Light Heavy-Duty Gasoline Vehicle Evaporative Emissions Test Program

United States
Environmental Protection
Agency

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

Prepared for EPA by
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EPA United States Environmental Protection Agency

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Glossary of Terms and Acronyms

CFR	Code of Federal Regulations
CFV-CVS	Critical Flow Venturi—Constant Volume Sampler
CH_4	Methane
CO	Carbon Monoxide
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
GVWR	Gross Vehicle Weight Rating
HC	Hydrocarbon
LA-4	Urban Dynamometer Driving Schedule
NMHC	Non-Methane Hydrocarbons
NOx	Oxides of Nitrogen
OBD	Onboard Diagnostics
ORVR	Onboard Refueling Vapor Recovery
QAPP	Quality Assurance Project Plan
RVP	Reid Vapor Pressure
SGS-Aurora	SGS- Environmental Testing Center at Aurora Colorado
SHED	Sealed Housings for Evaporative Determination
UDDS	Urban Dynamometer Driving Schedule
VIN	Vehicle Identification Number
VT	Variable Temperature

Executive Summary

This study, performed by Eastern Research Group (ERG) and subcontractor SGS-Environmental Testing Center (SGS-Aurora), under contract to the US Environmental Protection Agency (EPA), was designed and orchestrated by EPA characterize evaporative emissions control on two light-heavy duty gasoline vehicles. This work builds on prior evaporative emissions test programs performed to characterize evaporative emission rates in US vehicles[1,2,3,4,5,6].

The required laboratory testing for this program was done by a subcontractor, SGS-Aurora at their Aurora test facility. All test procedures followed the Code of Federal Regulation (CFR) 1066 Vehicle Test Procedures, Subpart J Evaporative Emissions. Two vehicles participated in this study; both were supplied by EPA. Both vehicles were modified to accommodate temperature sensors and fuel pressure measurement ports. Tests performed on each vehicle consisted of a combined procedure including a complete variable temperature SHED (Sealed Housing for Evaporative Determination) test, complete ORVR (On-Board Refueling Vapor Recovery) test and static tests. Fuel tank temperatures and pressures, evaporative housing temperatures and pressures, test cell temperatures, and continuous purge data was recorded using the J1979 protocol.

The primary finding of this study was that the hydrocarbon evaporative emissions of both the Ford E-450 and Isuzu NPR appeared to be controlled during the running loss, hot soak SHED, Variable Temperature SHED, and static pressurization test sequences which are presented in detail in Section 5. These vehicles are not regulated for on-board refueling vapor recovery (ORVR) and therefore the tests resulted in as expected uncontrolled emissions.

1.0 Objectives and Background

EPA has been updating evaporative emissions modeling with data from several recent studies[1-6]. Heavy duty gasoline emissions of recent technologies have been assumed based on the light duty evaporative emissions test results.

The objective of this study was to evaluate the evaporative emissions from two in-use light heavy-duty gasoline vehicles. The two vehicles were an Isuzu NPR and a Ford E-450 (further discussed in Section 2.1). Exhaust emissions were measured during the Federal Test Procedure drive cycle for HC, CO, NO_x, CH_4 and NMHC, as well as canister purge volume, and HC results from ORVR and 72-hour VT SHED testing with canister bleed.

2.0 Study Equipment and Preparation

2.1 Test Vehicles

The EPA provided two vehicles to be tested in this study. The two vehicles provided for the test program are listed in Table 2-1, and details regarding the selected vehicles and test parameters are listed in Table 2-2. Road load coefficients for testing were provided to SGS-Aurora by EPA. The same target road load coefficients were used for both vehicles and are representative of a typical light heavy-duty truck. Test vehicle 1 is a 2015 Isuzu NPR, standard cab, rear-wheel drive (RWD), with a 6.0L naturally aspirated V8 gasoline engine and dual wheels in the rear. The engine is rated at 297 hp and 372 ft-lbs of torque. The transmission is a 6-speed automatic. The vehicle arrived with 51,711 miles on it and no discernible damage or defects. Test vehicle 2 is a 2016 Ford E-450, standard cab, RWD, with a 6.8L naturally aspirated V10 gasoline engine and dual wheels in the rear. The engine is rated at 305 hp and 420 ft-lbs of torque. The transmission is a 5-speed overdrive automatic. The vehicle arrived with 33,667 miles on it and no discernible damage or defects. Vehicle volume was assumed as 50 cubic feet per 40 CFR Part 86.143-96[*].

Table 2-1. Test Vehicle Summary

Vehicle Make and Model	Model Year	Approx. Odometer	Evaporative Emissions Standard (grams/test)			[1]Canister Capacity (g)	Tank Volume (gal)	[2]Canister/Tank Ratio
			2 Day	3 Day	RL			
Isuzu NPR	2015	51711	2.3	1.9	0.05	150	30	5
Ford E-450	2016	33667	2.3	1.9	0.05	265	55	4.82

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

[*]40 CFR Part 86.143-96 states that "Net enclosure volume, ft^3, as determined by subtracting 50 ft^3 (1.42 m^3) (assumed volume of vehicle with trunk and windows open) from the enclosure volume. A manufacturer may use the measured volume of the vehicle (instead of the nominal 50 ft^3) with advance approval by the Administrator: *Provided*, the measured volume is determined and used for all vehicles tested by that manufacturer."

Table 2-2. Test Vehicle Details

Vehicle	Model Year	Inertia Weight (lbs)	Tank Capacity* (gal)	Dynamometer Coefficients						Engine Family	Evap Family
				Road Load A Target (lbf)	Road Load A Set (lbf)	Road Load B Target (lbf/mph)	Road Load B Set (lbf/mph)	Road Load C Target (lbf/(mph)^2)	Road Load C Set (lbf/(mph)^2)		
Isuzu NPR	2015	14500	30	95.95	76.03	0.96917	0.30287	0.125125	0.128935	FGMXE0 6.0584	FSZXF01 76ME0
Ford E-450	2016	9320	55	95.95	73.8444	0.96917	0.03127	0.125125	0.130002	GFMXE0 6.8BWZ	HFMXF0 265NAT

*Throughout the testing procedure, there were fuel fills of 40%, 10%, and 95%. These fill amounts were determined based off the manufacturer specified fuel tank capacity.

2.2 Laboratory and Test Equipment Overview

All testing was performed at SGS-Aurora's facility, which is equipped with one 40 CFR Part 86.1234-96 compliant point-source running loss test cell and three specially equipped variable temperature (VT) sealed housings for evaporative determination (SHEDs). The largest of these SHEDS was employed for hot soak, diurnal, ORVR, and static pressurization tests. SGS-Aurora provides emissions certification testing for new vehicles manufactured to meet US EPA emissions standards.

SGS-Aurora has 3 SHEDs onsite, the largest of which was used for this project. This SHED is 128 inches wide, 117 inches tall, and 330 inches deep (which makes for a volume of 2,860 cubic feet). This provided plenty of space for each vehicle to fit inside along with any equipment needed during testing. (Image 2-2). This SHED employs three mixing fans.

SGS-Aurora provided all quality assurance and traceability requirements defined in CFR Title 40 Part 86, Subpart B and other test procedures performed during this study.

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. This included the thermocouples for the fuel dispensing cart, vehicle fuel tank, and SHED. 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 Part 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 SGS-Aurora.

Image 2-1. Sampling and Analytical Systems for Evaporative Emissions

Image 2-2. SHED which accommodates Light Heavy-Duty Trucks

2.3 Fuel Procurement and Preparation

Real world regular unleaded gasoline, with 85 octane, that is commercially available in the Denver Metro Area was used for this study. The test fuel was all purchased at the same time from the same batch. This fuel was deemed acceptable because the engine knock index at altitude accommodates a lower octane fuel than at sea level. SGS-Aurora did not conduct an independent octane test on the fuel provided. Reid Vapor Pressure (RVP) was determined at SGS-Aurora and is presented in Table 2-3. Triplicate testing was conducted at three different points during the testing program.

Table 2-3. Fuel Properties

Date	Test	Sampled By	Tested By	RVP	Average
	1			8.53	*
8/7/2018	2	DM	DM	8.5	*
	3			8.57	8.5
	1			8.53	*
8/14/2018	2	DM	DM	8.56	*
	3			8.5	8.5
	1			8.62	*
8/22/2018	2	DM	DM	8.56	*
	3			8.56	8.6

The RVP range of E10 certification gasoline is 8.7-9.2 psi, while high altitude (above 4,000 feet) E10 certification gasoline has a range of 7.6–8.0 psi (CFR §86.113-04: Fuel specifications). The RVP of the test fuel was slightly above the standard for high altitude certification fuel.

