

Chassis Dynamometer Testing of Two Recent Model Year Heavy-Duty On-Highway Diesel Glider Vehicles

November 20, 2017

National Vehicle & Fuel Emissions Laboratory
U.S. Environmental Protection Agency
Ann Arbor, Michigan

Table of Contents

1. Executive Summary.....	3
2. Test Program	4
2.1 Glider Vehicle Descriptions	4
2.1.1 Glider #1 Vehicle Description	4
2.1.2 Glider #2 Vehicle Description	5
2.2 Road Load Coefficients.....	5
2.3 Test Fuel.....	6
2.4 Test Cycles	6
2.5 Vehicle Test Site and Emission Measurements	11
3. Emissions Results	13
3.1 Criteria Pollutants.....	13
3.2 Particulate Matter (PM).....	14
3.3 Conversion of Distance Specific Emissions to Engine Work Specific Emissions	16
3.4 Simulated HD Federal Test Procedure and Supplemental Emission Test Results	18
4. Comparison to other HD Vehicle Emission Performance.....	20
5. Appendix A.....	28
6. Appendix B.....	33
7. Appendix C.....	36

1. Executive Summary

This report summarizes the results from emissions testing of a 2016 model year (MY) Peterbilt 389 sleeper cab tractor and a 2017 MY Peterbilt 579 sleeper cab tractor that were produced as glider vehicles (i.e., a vehicle with a new chassis and a used powertrain). In addition, these glider test results are compared to equivalent tests of conventionally manufactured 2014 and 2015 MY tractors.

The glider vehicles tested include one of the more popular engine and vehicle configurations currently being produced as glider vehicles. These results are useful in evaluating the emission impacts of glider vehicles, and the observations made in this report are consistent with the expected emissions performance of heavy-duty highway diesel engines manufactured in the 1998-2002 timeframe.

The criteria pollutant emissions (NO_x, PM, HC, CO) from the 2016 MY Peterbilt 389 and 2017 Peterbilt 579 glider vehicles were consistently higher than those of the conventionally manufactured 2014 and 2015 tractors. The extent to which this occurred depended on the pollutant and the test cycle.

- Under highway cruise conditions, NO_x emissions from the Peterbilt 389 and Peterbilt 579 glider vehicles were approximately 43 times as high, and PM emissions were approximately 55 times as high as the conventionally manufactured 2014 and 2015 MY tractors.
- Under transient operations, absolute NO_x and PM emissions were higher for the Peterbilt 389 and Peterbilt 579 glider vehicles on all duty cycles. On a relative basis, the glider vehicle NO_x emissions were 4-5 times higher, and PM emissions were 50-450 times higher than the conventionally manufactured 2014 and 2015 MY tractors.
- HC and CO emissions for the Peterbilt 389 and Peterbilt 579 glider vehicles were also significantly higher than the conventionally manufactured 2014 and 2015 MY tractors on a relative basis. However, on an absolute basis, they appear to be less of a concern than the NO_x and PM emissions.
- CO₂ emissions from the Peterbilt 389 and Peterbilt 579 glider vehicles were lower than the conventionally manufactured vehicles when measured on the chassis dynamometer without taking into account the differences in the aerodynamic drag between the vehicles.

2. Test Program

All testing was conducted by the US Environmental Protection Agency (EPA) in October and November 2017 at the National Vehicle Fuel and Emissions Laboratory (NVFEL). Two glider vehicles were tested on a heavy-duty chassis dynamometer to measure the emissions in a controlled environment. The following subsections describe the elements of the test program.

The testing was conducted using the same test cycles and test procedures that EPA has previously used to measure emissions from heavy-duty diesel vehicles, which allows us to put glider vehicle emission results into context. Comparisons to these other highway heavy-duty vehicles are discussed in Section 4.

2.1 Glider Vehicle Descriptions

Two newer model year glider vehicles with remanufactured pre-2002 MY engines were emissions tested in this program.

2.1.1 Glider #1 Vehicle Description

The first glider vehicle tested (Glider #1) was a 2016 MY Peterbilt 389 Glider-Sleeper with a Fitzgerald-rebuilt 12.7 L Detroit Diesel Series 60 engine with 500 horsepower, an Eaton 13 speed manual transmission, and 3.55 rear axle ratio. The Peterbilt 389 exterior has a traditional design that has a squarer front rather than a more aerodynamic design that is more common for model year 2016 and later model vehicles. The engine did not include an emission label, but is believed to have been remanufactured from an engine originally certified in a model year between 1998 and 2002. It included electronically-controlled fuel injection, but not exhaust gas recirculation or any exhaust aftertreatment. The odometer read 179,273 miles at the start of testing.

The malfunction indicator light (MIL), also known as the check engine light, was illuminated when Glider #1 was received. Upon inspection it was determined that the engine fault code was “Engine Oil Pressure> Fault Mode ID:0-DATA VALID BUT ABOVE NORMAL OPERATIONAL RANGE.” EPA tested the as-received condition because it is representative of how the vehicle was driving in the real world. Upon completion of the first set of testing, diagnostics were performed to fix the issue. CAN bus data recorded during testing was reviewed and it was determined that in addition to the oil pressure signal, temperature readings from the fuel, oil and intake air sensor were all dropping low simultaneously. The sensor wiring harness was removed from the vehicle because the MIL was intermittent and identified an error with the oil pressure. The harness was inspected visually and evaluated for electrical continuity. During inspection it was determined that there was oil in the connector of the oil temperature sensor as well as fluid in the connector for the coolant sensor. These connectors were cleaned and the harness was reinstalled. Glider #1 was then driven and it was concluded that the repair was successful. The On-Board Diagnostics (OBD) system did not

detect an issue for the remainder of testing. The emissions tests were then repeated to evaluate the emissions of a properly performing vehicle.

2.1.2 Glider #2 Vehicle Description

The second glider vehicle tested (Glider #2) was a 2017 MY Peterbilt 579 Glider-Sleeper cab tractor with a Fitzgerald-rebuilt 12.7 L Detroit Diesel Series 60 engine with 500 horsepower and an Eaton RTX-16710B 10 speed manual transmission. The body of the Peterbilt 579 tractor was more aerodynamic than the Peterbilt 389. Similar to Glider #1, the engine in this vehicle did not include an emission label, but is believed to have been remanufactured from an engine originally certified in a model year between 1998 and 2002. It included electronically-controlled fuel injection, but not exhaust gas recirculation or any exhaust aftertreatment. The vehicle had approximately 30,600 miles at the start of testing. Unlike Glider #1, Glider #2 did not have any check engine light warnings during the testing.

2.2 Road Load Coefficients

Chassis dynamometer testing requires a simulation of the road load impacts, such as aerodynamics and losses associated with the driveline. These parameters simulate the amount of resistance (i.e., load) that the vehicle is under at different vehicle speeds. The actual road load impact varies significantly in-use because it is dependent on variables such as an actual trailer being pulled and the weight of the vehicle. Road load coefficients are frequently determined by conducting coastdown testing prior to chassis dynamometer testing. In this instance, EPA did not conduct coastdown testing to determine the road load coefficients of the vehicles due to the limited amount of time the glider vehicles were on loan to EPA. Rather, we tested the vehicles each with two sets of road load coefficients covering a range of typical operation. The first set of road load coefficients represents a 60,000 pound combined weight of the tractor, trailer, and payload. The second set of road load coefficients represents a less aerodynamic vehicle with 80,000 pound combined weight of the tractor, trailer, and payload. The target and actual road load coefficients used in the testing are shown in Table 1.

Table 1: Road Load Coefficients

Configuration	Target Coefficients			Set Coefficients		
	A (lbf)	B (lbf/mph)	C (lbf/mph ²)	A (lbf)	B (lbf/mph)	C (lbf/mph ²)
Glider #1, 60k Test Weight	345.090	0.0000	0.15380	235.350	-2.1042	0.143390
Glider #1, 80k test weight	446.350	7.76060	0.14780	336.690	5.5976	0.137120
Glider #2, 60k Test Weight	345.090	0.0000	0.15380	204.530	-1.4243	0.145510
Glider #2, 80k test weight	446.350	7.76060	0.14780	314.620	5.9516	0.145980

2.3 Test Fuel

The test fuel used in this program met the EPA highway certification diesel fuel specifications in 40 CFR part 1065. The fuel properties can be found in Table 2. The glider vehicles went through a triple drain and flush procedure as shown in Table 3 to ensure the engine was operating on the test fuel.

