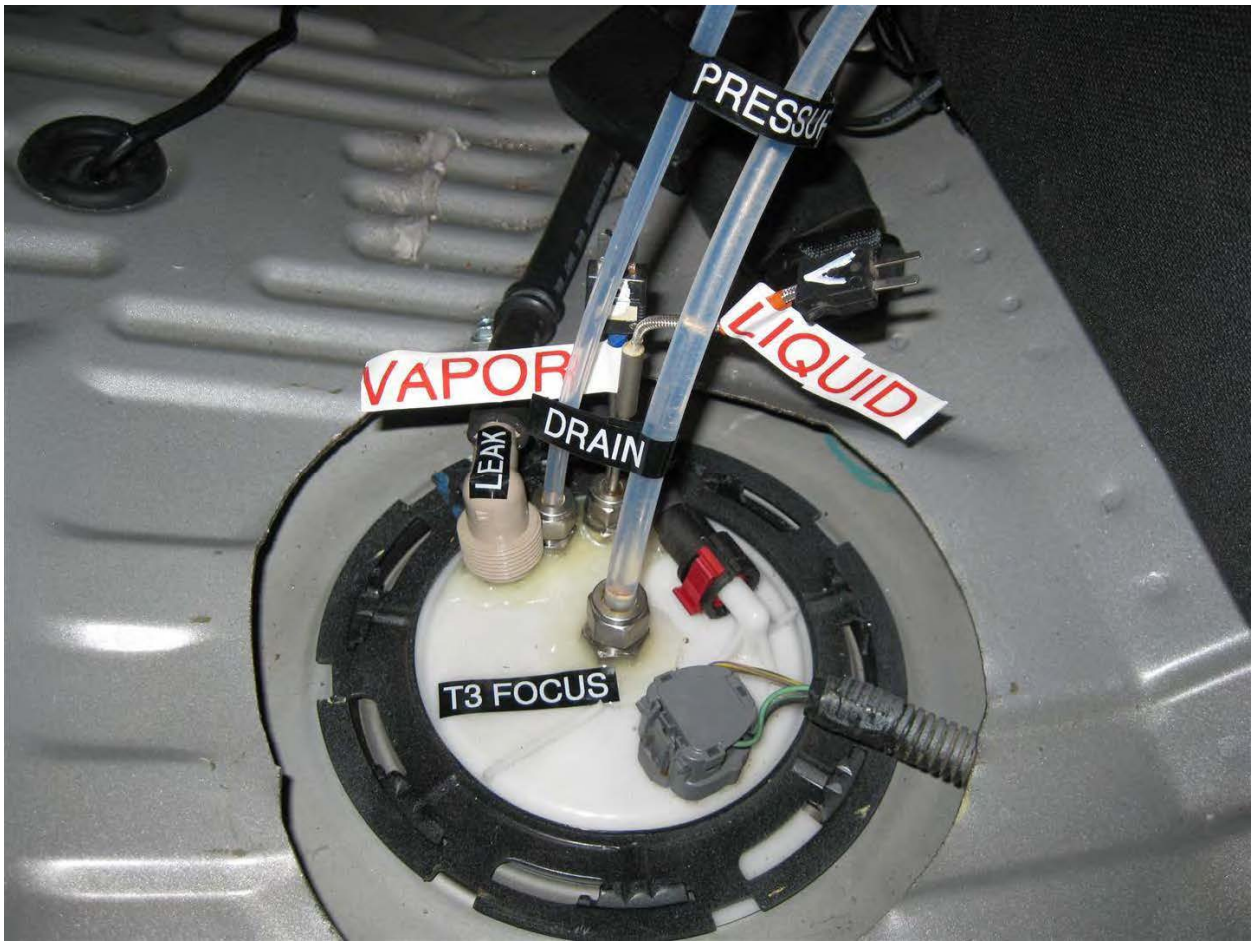


Figure E-35. Ford Focus Under Vehicle Details of Evaporative System

Figure E-36. Ford Focus Fuel Sending Unit

Figure E-37. Ford Focus Fuel Sending Unit as Installed



E.1.5 Chevrolet Silverado

Figure E-38. Chevrolet Silverado VECI Label

Figure E-39. Chevrolet Silverado Side of Vehicle

Figure E-40. Chevrolet Silverado Side of Vehicle

Figure E-41. Chevrolet Silverado Canister Connections (Vent and Leaks)

Figure E-42. Chevrolet Silverado Canister Connections (Load)

