Summary of "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

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1. Executive Summary

There has been significant progress in reducing evaporative emissions from gasoline-fueled passenger cars and light-duty trucks. Due to the increasing market share of gasoline engines in heavy-duty vehicles it is necessary that we evaluate the evaporative emissions from these vehicles' fuel systems. Evaporative emissions from heavy-duty vehicles can be a significant contribution to the vehicles overall hydrocarbon (HC) emissions, therefore controlling this source of emissions is important.

To evaluate the evaporative emission performance on current production heavy-duty gasoline vehicles, two vehicles were tested over a full set of evaporative emissions tests at the SGS Environmental Testing Center Laboratory in Aurora, Colorado, under contract with Eastern Research Group. Complete sets of running loss, hot soak, three-day diurnal, onboard refueling vapor recovery (ORVR) and static tests procedures were run on each vehicle. Pressures, temperatures and continuous on-board diagnostic (OBD) purge data were recorded in addition to the measurement of the HC emissions.

The primary finding of this study was that the HC evaporative emissions of both vehicles appeared to be controlled during the running loss, hot soak SHED, three-day diurnal, and static tests. These vehicles are not regulated for ORVR and therefore the tests resulted in high levels of HC emissions. However, further analysis of the ORVR data indicates that these test results likely underestimate the amount of emissions because of test procedure issues.

2. Test Program

The US Environmental Protection Agency (EPA) conducted benchmark evaporative emissions testing on two heavy-duty gasoline vehicles. The testing was conducted through a contractor, Eastern Research Group (ERG) at the SGS Environmental Testing Center (SGS) Laboratory in Aurora, Colorado. Testing objectives were to understand the current state of heavy-duty gasoline vehicle evaporative emissions performance. The test program details and results are available in the contractor report.[1]

2.1 Vehicles

Two heavy-duty trucks, as described in Table 1, were selected to represent a significant portion of the heavy-duty gasoline fleet. They were recruited under contract, by Jacobs Technology, Inc. They were in-use vehicles which were leased for the duration of the test program. The engines in both vehicles were certified as heavy-duty gasoline engines (HDGE) and certified to evaporative emission standards, as shown in Table 2. Neither vehicle was required to contain an onboard refueling vapor recovery (ORVR) system because these vehicles are not subject to ORVR emission standards.

Table 1: Test Vehicle Characteristics

Vehicle	Model Year	Engine Size (liters)	Transmission	Approx. Odometer (miles)	GVWR (lbs)
Ford E450	2016	6.8	Auto 6 speed	34,000	14,500
Izuzu NPR	2015	6.0	Auto 6 speed	52,000	14,500

Table 2: Evaporative and Exhaust Emissions Standards

Vehicle	Engine Certification	Evaporative Emission Standard (grams/test)			Canister Working Capacity (g)	Fuel Tank Volume (gal)	Canister Capacity / Tank Ratio (g/gal)
		2 Day	3 Day	Running Loss			
Ford E-450	HDGE >14.0k GVWR	2.3	1.9	0.05	265	55	4.82
Isuzu NPR	HDGE All Vehicles	2.3	1.9	0.05	150	30	5

[1] Eastern Research Group and SGS, Aurora. “Light Heavy-Duty Gasoline Vehicle Evaporative Emissions Test Program,” February 2019

2.2 Evaporative Emissions Testing

A full set of evaporative emissions tests on the two vehicles were performed at SGS, Aurora under contract with ERG. Running Loss, Hot Soak, Diurnal, ORVR and Static tests were performed with duplicate tests in most cases. Commercial regular grade fuel from the Denver Metro area was used for the study. The fuel was 85 octane and had a Reid Vapor Pressure of 8.5 psi on average. The box on each vehicle was removed so that it could fit into the SHED. The vehicles were also modified to include two type-J thermocouples in the fuel tank, one in the liquid and one in the vapor space, and fuel pressure measurement ports. Further details of the testing can be found in the referenced report.