Table 2: Certification Diesel Fuel Specifications

FTAG	Fuel Name	ALPHA	BETA	Cetane	Net Heating Value (BTU/lb)	Carbon Weight Fraction	Sulfur (ppm)	Specific Gravity
26758	Federal Cert Diesel 7-15 ppm Sulfur	1.78	0	44.3	18406	0.8699	8.4	0.8536

Table 3: Fuel change procedure

Step	Description
1	With the ignition key in OFF position, drain vehicle fuel completely via installed fuel drain or the fuel rail.
2	Fill fuel tank to 10% with Diesel Fuel, NVFEL FTAG 26758.
3	Operate the vehicle at idle for 10-15 minutes to allow the fuel system to purge and stabilize.
4	Repeat Steps 1-3. (If repeated steps 1-3, move to Step 5)
5	Repeat Steps 1-3, but fill the fuel tank to 100% with NVFEL Diesel Fuel, FTAG 26758.
6	Run vehicle road load derivations.

2.4 Test Cycles

The emission tests for both gliders were conducted on a chassis dynamometer using three different sets of heavy-duty drive cycles representing a variety of operation. A cold start Heavy-Duty Vehicle Urban Dynamometer Driving Schedule (UDDS) sequence, a World Harmonized Vehicle Cycle (WHVC) sequence, and a Super Cycle.

The cold start sequence consisted of the UDDS cycle, a twenty-minute soak period followed by another UDDS, another twenty-minute soak period, a third UDDS cycle and finishing with forty-five minutes of idling. The UDDS sequence is shown in Figure 1.

The World Harmonized Vehicle Cycle (WHVC) was first run as a warmup cycle without emission measurement followed by a second WHVC where emissions were measured. The WHVC cycle is shown in Figure 2.

The Super Cycle followed the WHVC sequence. If more than twenty minutes elapsed between the cycles, then another warm-up WHVC was run without emission measurement to ensure the Super Cycle included a hot start test. The Super Cycle consists of five California Air Resources Board (ARB) Heavy-Duty Transient Cycles (HDT), a ten-minute idle period, and 55 mph and 65 mph cruise cycles with 0.5 mph/sec acceleration/deceleration rates. The Super Cycle trace is shown in Figure 3.

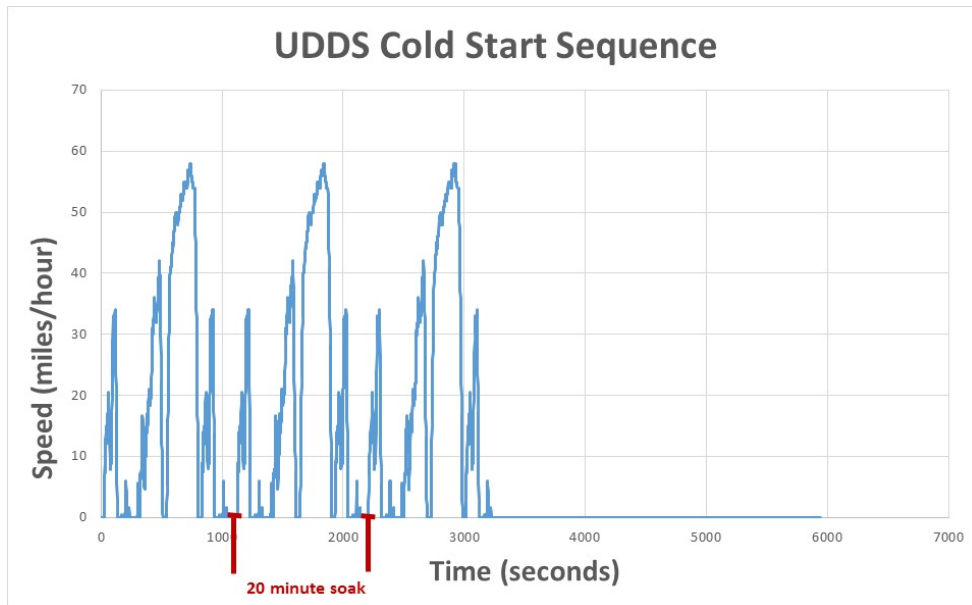


Figure 1: EPA UDDS test cycle speed vs. time profile

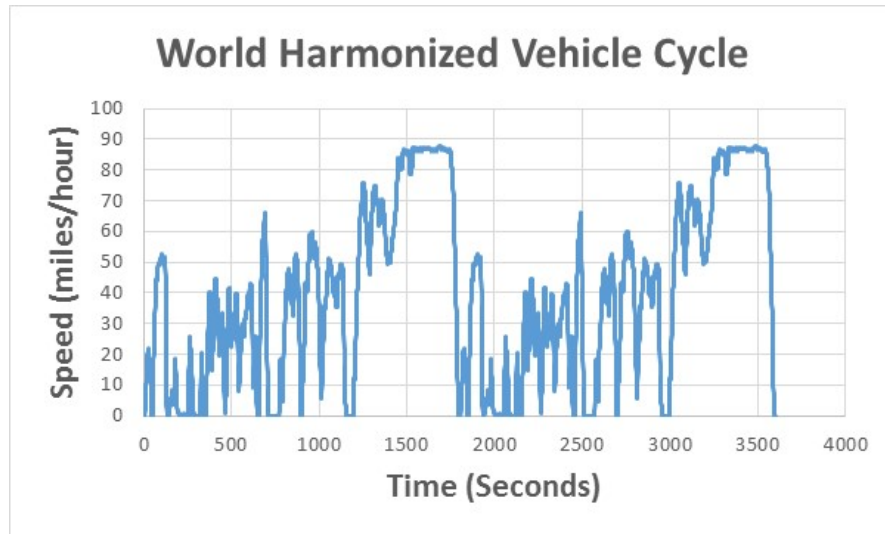


Figure 2: World Harmonized Vehicle Cycle speed vs. time profile

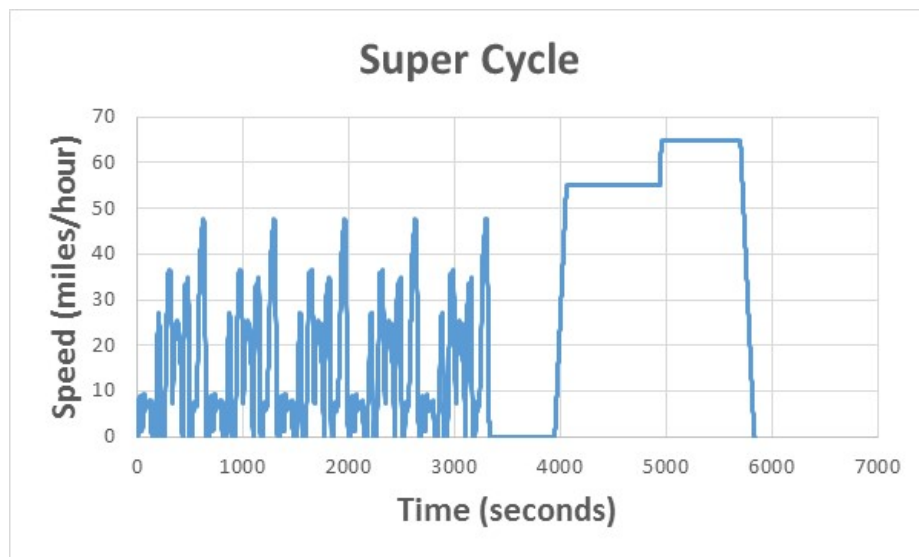


Figure 3: Super Cycle speed vs. time profile

Chassis testing of Glider #2 was also conducted to simulate the engine-based Supplemental Emission Test (SET) defined in 40 CFR 86.1360. Duty cycles were created that matched the defined engine speeds of the SET cycle by driving the vehicle at a constant speed and matched engine torque at the 100%, 75%, 50% and 25% load points at each speed by varying simulated road grade.