Figure E-43. Chevrolet Silverado Evaporative System Overview

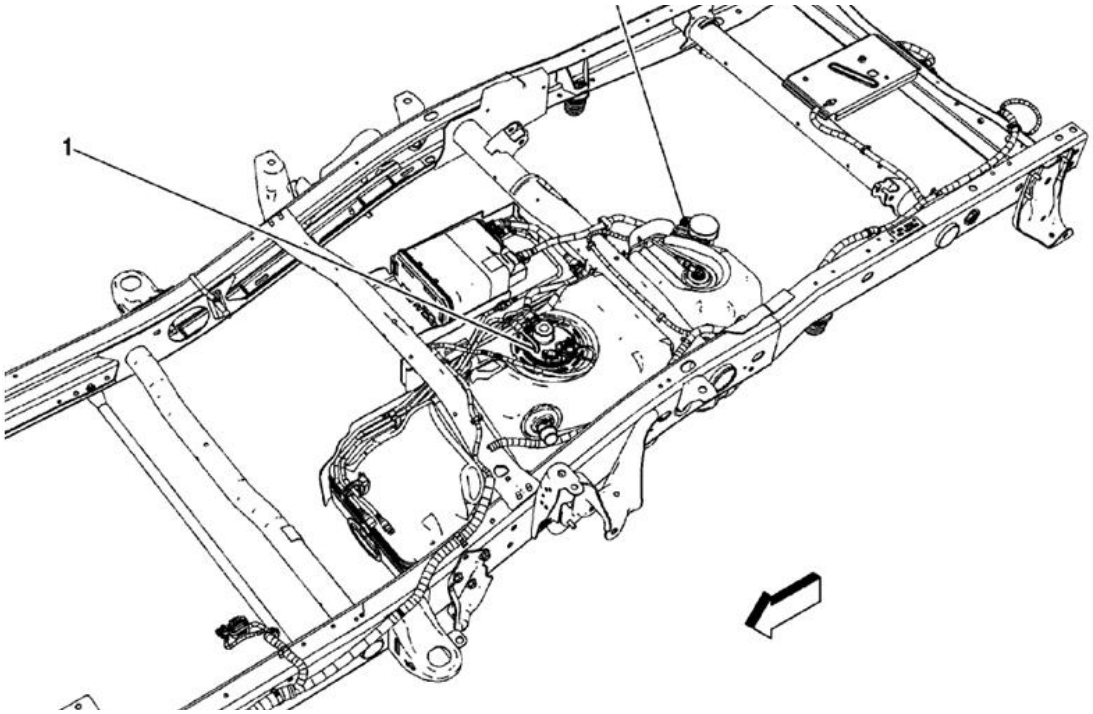


Figure E-44. Chevrolet Silverado Under Vehicle Details of Evaporative System

Figure E-45. Chevrolet Silverado Canister Details

Figure E-46. Chevrolet Silverado Fuel Sending Unit