3. Emissions Results

3.1 Permeation Emissions

Permeation emissions occur during all operating modes. Specifically they are the hydrocarbon (HC) emissions that escape through the micro-pores in pipes, fittings, fuel tanks and other vehicle components. They differ from leaks since they occur on the molecular level and are not a mechanical or material failure in a specific region. The first hour of the Static tests (Phase 1) is representative of permeation emissions. Both vehicles performed as expected and did not show any issues with permeation emissions, as shown in Table 3.

Table 3: Static Test Results

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

3.2 Vapor Venting Emissions

Vapor venting emissions are running loss, hot soak and diurnal emissions minus the constant permeation. Both vehicles were reasonably controlled for in-use vehicles. The testing that was performed differed from the certification test procedures so these tests only give us an estimation for comparing to the standards. The running loss results for both trucks are shown in Table 4. The Ford truck results for the 3-Day Diurnal test was just over half of the standard and the Isuzu was just over the standard, as shown in Table 5. See the testing report for more details on the procedure and results.

Table 4: 3-Day Running Loss Results

	72 Hour Variable Temperature Running Loss HC (g/mile)			
	Phase 1	Phase 2	Phase 3	WTD
Ford Test 3	0.0007	0.0002	0.0001	0.0010
Ford Test 4	0.0006	0.0003	0.0002	0.0011
Isuzu Test 1	0.0004	0.0001	0.0000	0.0002
Isuzu Test 2	0.0002	0.0001	0.0000	0.0003

Table 5: 3-Day Diurnal 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
Isuzu Test 1	0.609	0.682	0.672	1.962
Isuzu Test 2	0.530	0.717	0.581	1.828

3.3 Onboard Refueling Vapor Recovery

These two trucks are not subject to an Onboard Refueling Vapor Recovery (ORVR) emissions standard, therefore uncontrolled HC evaporative emissions were anticipated. The ORVR results for both trucks are shown in Table 6. However, after the analysis of the data, we determined that the emissions from the ORVR tests were lower than expected when compared to uncontrolled refueling emissions levels from predictive models, such as MOVES. Non-ORVR refueling emissions in the MOVES model are based on a Coordinating Research Council (CRC) study in the 1990's of 22 vehicles with uncontrolled refueling emissions. We would have expected the uncontrolled refueling hydrocarbon emissions to be approximately 3.34 grams per gallon based on the CRC study, which equates to approximately 168 grams from the Ford and 90 grams from the Isuzu assuming a 90% fuel tank fill.

Table 6: ORVR Test Results

	ORVR HC Results	
	Average g/gal	SHED grams
Ford Test 1	2.261	113.611
Ford Test 2	2.145	107.631
Isuzu Test 1	2.163	55.252
Isuzu Test 2	2.833	72.390

To investigate the discrepancy, a detailed investigation into the test procedure, equipment, and analysis was conducted. No issues were found with the calibration data from any of the analyzers or equipment used for this testing. Furthermore, no issues were found with the calculations or data analysis. After discussions with evaporative testing experts it was determined that the application of the existing EPA ORVR test procedures, which were designed for light-duty vehicles, may not have been appropriate for the size of these vehicles and the fact that the SHED used in this testing is approximately one third larger than typical SHEDs. The existing CFR requirements only require emission measurement for one minute after the completion of the refueling event. As shown in Figure 1 and Figure 2, the hydrocarbon emissions were still climbing at the end of the tests (one minute after refueling ends). We believe additional measurement time is required for mixing and likely more fans for circulation of the air in the SHED for the emissions to stabilize properly. It is not known how much additional mixing time is necessary without additional testing, but it is likely that between one to three additional minutes would be required based on extrapolation of the test results, as shown in Figure 3 and Figure 4.