2.4 Vehicle Preparation

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

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

2) 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.

3) Vehicle information such as VIN, year, make, model, engine and evaporative families was documented.

4) SGS-Aurora removed the cargo box from on top of the trailer from the Isuzu test vehicle (the Ford test vehicle arrived with the box removed) in order to access the fuel sending units. These units were modified on both vehicles to include two, type-J fuel tank thermocouples and a fuel drain. One thermocouple was extended into the liquid level and one thermocouple was kept in the vapor space at a 40% fill. (Image 2-4 a-g). SGS-Aurora also replaced the line from the fuel tank to the filler neck with a line that was modified with a tank pressure monitoring system.

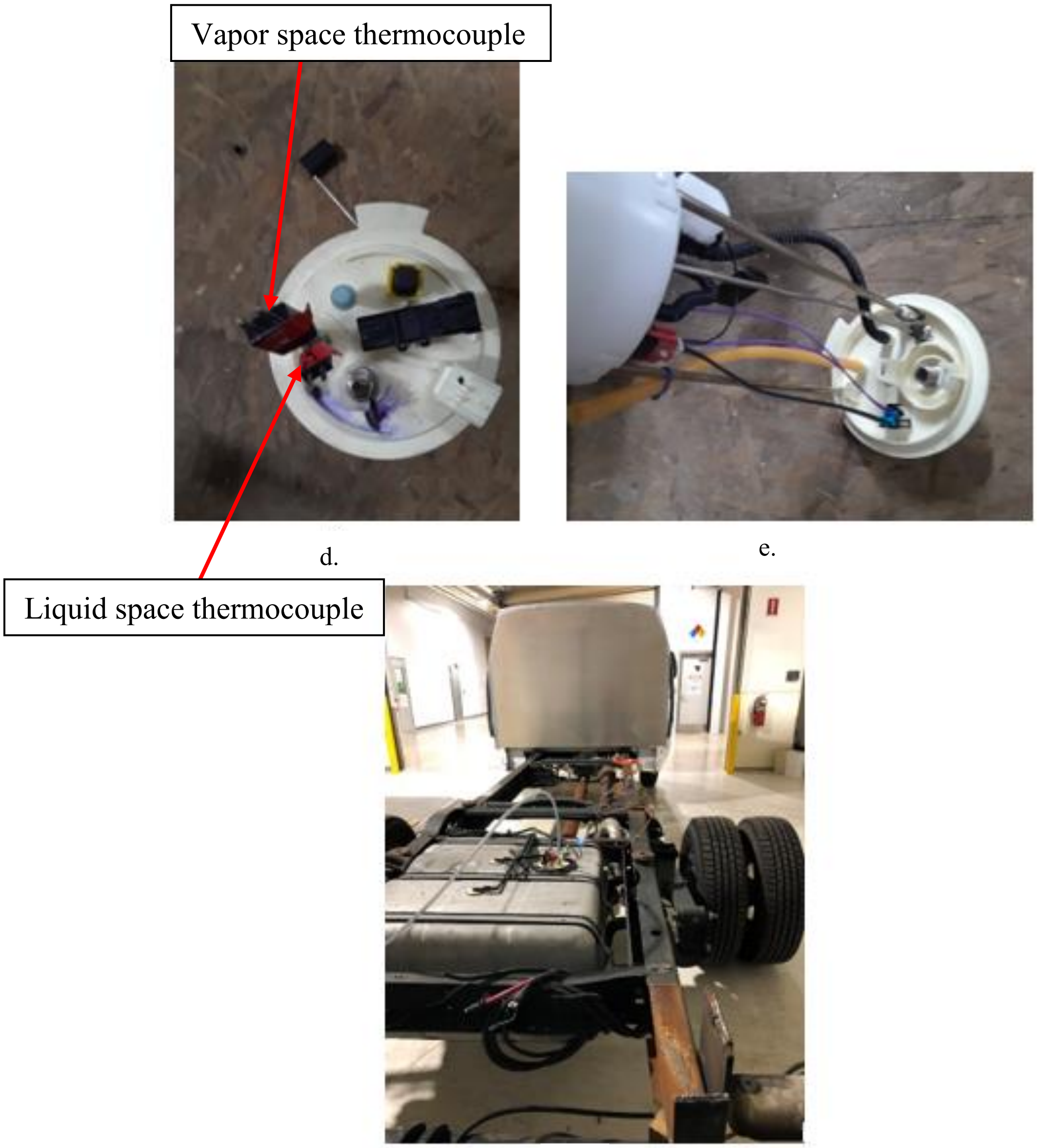
Image 2-3 a-c. Isuzu NPR modified sending unit

a.

b.

c.

Image 2-4. d-f Ford E-450 modified sending unit



d. e. f.

5) The vehicle's evaporative emissions control system was subjected to an initial static pressure test using a Snap-on Smart Smoke Evap Elite leak detection unit (Image 2-5).

Image 2-5. Snap-on Smart Smoke Evap Elite

6) Pressure tests were performed after the modifications on each vehicle's fuel and evaporative emissions control system using the Snap-On leak detection unit.

7) To minimize issues with crankcase oil impacting emissions, oil was not added unless necessary, since new oil may impact evaporative testing results. No oil was added to either vehicle during the testing.

8) The appropriate vehicle road load set coefficients for dynamometer testing were derived based on the targets provided by EPA in accordance with SAE J2264-201401: Chassis Dynamometer Simulation of Road Load Using Coastdown Techniques.

9) The wiper fluid reservoir and system were drained and flushed with distilled water to eliminate potential release of wiper fluid hydrocarbons into the SHED during static tests.

3.0 Test Program

3.1 Testing Overview

Tailpipe vehicle emissions were recorded during the FTP portion of the testing. Hydrocarbon emissions from engine exhaust and evaporative sources emitted during the running loss, hot soak SHED, VT SHED, ORVR, and static pressurization test sequence were collected and sampled per 40 CFR Part 86, Subpart B. 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. Canister purge volume was recorded on both the running loss and FTP portions of the test. Other data collected during this study consisted of vehicle and test setup information, temperature and pressure measurements from the fuel tank, test cell, and evaporative housing, and associated date and time for each of the measurements.

No special procedures were performed to initially flush the fuel system while changing fuel from what arrived in the vehicle to the test fuel used in the study. The standard procedure of drain and fill, preconditioning drive cycle, drain and fill, and canister load was deemed suitable for clearing the system of the previous test fuel.

The following steps detail the test sequence performed.

Step 1) Vehicle Prep, Modify / Restore & Documentation: SGS-Aurora prepared the vehicle for the test process (Section 2.4), scanned the OBD system for diagnostic trouble codes and readiness status, and established a data repository.

Step 2) 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 on the fuel tank, 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 3) 6 to 24 Hour Soak: The vehicle was then placed in a temperature-controlled room where the temperature was maintained at 68 °F to 86 °F for a time exceeding 6 hours but less than 24 hours.

Step 4) Vehicle Derivation (Road-Load Model): The vehicle was run on the dyno in order to obtain the coefficients needed to test according to SAE J2264. This is accomplished by performing a double highway cycle followed by a set of vehicle coast-downs.

Step 5) 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) (Figure 3-3).