The first step of the SET cycle development was to obtain the engine torque curve. This was done by having the dynamometer linearly ramp the vehicle speed from approximately 16 to 68 mph over 315 seconds with the pedal position at 100%. Since the dynamometer was controlling speed for this test instead of torque, the engine power was determined by using the

measured power from the dynamometer corrected for the tire and driveline losses by taking the difference of the losses of target and set coefficients and an assumed axle efficiency of 94%. The resulting torque curve from the test is shown in Figure 4. Using the torque curve, the intermediate test speeds “A”, “B”, and “C” were calculated according to 40 CFR 1065.610.

Finally, three vehicle duty-cycles were created to simulate the engine-based SET on the chassis dynamometer, one for each intermediate speed as shown in Figure 5, Figure 6 and Figure 7. This duty cycle is similar to running the SET as a discrete mode test where the engine is stabilized at each speed and torque setpoint before sampling emissions and the transitions from mode-to-mode are not sampled. The duty cycles were created in this manner because running a Ramped Modal Cycle (RMC) on a chassis dynamometer would be difficult and would not allow for the transmission to be kept in direct drive.

Figure 4 also shows the engine speed and torque where the engine operated for each SET setpoint during the testing. One observation from this figure is that the test speed for the C100 point was slightly lower than the setpoint. This was because the engine was not able to maintain vehicle speed at the defined road grade of the cycle, but since the shift in speed was slight the results were still meaningful for the purpose of this testing.