Figure E-47. Chevrolet Silverado Fuel Sending Unit as Installed

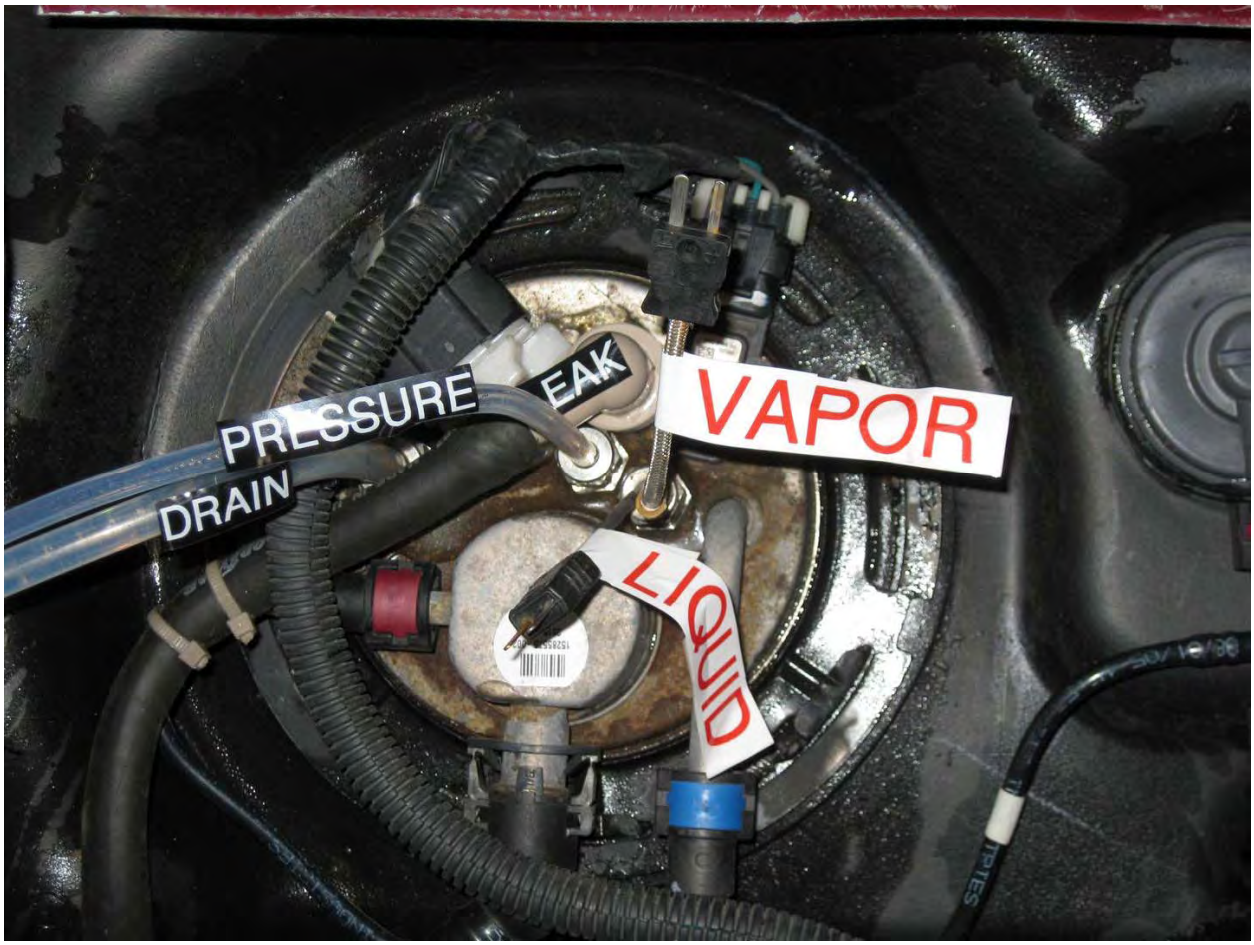


Figure E-48. Chevrolet Silverado Purge Solenoid (Red)

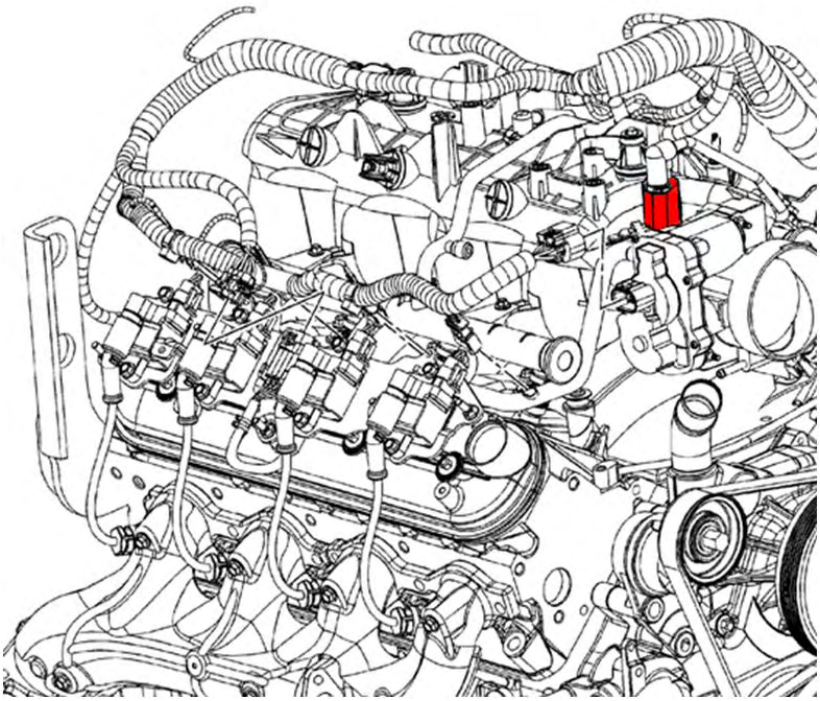


Figure E-49. Chevrolet Silverado Purge Solenoid Detail