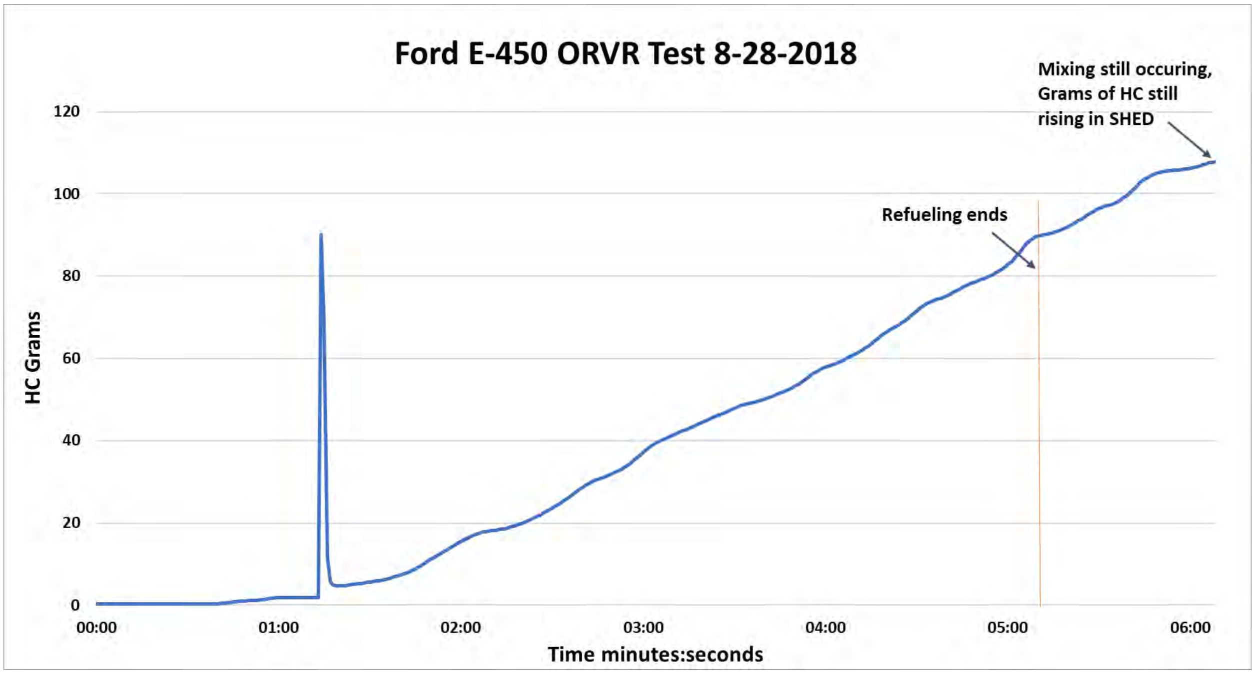

Figure 1: Ford E-450 ORVR Test

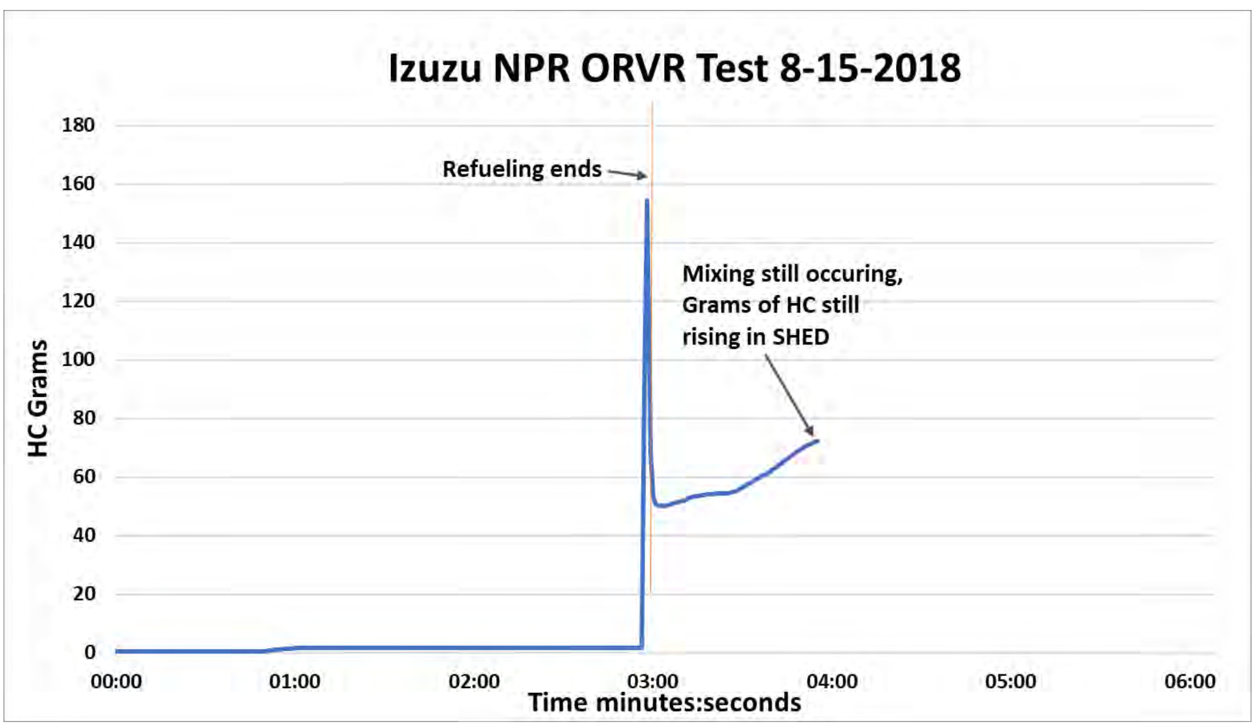