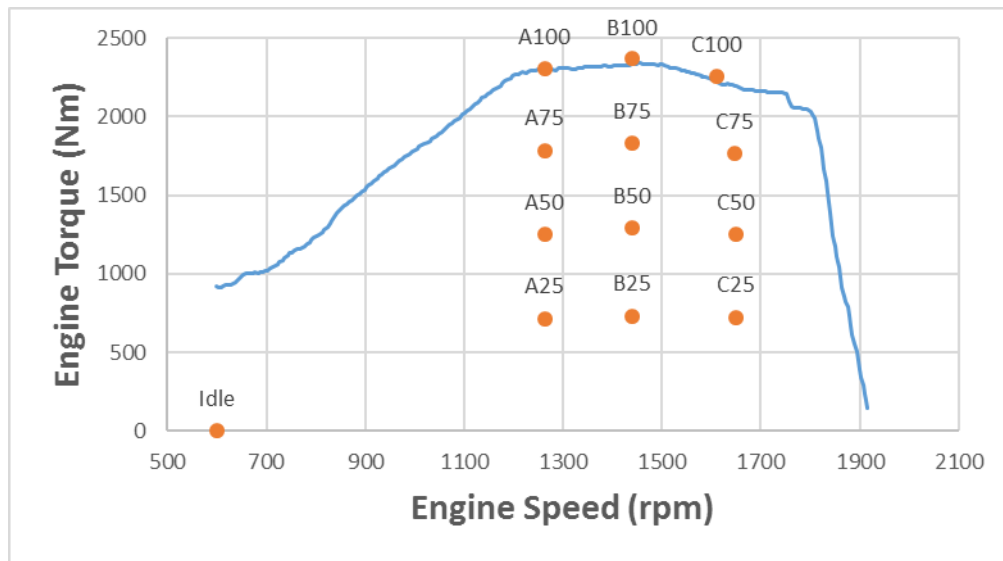


Figure 4: Glider #2 torque curve and SET test points

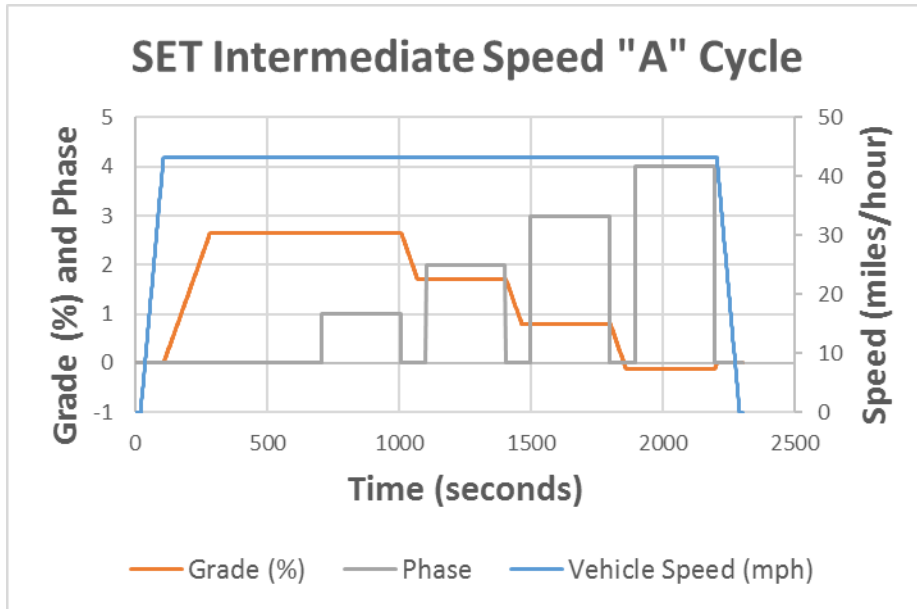


Figure 5: SET Intermediate Speed “A” Cycle speed, grade and phase vs. time

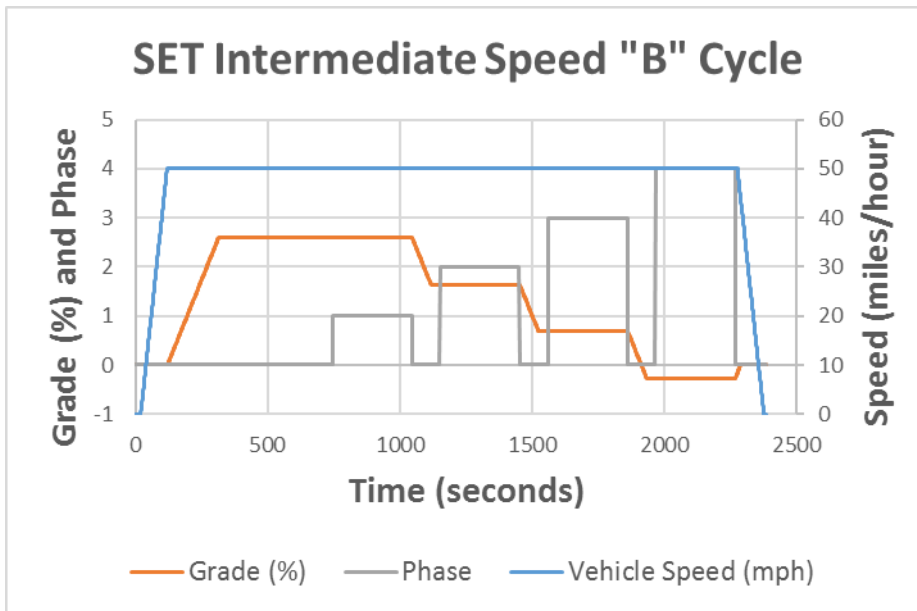


Figure 6: SET Intermediate Speed “B” Cycle speed, grade and phase vs. time

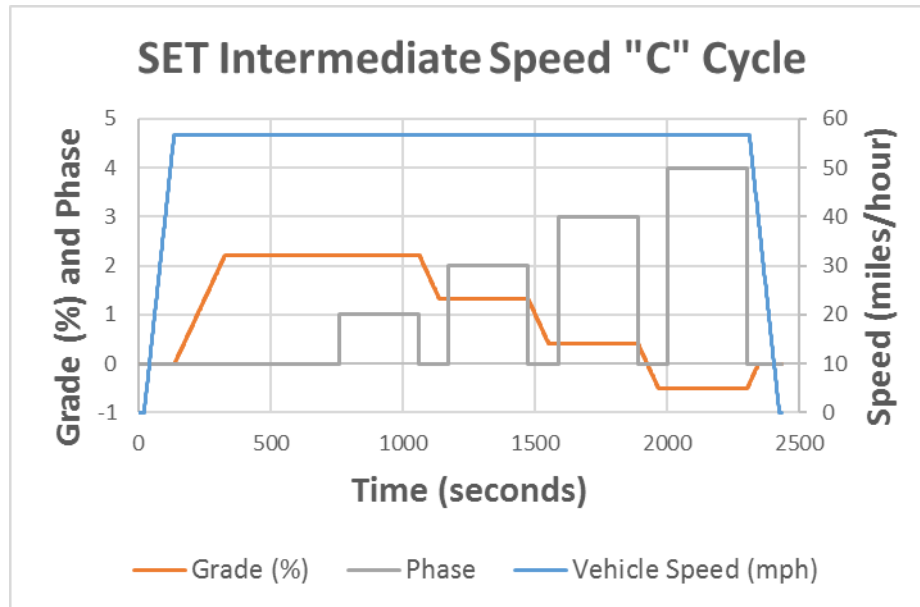


Figure 7: SET Intermediate Speed “C” Cycle speed, grade and phase vs. time

2.5 Vehicle Test Site and Emission Measurements

The chassis dynamometer used for this study is located at the EPA’s National Vehicle & Fuels Emissions Laboratory in Ann Arbor, Michigan. The test site features are shown in Figure 8. Table 4 provides information on the test site equipment. The emissions measured include total hydrocarbons (THC), methane (CH₄), nonmethane hydrocarbon (NMHC), carbon monoxide (CO), oxides of nitrogen (NO_x), and particulate matter (PM as PM₁₀).¹ The emission measurement system for both gaseous and PM based pollutants is based on the Horiba MEXA-ONE platform and is compliant with the requirements in 40 CFR part 1066. The particulate matter weighroom is compliant with 40 CFR 1065.190, including temperature and dewpoint control. The PM weighroom was designed to be compliant as a Class 6 cleanroom or better and meets all of the ambient requirements described in 40 CFR part 1065. The Mettler-Toledo microbalance is compliant with the requirements in 40 CFR 1065.290. The microbalance calibration is NIST traceable as required in 40 CFR part 1065. The weighroom and microbalance provide the ability to accurately measure PM mass gain down to the 1 ug level. The system as a whole can measure PM mass emission rates as low 0.001 g/hp-hr and as high as 2 g/hp-hr.

EPA also utilized an AVL Model 483 MicroSoot Sensor to collect continuous soot data on Glider #2 for a subset of the testing. That data is not presented in this test report.

¹ No attempt was made to measure crankcase emissions from the glider vehicles. However, the distinctive odor of blowby exhaust in the test cell during testing of both glider vehicles (compared to testing other vehicles) indicates that that crankcase emissions could be high.

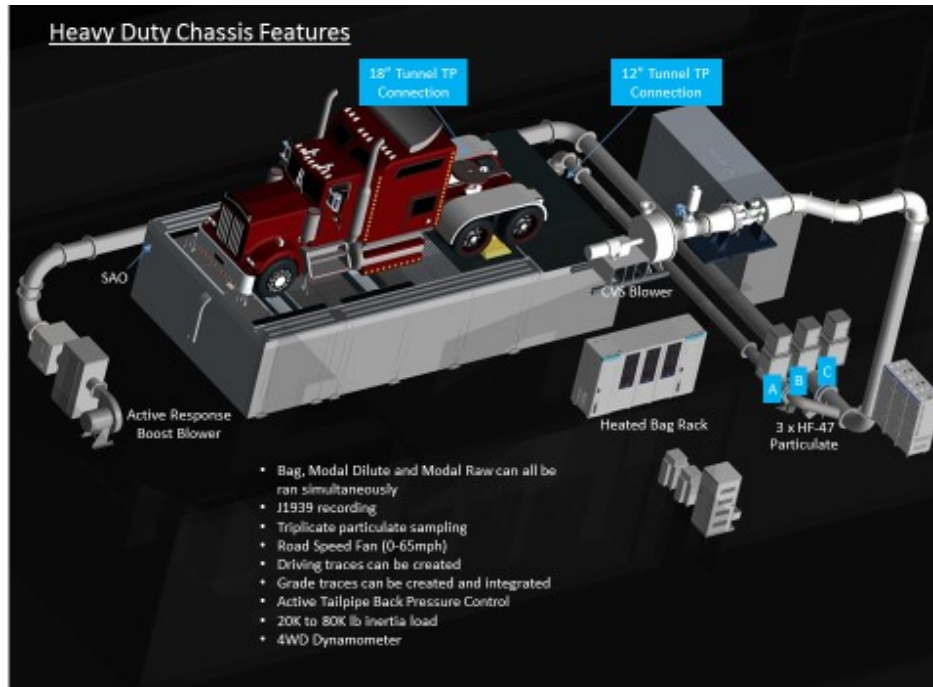


Figure 8: Chassis Dynamometer Overview

Table 4: Test site equipment

Features and Specifications	
4WD Chassis Dynamometer	Type: AIP-ECDM 72H-4WD Operating Speed Range: 0 – 100 mph (0 – 160 km/h) Max Axle Weight of the test vehicle: 44,000 lb (20000 kg) Inertia simulation of up to 80,000 lb (36500 kg)
Fuel	Diesel, Electric, Gasoline & Ethanol Blends
Emissions Sampling	Continuous Gaseous: Raw and Diluted simultaneous Batch: Gaseous Bag
Emission Analyzers	MEXA-ONE platform, Continuous: CO(L), CO(H), CO ₂ , O ₂ , THC, CH ₄ , NO/NO _x Batch: CO(L), CO ₂ (L), THC, CH ₄ , NO/NO _x , N ₂ O
Dilution Tunnel	Heated 12 inch (30.5cm) and 18 inch (45.7cm) diameter tunnel, 4 Critical Flow Venturis allow flow combinations from 19.8 to 116.1 m ³ /min (700 to 4100 scfm). Active tailpipe pressure control
Road Speed Fan	70" x 70" road speed modulated vehicle cooling fan
Particulate	Up to 4 phases sampled in triplicate with secondary dilution available, mass determined with Mettler-Toledo microbalance.
Research Focus	On road heavy-duty and medium-duty vehicles above 20,000 pounds GVWR
CFR scope	40 CFR Part 86 & 1066 define the heavy-duty vehicle test procedures.

There were several verification and maintenance activities conducted in the test site to maintain quality assurance. All analyzer checks were performed according to 40 CFR part 1066 specifications. The activities included, but were not limited to, the following:

- Daily: Cell preparation checks ran included bag leak checks, sample line leak checks and analyzer zero and span checks.
- Weekly: Dynamometer coastdowns at 20,000 lb and 80,000 lb for MAHA 4WD dynamometer, Dynamometer Parasitic Losses Verification, Gravimetric Propane Injection for THC, Sample Analysis Correlations for bag checks on CO, CO₂, CH₄, NO_x emissions.
- Every 35 days: CH₄ Gas Chromatography column efficiency check, NO_x converter check, chemiluminescent detector CO₂ + H₂O Quench Check, and gas analyzer linearity checks per 40 CFR part 1066.
- Typically, annually: Flame ionization detector (FID) O₂ inference check, FID response factor check, nondispersive infrared (NDIR) analyzer interference checks, and emissions sampling unit (ESU) leak check.

3. Emissions Results

3.1 Criteria Pollutants

The average emission results of the individual vehicles tested over the UDDS, WHVC, and Super Cycle are found in the following tables for NO_x, NMHC, and CO. The other gaseous emissions such as THC, CH₄, and CO₂ are found in Appendices A, B and C.

The UDDS cycle began with a cold start. The testing sequence included an initial cold start UDDS, then a 20-minute soak followed by another UDDS, a 20-minute soak and UDDS followed by 45 minutes of idle. The emission results for testing at 60,000 pounds and 80,000 pounds for both glider vehicles are shown in Table 5. Glider #1, a 2016 MY Peterbilt 389 sleeper cab tractor, values only include the results from the tests after the check engine light issue was fixed. The results represent an average emissions of the tests performed for a given vehicle and configuration. See Appendix A for additional emissions results, including the results from the individual tests and the results from Glider #1 with the check engine light on.