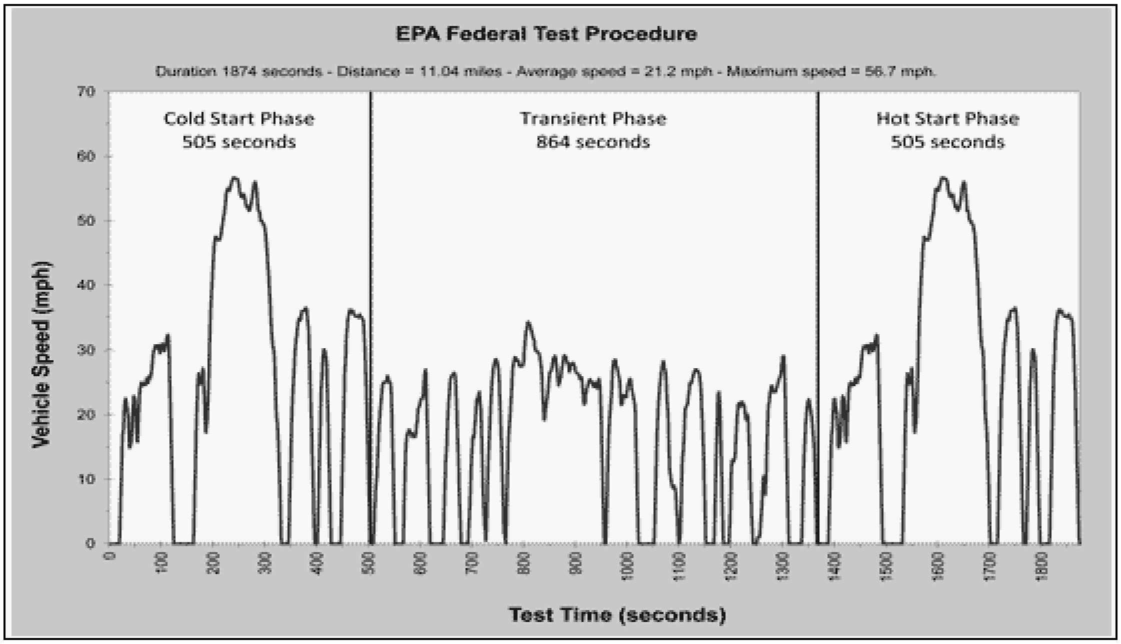
Step 6) Drain and Refuel 2: This procedure is identical to the "Drain and Refuel 1" procedure described in Step 2 (again, to 40% fill).

Step 7) Canister Load with Butane/Nitrogen mixture: Within one hour of the fueling event, the evaporative emissions carbon canister on the vehicle was loaded with a 50/50 mixture by volume of butane and Nitrogen, at a rate of 40 grams per hour, until a 2 gram breakthrough occurred, or to 1.5x working capacity of the canister, depending on the test sequence (ORVR tests used a 2g breakthrough while 72 hour VT SHED tests used 1.5x working capacity). This step was done in parallel to Step 8 below.

Step 8) 12 to 36 Hour Soak: The vehicle was placed in a temperature-controlled room where the temperature was maintained at 68 °F to 86 °F for a time exceeding 12 hours but less than 36 hours.

Step 9) FTP-75 three phase cycle: The vehicle was then operated on the chassis dynamometer over the FTP-75 cycle, the driving cycle that is part of the certification process and graphically shown in Figure 3-1. Each phase fills an emissions bag which is analyzed after the conclusion of that phase. Canister purge volume was measured during this portion of the test with the Alicat purge meter (Image 3-1).

Figure 3-1. FTP-75 Cycle



Step 10) Running Loss Test: A running loss test was then performed employing the following steps and procedures:

If performing the Running Loss procedure for a VT SHED:

1) For the three-day VT SHED, 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.

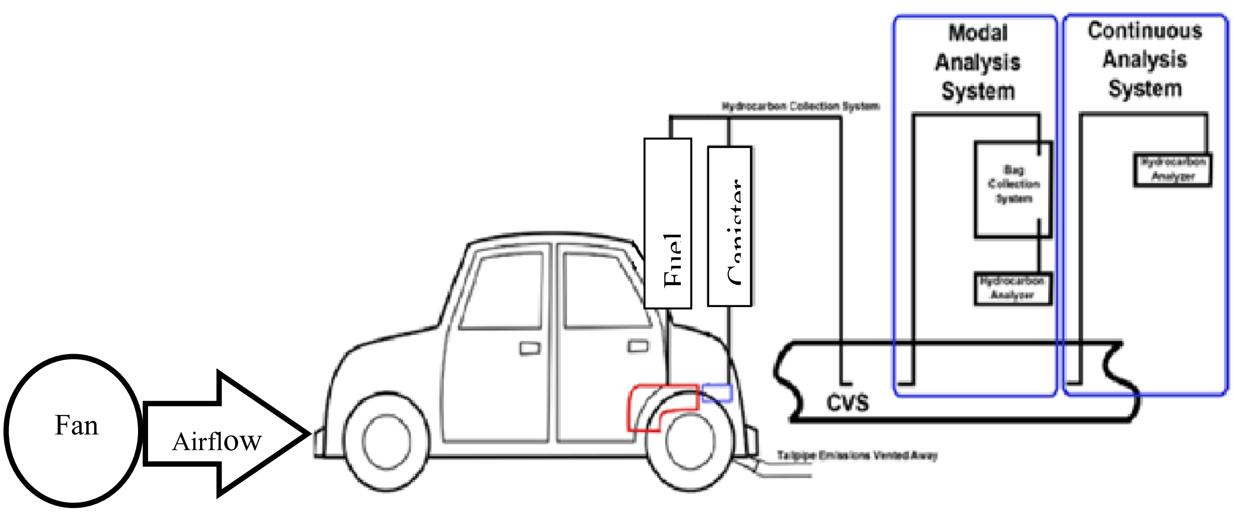
3) Running Loss Test. The running loss test was conducted using the point-source method described in §86.134–96(g)(2). Measurements were taken at point sources: canister vent and gas cap, as shown in Figure 3-2. Canister purge volume was also measured during this portion of the test with the Alicat purge meter (Image 3-1).

Image 3-1. Image 2-1. Sampling and Analytical Systems for Evaporative Emissions

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

5) The running loss vapor vent collection system was properly positioned at the fuel vapor vents and in the vehicle's fuel and evaporative emission systems. This is standard practice for all 3-day running loss tests. The sampling system configuration is shown in Figure 3-2.

Figure 3-2. Hydrocarbon Sampling System



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

7) 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. Both vehicles were equipped with automatic air conditioning.

8) 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.

9) 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.

10) 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 (NYCC), another 2-minute idle, another UDDS, and then a final 2-minute idle (see §86.115). These are shown graphically in Figure 3-3 and Figure 3-4. Phase one of the Running Loss cycle is the first UDDS cycle, phase two is both of the NYCCs, and phase three is the final UDDS cycle.

Figure 3-3. Urban Dynamometer Driving Schedule

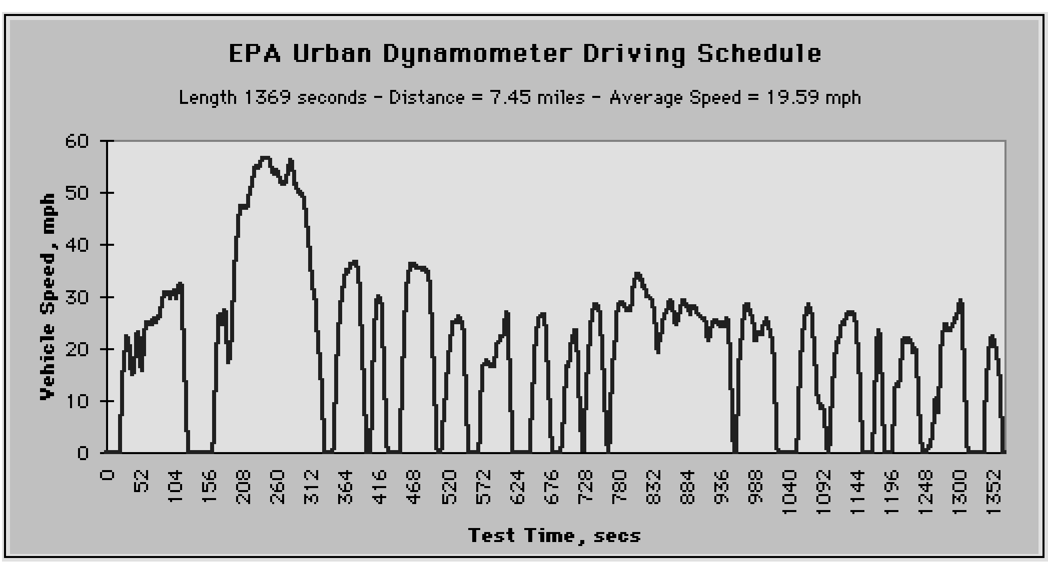
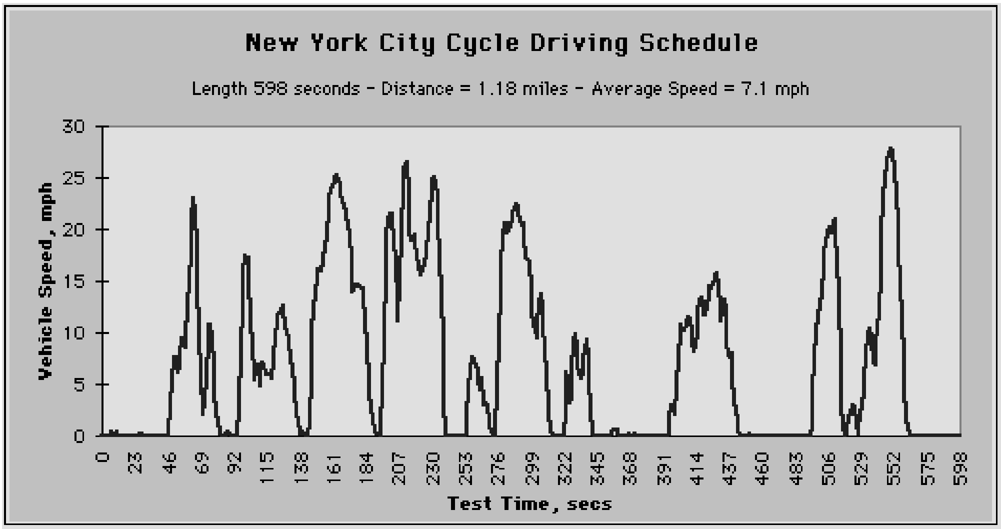


Figure 3-4. New York City Cycle



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

12) Fuel temperatures were controlled according to the specifications of the temperature profile provided. See Figure 4-1.