Figure 2: Isuzu ORVR Test

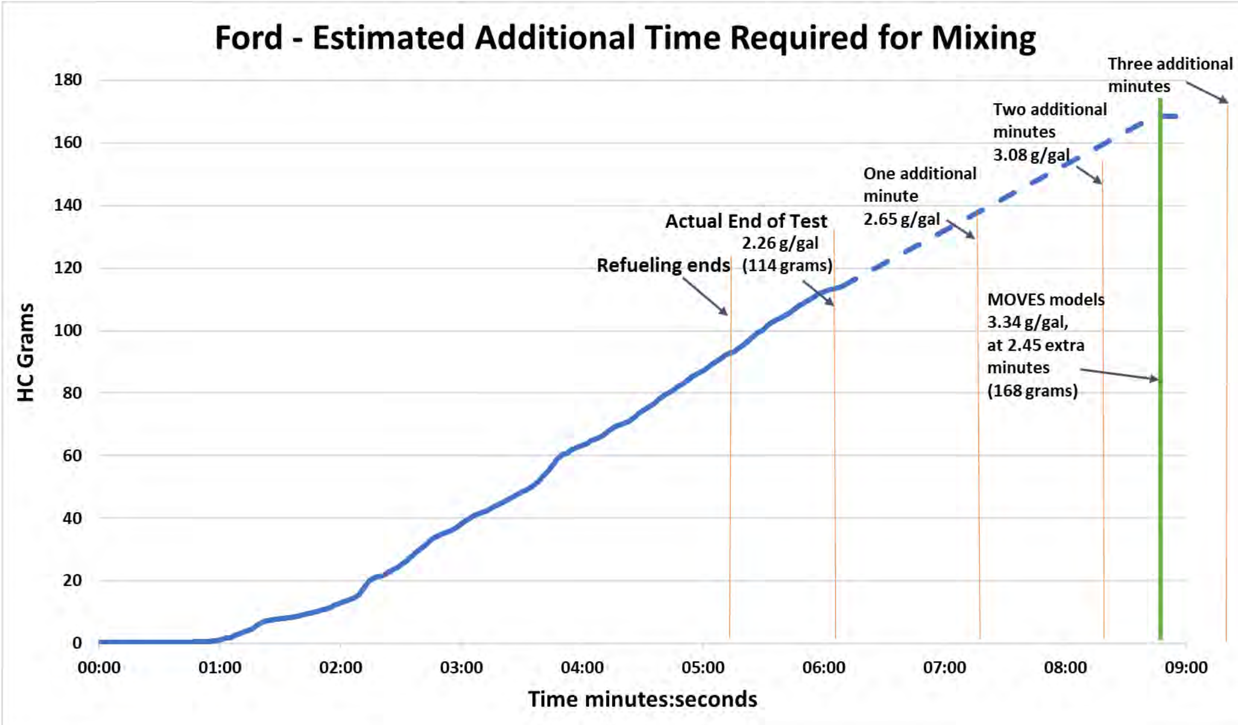

Figure 3: Projected Ford E-450 ORVR Results based on Extrapolation