Table 5: UDDS Results from the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2

UDDS		NO _x			Non-Methane Hydrocarbons (NMHC)			Carbon Monoxide (CO)		
Vehicle Test Weight (lbs)	Vehicle	Cold UDDS (g/mi)	Inter. UDDS (g/mi)	Hot UDDS (g/mi)	Cold UDDS (g/mi)	Inter. UDDS (g/mi)	Hot UDDS (g/mi)	Cold UDDS (g/mi)	Inter. UDDS (g/mi)	Hot UDDS (g/mi)
60,000	Glider #1	27.80	20.24	20.02	0.427	0.437	0.454	13.59	10.91	10.76
	Glider #2	32.42	25.01	23.55	0.613	0.388	0.397	12.32	11.16	10.85
80,000	Glider #1	36.18	27.66	27.04	0.426	0.429	0.436	17.50	15.78	14.86
	Glider #2	40.26	33.50	32.01	0.241	0.063	0.073	15.47	15.13	15.16

For the WHVC, the first cycle was a warmup and emissions were not measured. The average results for the hot start cycle are shown in Table 6. See Appendix B for additional emission results.

Table 6: WHVC Results from the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2

World Harmonized Vehicle Cycle		NO _x	NMHC	CO
Vehicle Test Weight (lbs)	Vehicle	WHVC (g/mi)	WHVC (g/mi)	WHVC (g/mi)
60,000	Glider #1	16.81	0.386	9.24
	Glider #2	20.15	0.290	8.96
80,000	Glider #1	23.43	0.343	13.92
	Glider #2	26.73	0.308	11.86

The Super Cycle provided information across more driving conditions as it contains five ARB Heavy Duty Transient Cycles (HHDDT), a ten-minute idle period followed by 55 mph and 65 mph cruise periods with 0.5 mph/sec acceleration and deceleration rates. The results are shown in Table 7 for 60,000 lb and 80,000 lb loads respectively for both glider vehicles. See Appendix C for additional emission results.

Table 7: Super Cycle Results from the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2

Super Cycle		NO _x			Non-Methane Hydrocarbons (NMHC)			Carbon Monoxide (CO)		
Vehicle Test Weight (lbs)	Vehicle	ARB Transient 1 (g/mi)	ARB Transient 2 (g/mi)	55/65 Cruise (g/mi)	ARB Transient 1 (g/mi)	ARB Transient 2 (g/mi)	55/65 Cruise (g/mi)	ARB Transient 1 (g/mi)	ARB Transient 2 (g/mi)	55/65 Cruise (g/mi)
60,000	Glider #1	22.26	22.28	13.55	0.705	0.759	0.209	16.68	16.25	1.55
	Glider #2	24.94	24.92	16.64	0.603	0.620	0.157	15.61	15.48	1.41
80,000	Glider #1	29.14	28.68	25.22	0.715	0.710	0.202	21.79	21.10	2.64
	Glider #2	32.57	32.69	28.62	0.563	0.607	0.180	18.07	18.57	2.42

3.2 Particulate Matter (PM)

Particulate matter emissions were measured in triplicate to provide replicate samples for analysis. The glider vehicles emitted significantly more particulate matter than the typical heavy-duty diesel vehicles tested in the laboratory. Therefore, using our typical dilution rates and filter face velocity settings, the filters were overloaded with particulate matter during our initial testing with Glider #1. This caused a PM equipment alarm during phase 2 of the Super Cycle and therefore phases 3 and 4 were not sampled. A picture of the filters is show in Figure 9. Several iterations were performed with different filter face velocity and dilution ratio settings to address

the issue. In the end, the filter face velocity was decreased from 100 cm/s to 65 cm/s and a secondary dilution flow was added at 4:1.



Figure 9: PM Filters from Glider #1 testing over the Super Cycle Test²

The PM results for each of the test cycles at both test weights for both glider vehicles are shown in Table 8 through Table 10. Each value in the tables reflects the average of all tests for a given vehicle and configuration. The values for Glider #1 only include the emission values for the tests with the check engine light issue fixed. See Appendix A, B, and C for the results from the individual tests, including the Glider #1 tests before the check engine light issue was resolved.

Table 8: UDDS PM Emissions from the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2

UDDS		Particulate Matter		
Vehicle Test Weight (lbs)	Vehicle	Cold UDDS (mg/mi)	Inter. UDDS (mg/mi)	Hot UDDS (mg/mi)
60,000	Glider #1	500	567	602
	Glider #2	349	371	370
80,000	Glider #1	742	778	737
	Glider #2	451	445	434

² A1: Phase 1, hot start ARB Transient cycle; A2: Phase 2, four hot running ARB Transient cycles; A3: 10 minutes of measured idle; A4: 55/65 mph cruise. The PM sampling equipment shut down at phase 2 so filters A3 and A4 were not collecting PM.

Table 9: WHVC PM Emissions from the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2

World Harmonized Vehicle Cycle		Particulate Matter
Vehicle Test Weight (lbs)	Vehicle	WHVC (mg/mi)
60,000	Glider #1	560
	Glider #2	349
80,000	Glider #1	745
	Glider #2	426

Table 10: Super Cycle PM Emissions from the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2

Super Cycle		Particulate Matter		
Vehicle Test Weight (lbs)	Vehicle	ARB Transient 1 (mg/mi)	ARB Transient 2 (mg/mi)	55/65 Cruise (mg/mi)
60,000	Glider #1	1028	997	177
	Glider #2	653	677	78
80,000	Glider #1	1340	1288	169
	Glider #2	701	705	90

3.3 Conversion of Distance Specific Emissions to Engine Work Specific Emissions

NO_x, PM, CO, and HC emissions from highway heavy-duty diesel vehicles are controlled through EPA emission standards based on engine dynamometer testing using engine test cycles. There are various ways to estimate engine work from vehicle testing. The most common is to use engine reported speed and torque to calculate power. This methodology works well for modern engines where the engine’s reference torque is known. Since the reference torque was not known for this engine, the engine work was estimated by using the chassis dynamometer target coefficients and the simulated vehicle mass, along with estimates for driveline efficiency.

To calculate the axle power, a modified version of Equation 1 in 40 CFR 1066.210 was used as shown in Equation A below.³ This equation was modified in two ways. The first was multiplying the equation by vehicle speed to calculate power instead of force. The second

³ See https://ecfr.io/Title-40/se40.37.1066_1210 for the description of the equation and units.

modification was removing the road grade terms from the equation since none of the cycles tested included road grade.

$$P_{\text{wheel},i} = \left(A + B \cdot v_i + C \cdot v_i^2 + M_e \cdot \frac{v_i - v_{i-1}}{t_i - t_{i-1}} \right) \cdot v_i, \text{ Eq. A}$$

Equation B was used to calculate engine power from wheel power. For this equation the axle and transmission efficiencies were estimated to be 94 percent. These values were based on the 2018 baseline data from the Heavy-Duty Greenhouse Gas and Fuel Efficiency Standards - Phase 2 rule.

$$P_{\text{engine},i} = \frac{P_{\text{wheel},i}}{0.94^2}, \text{ Eq. B}$$

All of the points where engine power was below zero were set to zero before the power was integrated to calculate work. This was done to be consistent with how work specific emissions are calculated in 40 CFR part 1065. Finally, all the tests and phases where the vehicle, configuration, and vehicle speed trace were the same, were averaged together. This was done because the only source of variation for this analysis is the slight changes in driven vehicle speed from test to test. The coefficient of variation was typically below 2 percent for the tests, which is below other sources of error that could influence this analysis to calculate engine work from chassis dynamometer tests. Table 11 contains a summary of the conversion rates for the glider vehicles.

Table 11: Summary of vehicle miles per engine horsepower-hour

Glider Vehicle	Test Weight (pounds)	WHVC Phase 1	HD UDDS Phase 1, 2 and 3	Super Cycle Phase 1 and 2	Super Cycle Phase 4
miles / (hp-hr)					
#1	60,000	0.321	0.293	0.271	0.362
#1	80,000	0.224	0.201	0.189	0.228
#2	60,000	0.320	0.286	0.266	0.362
#2	80,000	0.219	0.198	0.188	0.229

This analysis estimates the engine work from chassis dynamometer testing and does not take into account a number of additional sources of load on the engine. Two of these sources are the engine accessory load and the additional power from when the engine is idling at a higher speed during warm-up.