13) Proceed to step 11a to continue the VT SHED procedure.

If performing the Running Loss procedure for an ORVR:

1) For the ORVR test, the temperature remains at ambient conditions and there is no soak period after the FTP finishes.

2) Fuel temperature is not monitored or controlled.

3) The running loss test is conducted with no emissions sampling equipment.

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

5) The vehicle air conditioning system is set to off.

6) 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 (NYCC), another 2-minute idle, another UDDS, and then a final 2-minute idle (see §86.115). These are shown graphically in Figure 3-3 and Figure 3-4. Phase one of the Running Loss cycle is the first UDDS cycle, phase two is both of the NYCCs, and phase three is the final UDDS cycle.

7) The ambient temperature was maintained at 68 °F to 86 °F during the running loss test.

8) Proceed to step 11b to continue the ORVR procedure.

Step 11 a) Hot Soak Test/SHED Cool down: For the VT SHED 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 (±2) °F in accordance with 40 CFR 86.138-96, "Hot soak test". The SHED is then cooled to 72 °F to prepare for the VT SHED test. See Image 3-1. VT SHED procedure resumes at Step 12 a).

Image 3-2. Ford E450 in SHED

Step 11 b) ORVR Drain and Refuel/SHED Soak: For the ORVR test, following the completion of the running loss test, the vehicle was drained and filled to 10% of the total tank capacity, and then the vehicle was soaked at 80 (±2) °F for a time exceeding 6 hours but less than 24 hours. ORVR procedure resumes at Step 12 b).

Step 12 a) 72 Hour VT SHED: The three-day VT SHED is performed in accordance with 40 CFR 1066.910, "SHED enclosure specifications", using the temperature profile shown in Figure 3-5. Canister bleed emissions were also recorded during this test. (See Figure 3-6 for test procedure flow chart. See Image 3-2 for VT-SHED).

Step 12 b) ORVR: The ORVR test is performed. Fuel is dispensed inside the SHED and HC mass is measured in accordance with 40 CFR 86.150-98, "Refueling test procedure". (See Figure 3-7 for test procedure flow chart. See Image 3-3 for ORVR prep). Temperature measurement devices used in this test sequence have been verified.

Step 13) Static Test: Once the ORVR or VT SHED sequence is completed, the static testing will be performed on the vehicle. See Figure 3-8. This is performed by:

1) The vehicle is prepared for the test by installing a pressure line in the fuel tank of the vehicle.

2) The fuel pump is modified so that it can be actuated remotely.

3) The vehicle is leak-checked with the Snap-on leak check device to confirm that there are no static leaks on the vehicle.

4) The vehicle is placed in the SHED and the pressure and temperature lines are hooked up.

5) The SHED sniffs the background to establish a baseline. The vehicle then soaks in the SHED for one hour.

6) Once the vehicle has soaked for an hour, the SHED begins measurement to determine the permeation rate of the vehicle over one hour.

7) The vapor space in the fuel tank is pressurized for 30 minutes while the SHED measures the HC concentration.

8) For the next 30 minutes, the fuel pump on the vehicle is activated, while the HC concentration is measured.

Figure 3-5. 72 Hour VT SHED

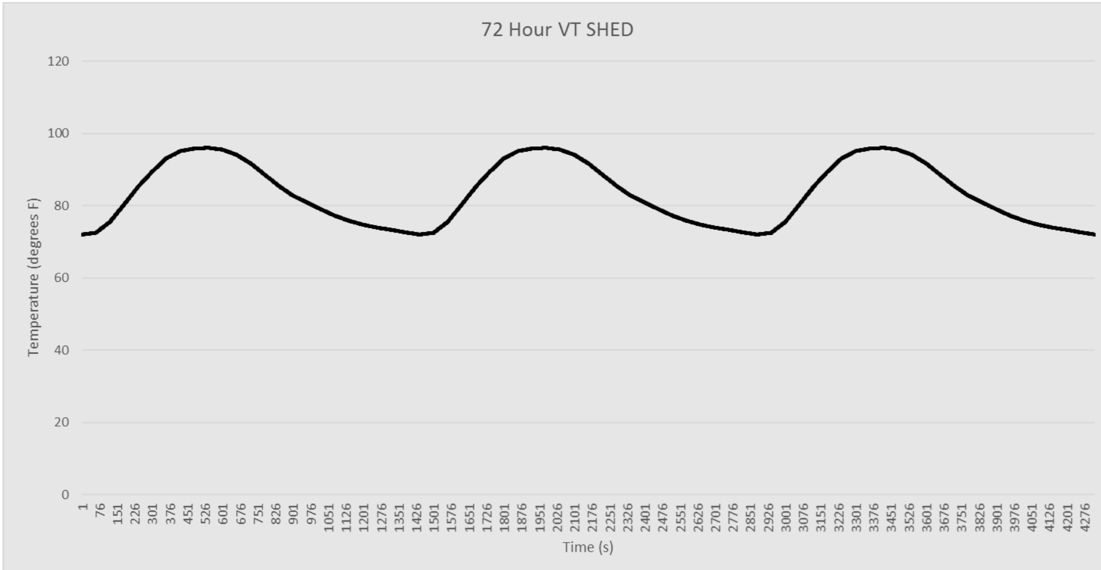
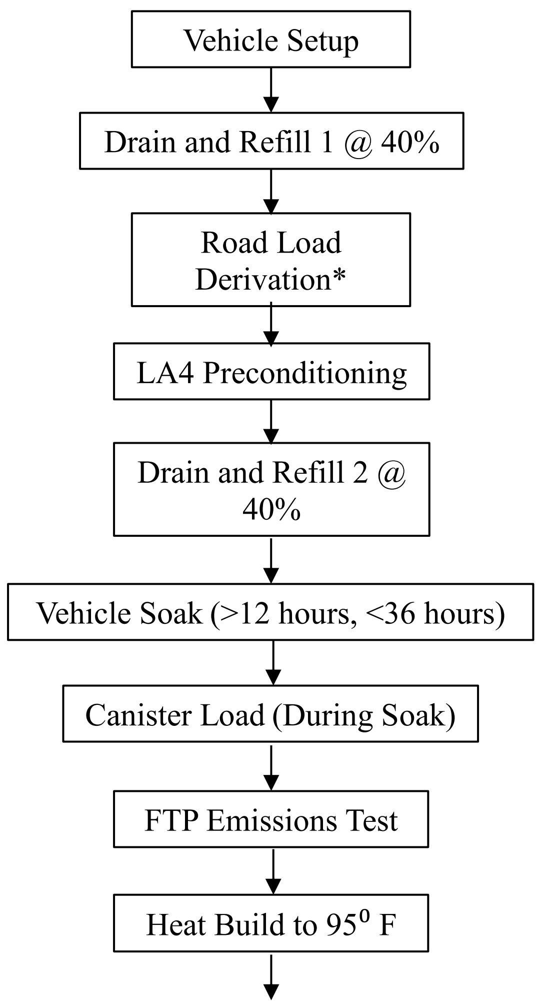
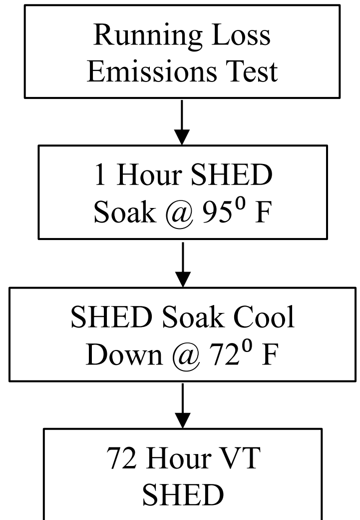


Figure 3-6. 72 Hour VT SHED Procedure





*Road Load Derivation is only completed once per vehicle. It is not performed as a part of each individual test sequence.