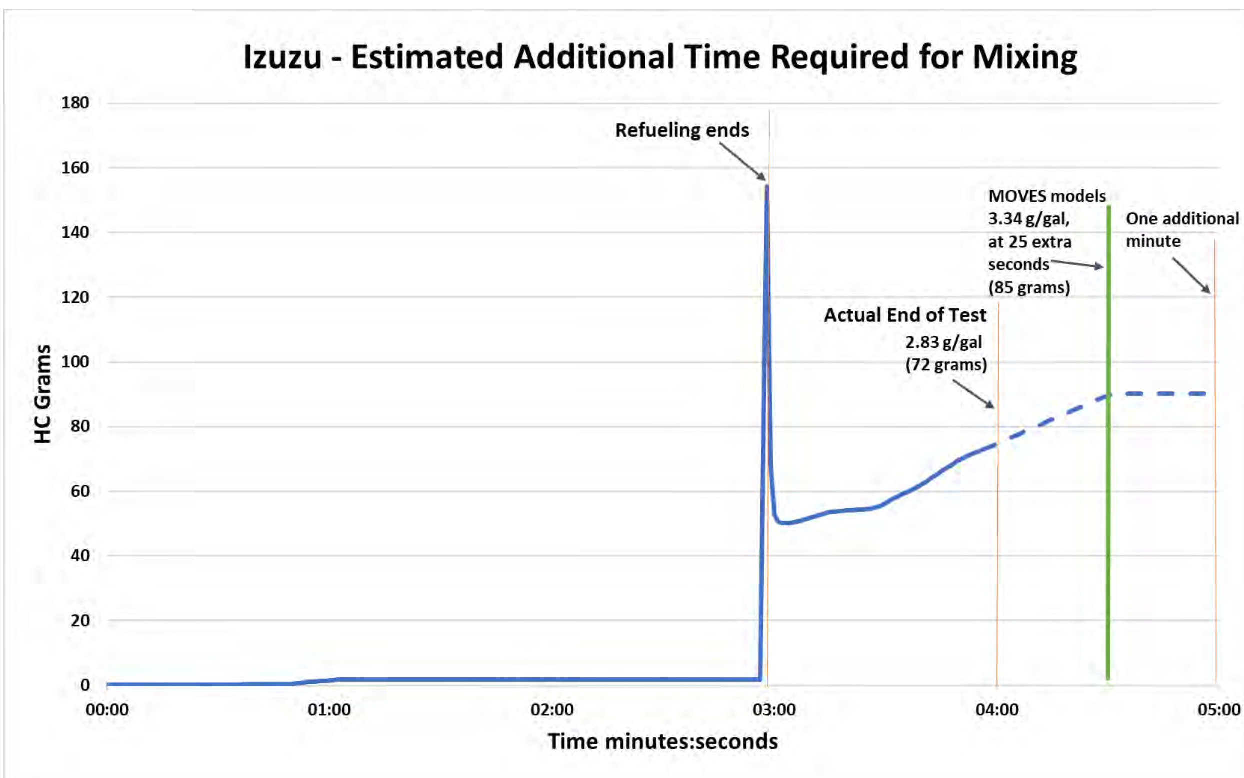

Figure 4: Projected Isuzu ORVR Results based on Extrapolation