3.4 Simulated HD Federal Test Procedure and Supplemental Emission Test Results

The on-highway heavy-duty engine emission standards are in grams per horsepower-hour based on engine test cycles. The current exhaust emissions standards for heavy-duty engines are 0.2 g/hp-hr for NO_x, 0.01 g/hp-hr for PM, 15.5 g/hp-hr for CO, and 0.14 g/hp-hr for NMHC.⁴ The emission standards are evaluated over a transient cycle, the Heavy-Duty Federal Test Procedure (HD Engine FTP) cycle, and a steady-state cycle.

To conduct a rough comparison of the emissions over a transient cycle to the engine emissions standards, we calculated the estimated NO_x, PM, CO, and NMHC emissions in grams per horsepower-hour using the conversion rates shown in Table 11. The comparison was limited to the chassis test results from the UDDS cycle because this is the vehicle cycle that was used originally to create the HD Engine FTP cycle. As shown in Table 12 and Table 13, the estimated NO_x and PM emissions results are significantly higher than the model year 2010 and later on-highway heavy-duty diesel emission standards, and are more typical of the emission results expected from an on-highway heavy-duty diesel engine built between model years 1998 and 2002.

Table 12: Estimated Grams of NO_x and NMHC per Horsepower-Hour Results over the UDDS Cycle for 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2

UDDS		NO _x			Non-Methane Hydrocarbons (NMHC)		
Vehicle Test Weight (lbs)	Vehicle	Cold UDDS (g/hp-hr)	Inter. UDDS (g/hp-hr)	Hot UDDS (g/hp-hr)	Cold UDDS (g/hp-hr)	Inter. UDDS (g/hp-hr)	Hot UDDS (g/hp-hr)
60,000	Glider #1	8.15	5.93	5.87	0.125	0.128	0.133
	Glider #2	9.27	7.15	6.74	0.175	0.111	0.114
80,000	Glider #1	7.27	5.56	5.44	0.086	0.086	0.088
	Glider #2	7.97	6.63	6.34	0.048	0.013	0.015

⁴ See 40 CFR 86.007-11 for emission standards and supplemental requirements for 2007 and later model year diesel heavy-duty engines and vehicles.

Table 13: Estimated Grams of CO and PM per Horsepower-Hour Results over the UDDS Cycle for 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2

UDDS		Carbon Monoxide (CO)			Particulate Matter		
Vehicle Test Weight (lbs)	Vehicle	Cold UDDS (g/hp-hr)	Inter. UDDS (g/hp-hr)	Hot UDDS (g/hp-hr)	Cold UDDS (g/hp-hr)	Inter. UDDS (g/hp-hr)	Hot UDDS (g/hp-hr)
60,000	Glider #1	3.98	3.20	3.15	0.146	0.166	0.176
	Glider #2	3.52	3.19	3.10	0.100	0.106	0.106
80,000	Glider #1	3.52	3.17	2.99	0.217	0.228	0.216
	Glider #2	3.06	3.00	3.00	0.089	0.088	0.086

Chassis testing of Glider #2 was also conducted to simulate the engine-based steady state cycle, the Supplemental Emission Test (SET), as discussed in Section 2.4. The simulation was conducted by running a series of steady-state cycles with varying grade using the mass and road load coefficients of the 80,000 pound vehicle. The engine power for each SET test point was determined using the method defined in Section 3.3 and the corresponding speed and torque values are shown in Table 14.

Table 14: Engine Speed and Torque at SET Test Points

Test Point	Engine Speed (rpm)	Engine Torque (Nm)
A100	1262	2302
A75	1262	1783
A50	1263	1251
A25	1262	716
B100	1440	2371
B75	1440	1831
B50	1440	1289
B25	1440	732
C100	1610	2255
C75	1648	1764
C50	1648	1249
C25	1648	722
Idle	600	0

The overall emission test results from the SET are shown in Table 15. For the “idle” test point of the SET, the idle results from the 3rd phase of the Super Cycle were used. The NO_x emissions are consistent with the results of the UDDS but the CO and PM emissions are measurably lower. This is not surprising since the transient CO and PM emissions are likely a result of poor air fuel ratio control and mixing during transient operation when compared to the steady-state operation that the SET captures.

Table 15: Glider #2 Simulated SET Results

Test Point	THC (g/hp-hr)	CO (g/hp-hr)	NOx (g/hp-hr)	N2O (g/hp-hr)	CH4 (g/hp-hr)	NMHC (g/hp-hr)	PM (g/hp-hr)
A100	0.0382	1.3560	6.817	0.00166	0	0.0399	0.028
A75	0.0343	0.8307	6.540	0.00177	0.00030	0.0355	0.016
A50	0.0320	0.5130	6.369	0.00205	0	0.0338	0.017
A25	0.0578	0.3805	6.001	0.00285	0	0.0607	0.019
B100	0.0375	0.7036	6.996	0.00180	0	0.0395	0.027
B75	0.0359	0.4510	7.379	0.00193	0.0002	0.0380	0.017
B50	0.0333	0.3316	6.880	0.00215	0	0.0351	0.015
B25	0.0569	0.3850	5.733	0.00296	0	0.0599	0.024
C100	0.0361	0.3926	6.020	0.00211	0	0.0385	0.040
C75	0.0394	0.2950	7.236	0.00226	0	0.0420	0.028
C50	0.0405	0.2648	6.594	0.00254	0	0.0427	0.024
C25	0.0635	0.3939	5.997	0.00340	0	0.0666	0.031
Idle*	5.002	23.72	113.5	0.0690	0.018	5.0127	0.175
Weighted 40 CFR 86.1362	0.0446	0.6182	6.73	0.00219	7.53E-05	0.0467	0.025
*Idle emissions are in (grams/hr)							

4. Comparison to other HD Vehicle Emission Performance

The emission results from the glider vehicles were compared to two other recent model year tractors. The vehicle specifics of these two other tractors are listed below.

- The day cab tractor tested was a 2015 MY International Day Cab with over 10,000 miles. The vehicle contained a 2015 MY Cummins ISX 600 HP engine, an Eaton 13 speed automated manual transmission, and a 3.55 rear axle ratio.
- The sleeper cab tractor tested was a 2014 MY Freightliner Cascadia with 362,652 miles. The vehicle contained a 2014 MY Detroit Diesel DD-15 505 HP engine, an Eaton 10 speed manual transmission, and a 3.55 rear axle ratio.

A principle difference between these vehicles and the 2016 MY Peterbilt 389 and 2017 MY Peterbilt 579 glider vehicles are the engines. The glider vehicles use a rebuilt engine that was originally manufactured in the 1998-2002 timeframe, while the two comparison vehicles have engines certified to the 2014 MY and 2015 MY EPA emissions standards and utilize cooled exhaust gas recirculation (EGR), diesel particulate filters, and selective catalytic reduction (SCR) systems.

All of the tractors were tested in the same HD chassis dynamometer cell as the glider vehicles. The target road load coefficients for the International day cab matched the glider vehicles when tested at 60,000 pounds. The target road loads of the Freightliner sleeper cab matched the glider vehicles when tested at 80,000 pounds. This means that the comparisons reflect differences observed for the drivetrain (engine, transmission, and axle) of the vehicles, but do not account for differences associated with the vehicles' aerodynamics or tire performance. The road load coefficients for both of these vehicles are show in Table 16.

Table 16: Road Load Coefficients

Configuration	Target Coefficients			Set Coefficients		
	A (lbf)	B (lbf/mph)	C (lbf/mph ²)	A (lbf)	B (lbf/mph)	C (lbf/mph ²)
2015 MY International Day Cab, 60k Test Weight	345.090	0.0000	0.15380	75.100	-0.7408	0.143200
2014 MY Freightliner Sleeper Cab, 80k Test Weight	446.350	7.76060	0.14780	294.170	6.0668	0.139900

As shown in the following figures, we compared the emission rates from the gliders to that of the comparable tractor configuration. The glider results in the figures represent the average of all of the tests for a given vehicle configuration, excluding the tests with the MIL on for Glider #1.⁵ Figure 10 through Figure 13 compare the 2016 MY and 2017 MY Peterbilt Gliders at 60,000 pound test weight to the 2015 MY International Day Cab at the same test weight and road load coefficients over the Super Cycle. Figure 14 through Figure 17 show the emission rate differences between the 2016 MY and 2017 MY Peterbilt Gliders at 80,000 pound test weight to the 2014 MY Freightliner Sleeper Cab at the same test weight and road load coefficients over the ARB Transient Cycle.