Figure 3-7. ORVR Procedure

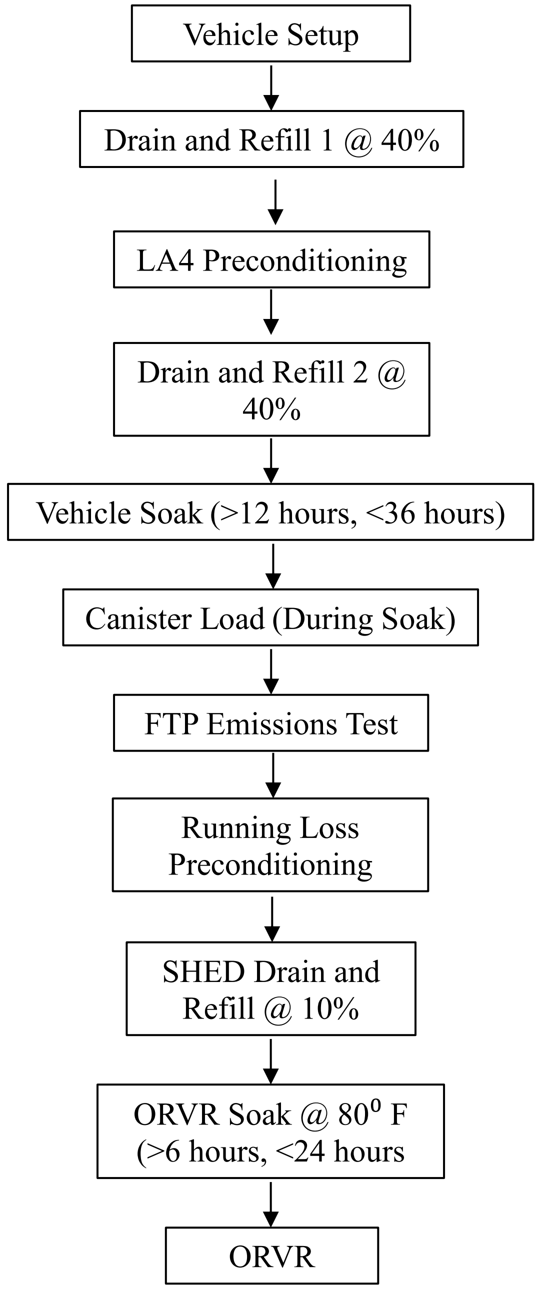


Image 3-3. ORVR Prep

Figure 3-8. Static Test Procedure

1 Hour Permeation Rate Test

↓

½ Hour Tank Pressure Test

↓

½ Hour Fuel System Pressure Test

3.2 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 for VT SHED
- Start of hot soak test within allotted time after completion of running loss test for VT SHED
- Correct amount of fuel dispensed for ORVR

Issues that were discovered during the test program or during the data validation and analysis stage were documented and addressed as described in Section 6. More details are found in the Quality Assurance Project Plan (QAPP).

4.0 Final Results

The following tables and figures characterize the total emissions measured through each vehicle's series of tests. Figure 4-1 shows the temperature profiles that were used during the 72-hour SHED running loss driving trace (provided by the EPA). The Ford E-450's 72-hour SHED results for Test 1 and 2 were voided due to (1) a power outage, and (2) a SHED auto start error. Those results are presented in Section 6.0. The VT SHED re-test results from Test 3 and 4 on the Ford were valid and are reported below.

Figure 4-1. Running Loss Tank Temperature Profiles

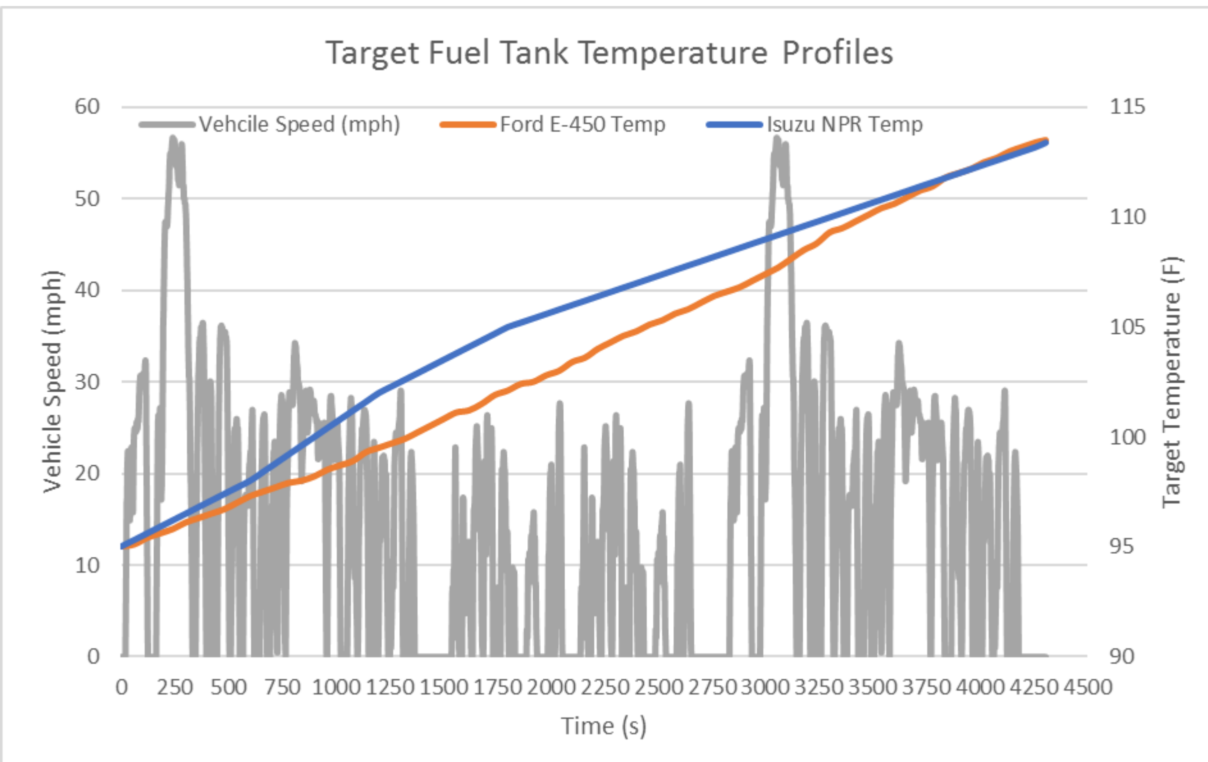


Table 4-1. Ford E-450 72-Hour VT SHED FTP Tailpipe Exhaust Emission Results

	72 hour VT SHED FTP Weighted Results (g/mi)						
	HC	**CO**	**CO2**	**NOx**	**CH4**	**n-CH4**	**mpg**
Ford Test 3	0.3787	2.62	942.93	0.4038	0.0602	0.3227	9.1
Ford Test 4	0.3717	3.73	960.60	0.3585	0.0616	0.3142	8.9

	72-hour VT SHED FTP Purge Volume (L)			
	Phase 1	**Phase 2**	**Phase 3**	**Total**
Ford Test 3	98.74	567.27	248.00	914.01
Ford Test 4	103.41	579.54	197.07	880.01

Table 4-2. Isuzu NPR 72-Hour VT SHED FTP Tailpipe Exhaust Emission Results

	72-hour VT SHED FTP Weighted Results (g/mi)						
	HC	**CO**	**CO2**	**NOx**	**CH4**	**n-CH4**	**mpg**
Isuzu Test 1	0.1928	4.45	1135.27	0.4824	0.0581	0.1387	7.5
Isuzu Test 2	0.1841	3.69	1128.00	0.4318	0.0569	0.1311	7.6

	72-hour VT SHED FTP Purge Volume (L)			
	Phase 1	**Phase 2**	**Phase 3**	**Total**
Isuzu Test 1*	N/A	N/A	N/A	N/A
Isuzu Test 2	43.68	321.92	165.74	531.34

*Purge meter did not record purge volume correctly on test 1

Table 4-3. Ford E-450 72-Hour VT SHED Running Loss Results

	72-hour VT SHED Running Loss Purge Volume (L)			
	Phase 1	**Phase 2**	**Phase 3**	**Total**
Ford Test 3	866.87	963.72	975.17	2805.77
Ford Test 4	751.85	839.55	894.36	2485.76

	72-hour VT SHED Running Loss Weighted HC (g/mi)			
	Phase 1	**Phase 2**	**Phase 3**	**Total**
Ford Test 3	0.0007	0.0002	0.0001	0.0010
Ford Test 4	0.0006	0.0003	0.0002	0.0011

Table 4-4. Isuzu NPR 72-Hour VT SHED Running Loss Results

	72-hour VT SHED Running Loss Purge Volume (L)			
	Phase 1	**Phase 2**	**Phase 3**	**Total**
Isuzu Test 1	N/A	N/A	N/A	N/A
Isuzu Test 2	462.40	398.92	400.18	1261.51

	72-hour VT SHED Running Loss Weighted HC (g/mi)			
	Phase 1	**Phase 2**	**Phase 3**	**Total**
Isuzu Test 1	0.0004	0.0001	0.0000	0.0002
Isuzu Test 2	0.0002	0.0001	0.0000	0.0003

Table 4-5. Ford E-450 72-Hour VT SHED Results †, ‡

	72-hour VT SHED HC Mass (g)			
	Day 1	**Day 2**	**Day 3**	**Total**
Ford Test 3	0.303	0.270	0.301	0.874
Ford Test 4	0.302	0.240	0.295	0.836

	72-hour VT SHED Canister Bleed (g)			
	Day 1	**Day 2**	**Day 3**	**Total**
Ford Test 3	0.0231	0.0261	0.0383	0.0875
Ford Test 4	0.0194	0.0158	0.0207	0.0559

† 40 CFR Part 86.1813-17 states that "In the case of rig, diurnal, hot soak, and running loss testing with E10 test fuel, multiply measured (unspeciated) FID values by 1.08 to account for the FID's reduced response to ethanol." However, the test fuel was market gasoline and therefore no certificate of analysis (COA) was available, the results are reported uncorrected.

‡ This testing was conducted for inventory purposes only, and do not reflect evaporative emissions compliance as described in 40 CFR Part 1813-17. As such, these results should not be used to determine compliance.

Table 4-6. Isuzu NPR 72-Hour VT SHED Results§,**

	72-hour VT SHED HC Mass (g)			
	Day 1	Day 2	Day 3	Total
Isuzu Test 1	0.609	0.682	0.672	1.962
Isuzu Test 2	0.530	0.717	0.581	1.828

	72-hour VT SHED Canister Bleed (g)			
	Day 1	Day 2	Day 3	Total
Isuzu Test 1	0.0550	0.0330	0.0245	0.1125
Isuzu Test 2††	0.0007	0.0192	0.0460	0.0659

Table 4-7. Ford E-450 ORVR FTP Exhaust Emissions Results

	ORVR FTP Weighted Results (g/mi)						
	HC	CO	CO2	NOx	CH4	n-CH4	mpg
Ford Test 1	0.3982	2.63	972.58	0.4274	0.0551	0.3469	8.8
Ford Test 2	0.3544	2.25	965.01	0.3948	0.0533	0.3049	8.9

	ORVR FTP Purge Volume (L)			
	Phase 1	Phase 2	Phase 3	Total
Ford Test 1	90.20	585.38	274.89	950.48
Ford Test 2	N/A	N/A	N/A	N/A

§ 40 CFR Part 86.1813-17 states that "In the case of rig, diurnal, hot soak, and running loss testing with E10 test fuel, multiply measured (unspeciated) FID values by 1.08 to account for the FID's reduced response to ethanol." However, the test fuel was market gasoline and therefore no certificate of analysis (COA) was available, the results are reported uncorrected.

** This testing was conducted for inventory purposes only, and do not reflect evaporative emissions compliance as described in 40 CFR Part 1813-17. As such, these results should not be used to determine compliance.

†† Canister bleed emissions did not report correctly for Isuzu Test 2

Table 4-8. Isuzu NPR ORVR FTP Exhaust Emissions Results

	ORVR FTP Weighted Results (g/mi)						
	HC	**CO**	**CO2**	**NOx**	**CH4**	**n-CH4**	**mpg**
Isuzu Test 1	0.1791	3.58	1127.95	0.3509	0.0461	0.1363	7.6
Isuzu Test 2	0.1841	3.69	1128.00	0.4318	0.0569	0.1311	7.6

	ORVR FTP Purge Volume (L)			
	Phase 1	**Phase 2**	**Phase 3**	**Total**
Isuzu Test 1	N/A	N/A	N/A	N/A
Isuzu Test 2	34.91	295.90	161.81	492.61

Table 4-9. Ford E-450 ORVR Results

	ORVR Results	
	Average g/gal	**SHED grams**
Ford Test 1	2.261	113.611
Ford Test 2	2.145	107.631

Table 4-10. Isuzu NPR ORVR Results

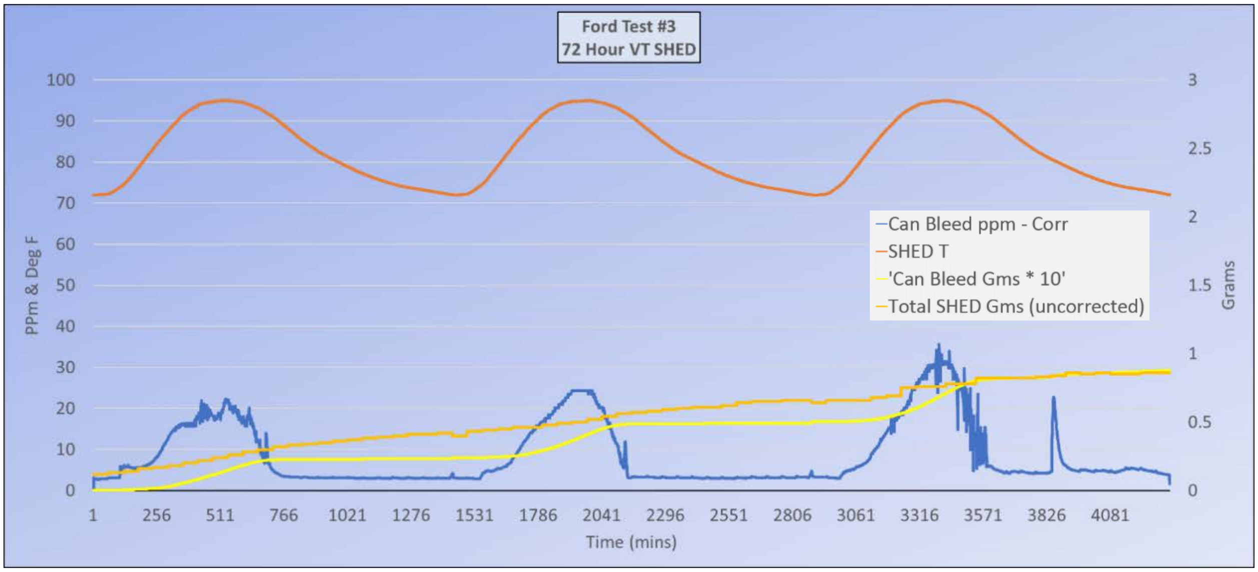
	ORVR Results	
	Average g/gal	**SHED grams**
Isuzu Test 1	2.163	55.252
Isuzu Test 2	2.833	72.390
Isuzu Test 3[‡‡]	2.775	71.215

Table 4-11. Static Test Results, Permeation Rates

	Static Test Results SHED Mass (g)				Static Test Results SHED Mass (g/hr)			
	Phase 1	**Phase 2**	**Phase 3**	**Total**	**Phase 1**	**Phase 2**	**Phase 3**	**Total**
Isuzu Test 1	0.032	0.017	0.028	0.078	0.032	0.034	0.056	0.039
Ford Test 1	0.013	0.008	0.010	0.031	0.013	0.016	0.020	0.0155

[‡‡] This ORVR result was the refueling event only. It did not include the initial prep, canister load, FTP, or Running Loss. The vehicle canister was purged, then the vehicle was drained and filled per the ORVR procedure, underwent the ORVR soak, and then underwent the ORVR refueling event. This was done as a check due to the discrepancy in the initial ORVR results.