The NO_x, CO, THC, and PM emissions from the glider vehicles were significantly higher than the newer model year tractors over all cycles.

⁵ See Appendix A, B, and C for the emission rates before and after the repair.

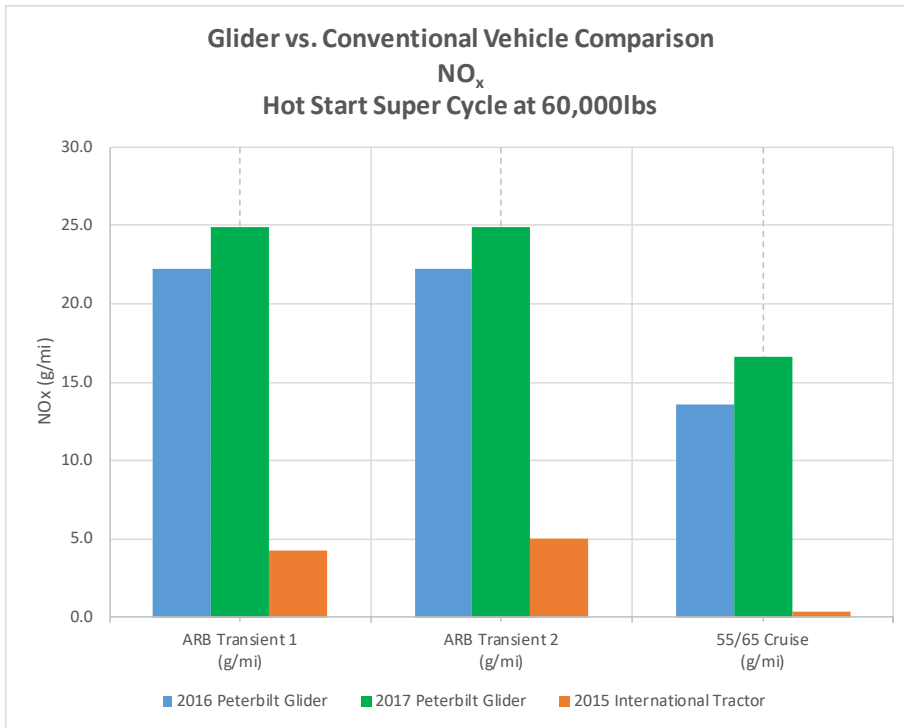


Figure 10: NO_x Emissions Comparison of 2015 MY Day Cab to the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2 over the Super Cycle

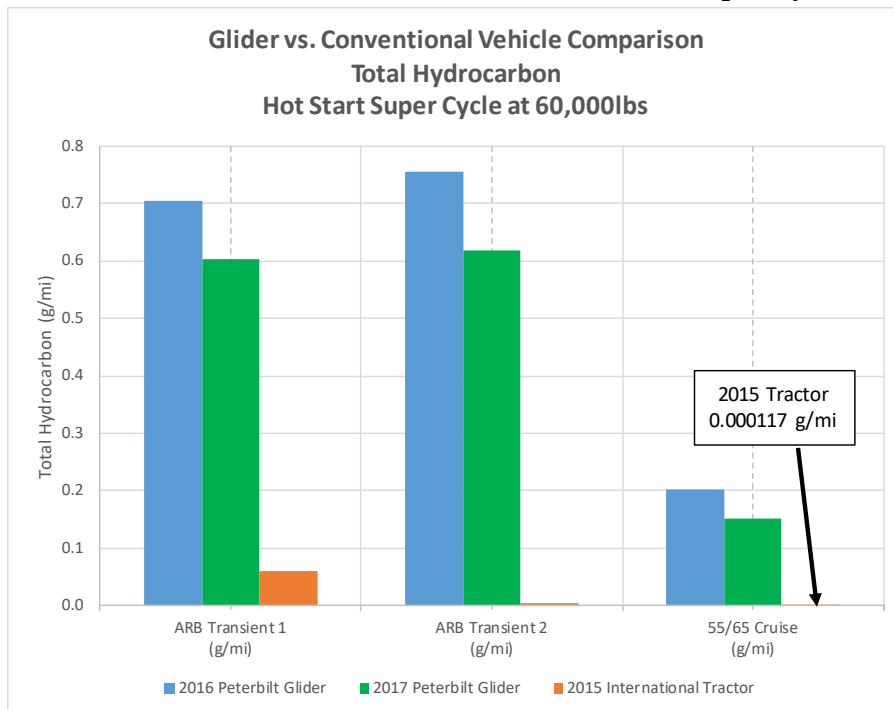


Figure 11: THC Emissions Comparison of 2015 MY International Tractor to the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2 over the Super Cycle

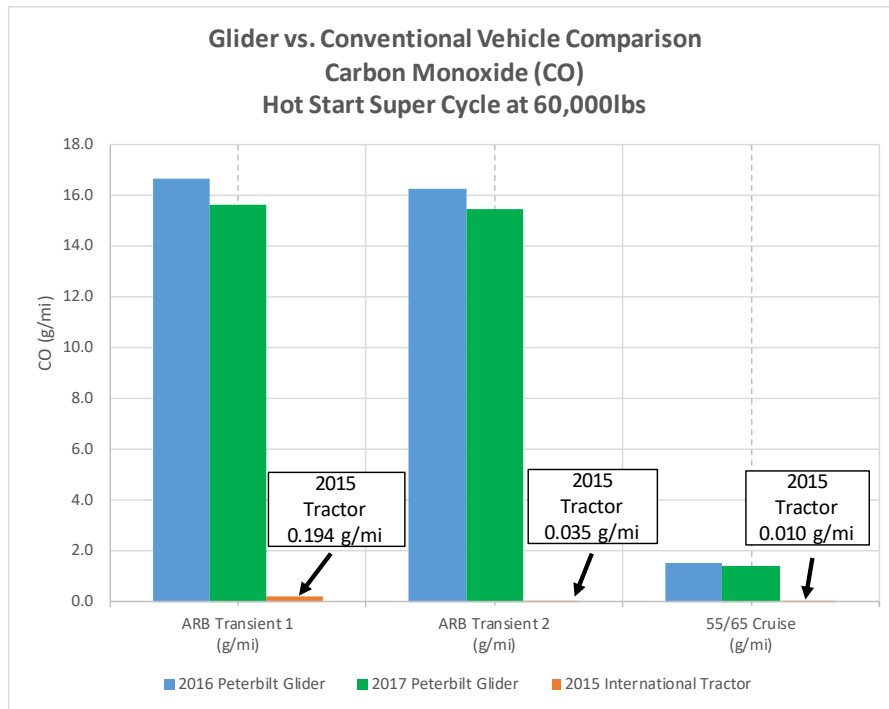


Figure 12: CO Emissions Comparison of 2015 MY Day Cab to the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2 over the Super Cycle