Figure 4-2. Ford E-450 72-Hour VT SHED Graphical Results



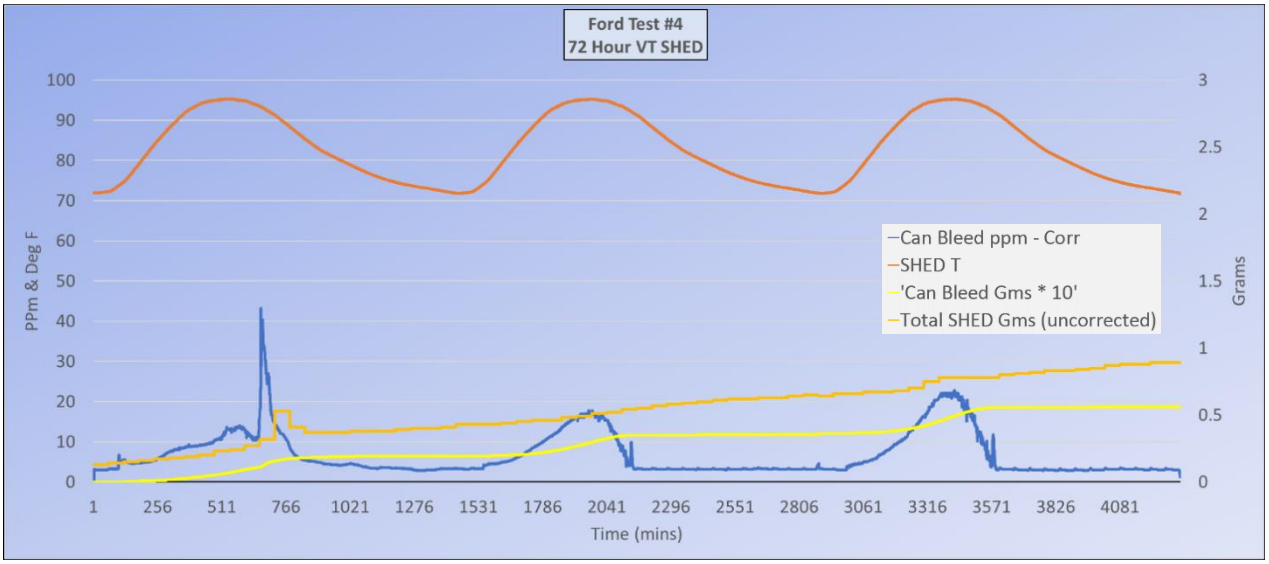
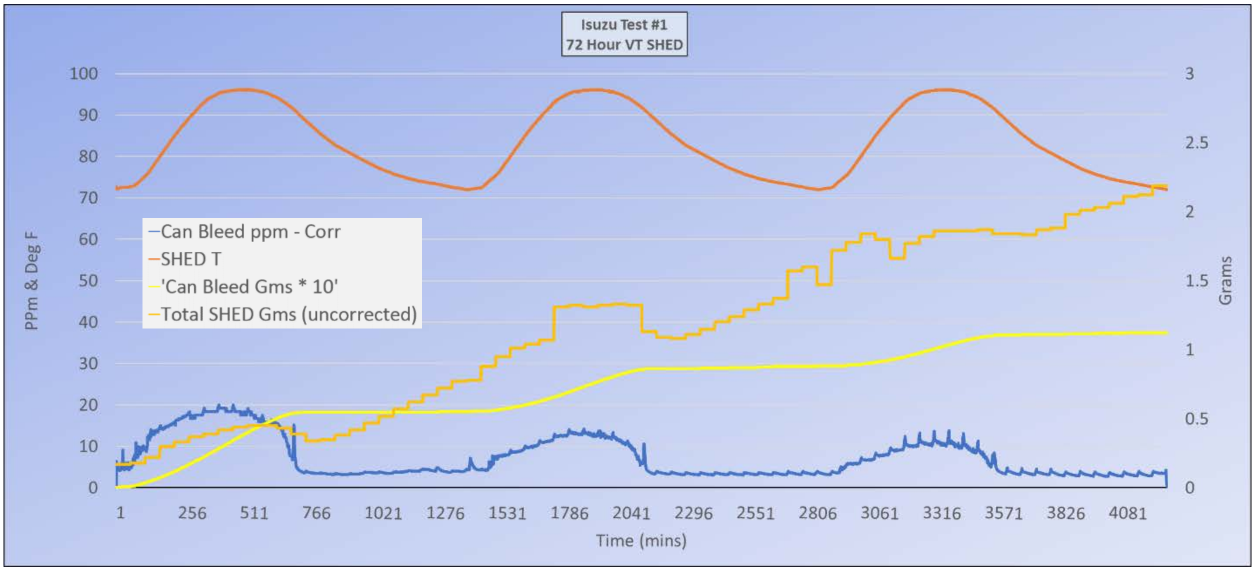
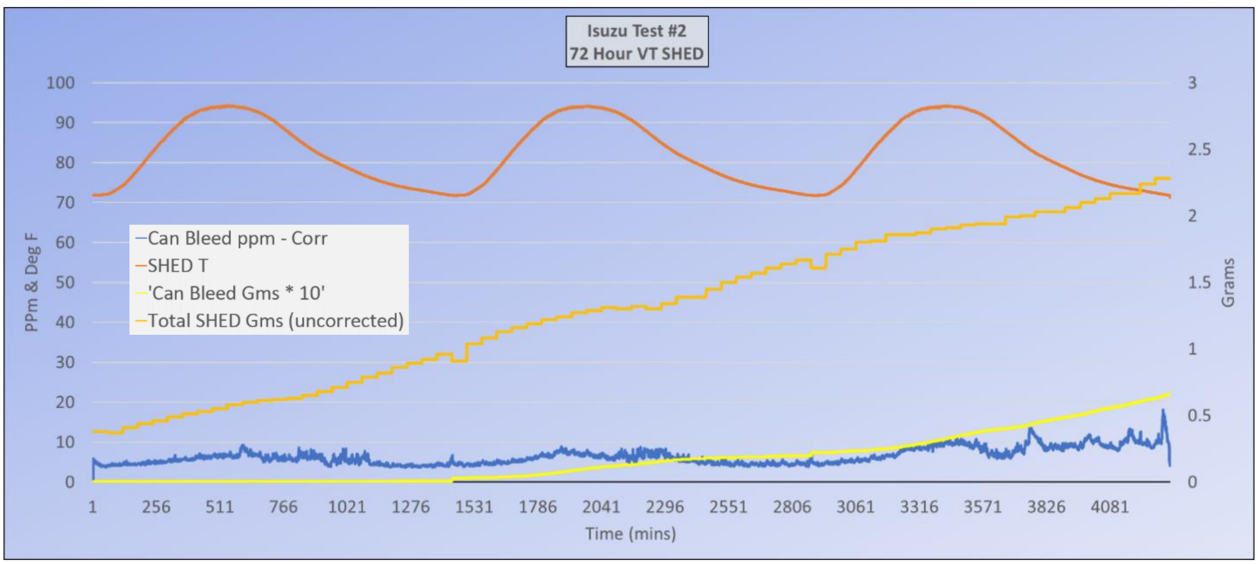


Figure 4-3. Isuzu NPR 72-Hour VT SHED Graphical Results





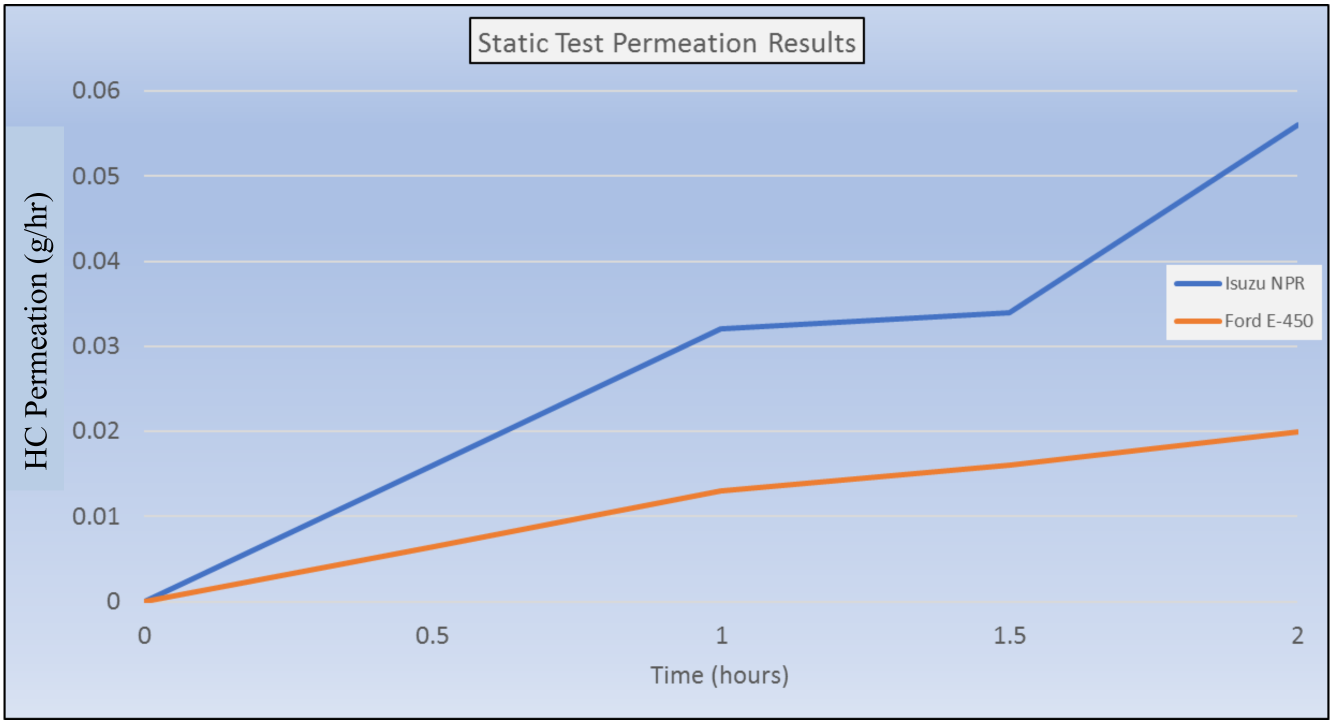


Figure 4-4. Isuzu NPR Static SHED Test Graphical Results

5.0 Observations and Conclusions

Comparing the performance of the two vehicles throughout the testing procedures show that the purge strategy of both vehicles is very similar, with the Ford purging approximately 8% of total canister weight between the end of canister loading and the end of the SHED hot soaks, while the Isuzu purged approximately 8.5% of its canister weight.

The ORVR testing showed both vehicles performed similarly in terms of the grams emitted per gallon of fuel recorded during the fueling procedure. The total SHED grams were significantly higher on the Ford when compared to the Isuzu, but the amount of fuel dispensed is also significantly higher due to the Ford's larger fuel tank (55 gallons compared to 30 for the Isuzu). When results are compared on a basis of grams per gallons of fuel dispensed, both vehicles performed similarly. The larger fuel tank in the Ford is also the reason its ORVR test is slightly longer than that of the Isuzu (5 minutes vs. 3 minutes).

The static emissions test was conducted to obtain the permeation rate of HC on the vehicles. The HC concentration was measured in the SHED for each phase of the Static Test: The vehicle sat in the SHED for the first hour, then the vapor space was pressurized for next thirty minutes, and for the final thirty minutes the fuel pump was activated. This testing yielded very little HC mass for both vehicles. The rate at which the Ford E-450 permeates stayed consistent throughout the test. The rate at which the Isuzu NPR permeates did increase when the fuel pump is activated (as shown in Figure 4-4), indicating a small liquid leak somewhere in the system.

Results for the 72-hour VT SHED show the Isuzu having a higher HC mass than the Ford. The Ford showed canister bleed emission spikes during both 72 hour VT SHED tests (Figure 4-2, day 3 for the third test, day 1 for the fourth). This could indicate the canister breaking through, or just releasing a brief burst of HC.

Repeatability for purge volume and emissions was consistent for both vehicles throughout testing.

6.0 Problems Encountered

During the testing process, the problems encountered included two of the 72-hour VT SHEDS being voided on the Ford E-450. Test 1 was due to a power outage, and Test 2 was due to an error with the test auto-start on the SHED.

During the FTP and running loss portions of testing, there were instances of the canister purge data not recording. The data from the voided tests is presented below.

Table 6-1. Voided Test Results

	72 hour VT SHED FTP Weighted Exhuast Emissions Results (g/mi)						
	HC	CO	CO2	NOx	CH4	n-CH4	mpg
Ford 1 (SHED Void)	0.3434	3.01	954.01	0.3878	0.0526	0.2944	9.0
Ford 2 (SHED Void)	0.3285	3.13	1029.10	0.4565	0.0613	0.2715	8.3

	72-hour VT SHED FTP Purge Volume (L)			
	Phase 1	Phase 2	Phase 3	Total
Ford 1 (SHED Void)	77.81	562.91	232.12	872.85
Ford 2 (SHED Void)	84.25	583.55	276.85	944.65

	72-hour VT SHED Running Loss HC (g/mi)			
	Phase 1	**Phase 2**	**Phase 3**	**Total**
Ford 1 (SHED Void)	0.0004	0.0002	0.0001	0.0006
Ford 2 (SHED Void)	0.0011	0.0027	0.5145	0.5184

	72-hour VT SHED Running Loss Purge Volume (L)			
	Phase 1	**Phase 2**	**Phase 3**	**Total**
Ford 1 (SHED Void)	805.76	1064.78	964.60	2835.14
Ford 2 (SHED Void)	N/A	N/A	N/A	N/A

7.0 References

[1] Haskew, H., Liberty, T. (2008), Vehicle Evaporative Emission Mechanisms: A Pilot study. (Coordinating Research Council E-77)

[2] Haskew, H., Liberty, T. (2010), Enhanced Evaporative Emission Vehicles. (Coordinating Research Council E-77-2)

[3] Haskew, H., Liberty, T. (2010), Evaporative Emissions from In-Use Vehicles: Test Fleet Expansion. (Coordinating Research Council E-77-2b)

[4] 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. (Coordinating Research Council E-77-2c)

[5] 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.

[6] 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.

Appendix A

List of Electronic Files Provided to OTAQ

Excel Files

- 04162600.csv – Isuzu NPR FTP 8/5/18
- 04162601.csv – Isuzu NPR Running Loss (Prep) 8/4/18
- 04162714.csv – Isuzu NPR FTP 8/8/18
- 04162717.csv – Isuzu NPR Running Loss 8/8/18
- 04162952.csv – Isuzu NPR FTP 8/15/18
- 04162962.csv – Isuzu NPR Running Loss (Prep) 8/15/18
- 04163104.csv – Isuzu NPR FTP 8/17/18
- 04163116.csv – Isuzu NPR Running Loss 8/17/18
- 04163314.csv – Ford E450 FTP 8/21/18
- 04163318.csv – Ford E450 Running Loss (Prep) 8/21/18
- 04163501.csv – Ford E450 FTP 8/24/18
- 04163508.csv – Ford E450 Running Loss 8/24/18
- 04163655.csv – Ford E450 FTP 8/28/18
- 04163656.csv – Ford E450 Running Loss (Prep) 8/28/18
- 04163822.csv – Ford E450 FTP 8/30/18
- 04163825.csv – Ford E450 Running Loss 8/30/18
- 04163909.csv – Ford E450 FTP 9/1/18
- 04163910.csv – Ford E40 Running Loss 9/1/18
- 04164117.csv – Ford E450 FTP 9/6/18
- 04164119.csv – Ford E450 Running Loss 9/6/18

HTML Files

- 7500162716.html- Test No. 162716, Isuzu NPR, Hot Soak
- 7500162754.html- Test No. 162754, Isuzu NPR, VT SHED
- 7500163001.html- Test No. 163001, Isuzu NPR, ORVR
- 7500163122.html- Test No. 163122, Isuzu NPR, VT SHED
- 7500163382.html- Test No. 163382, Ford E-450, ORVR
- 7500163543.html- Test No. 163543, Ford E-450, VT SHED
- 7500163666.html- Test No. 163666, Isuzu NPR, VT SHED
- 7500163687.html- Test No. 163687, Ford E-450, ORVR
- 7500162642 html- Test No. 162642, Isuzu NPR, ORVR
- 7500163745.html- Test No. 163745, Ford E-450, VT SHED
- 7500163857.html- Test No. 163857, Ford E-450, VT SHED
- 7500163912.html- Test No. 163912, Ford E-450, VT SHED
- 7500164132.html- Test No. 164132, Ford E-450, VT SHED