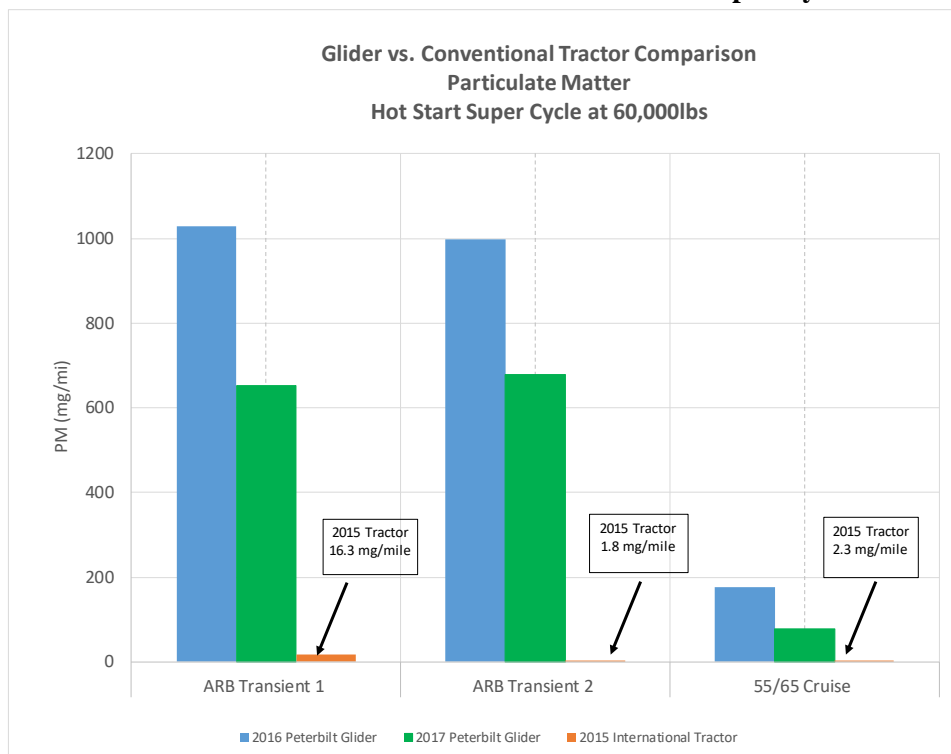


Figure 13: PM Emissions Comparison of 2015 MY Day Cab to the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2 over the Super Cycle

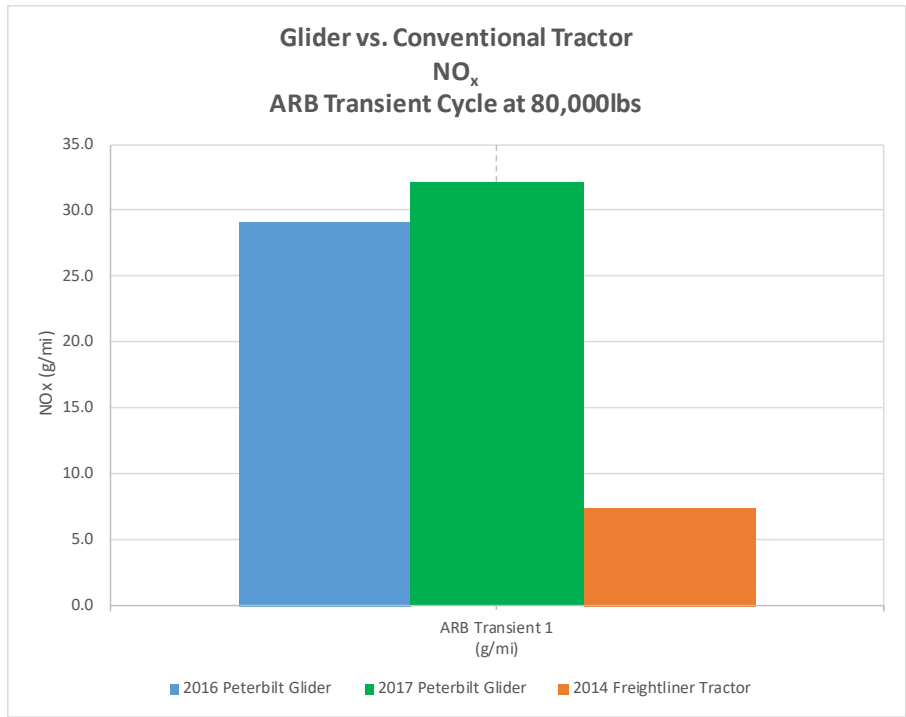


Figure 14: NOx Emissions Comparison of 2014 MY Freightliner to the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2 over the ARB Transient Cycle

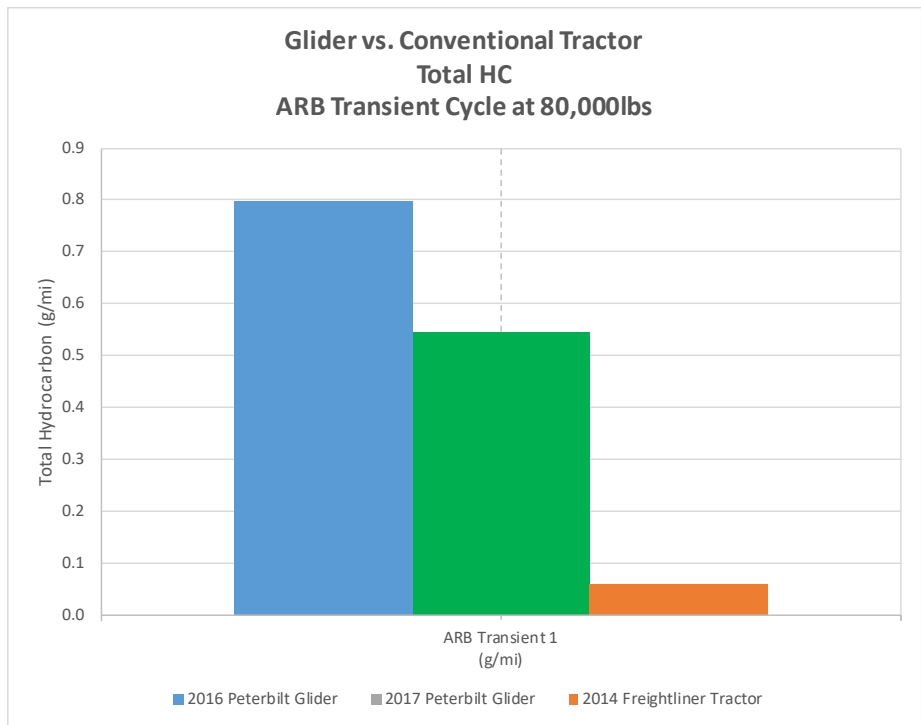


Figure 15: HC Emissions Comparison of 2014 MY Freightliner to the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2 over the ARB Transient Cycle

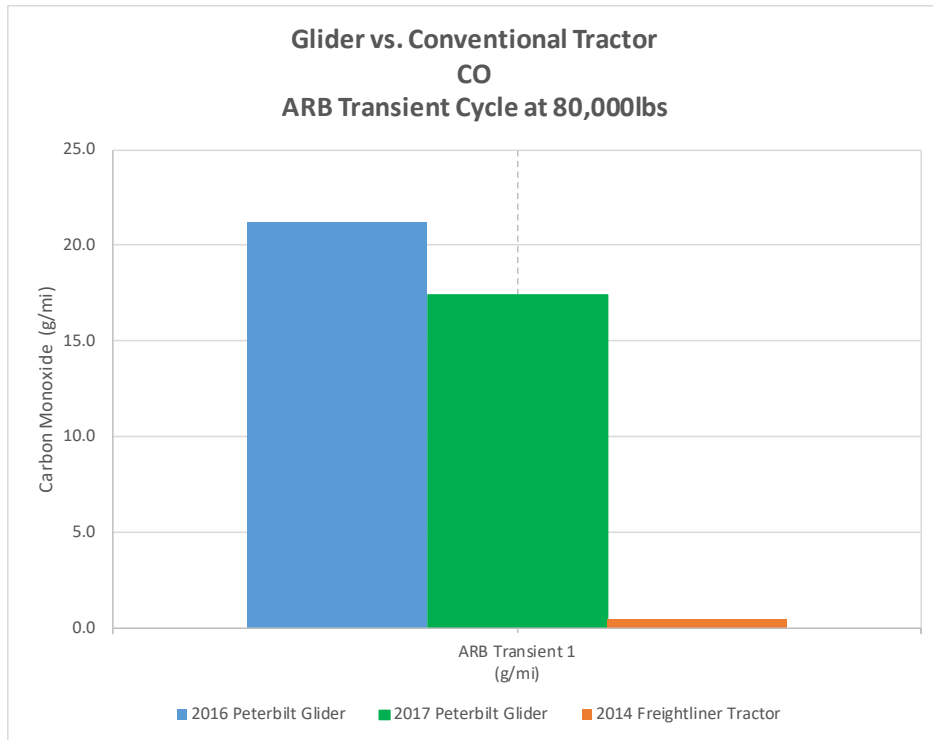


Figure 16: CO Emissions Comparison of 2014 MY Freightliner to the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2 over the ARB Transient Cycle

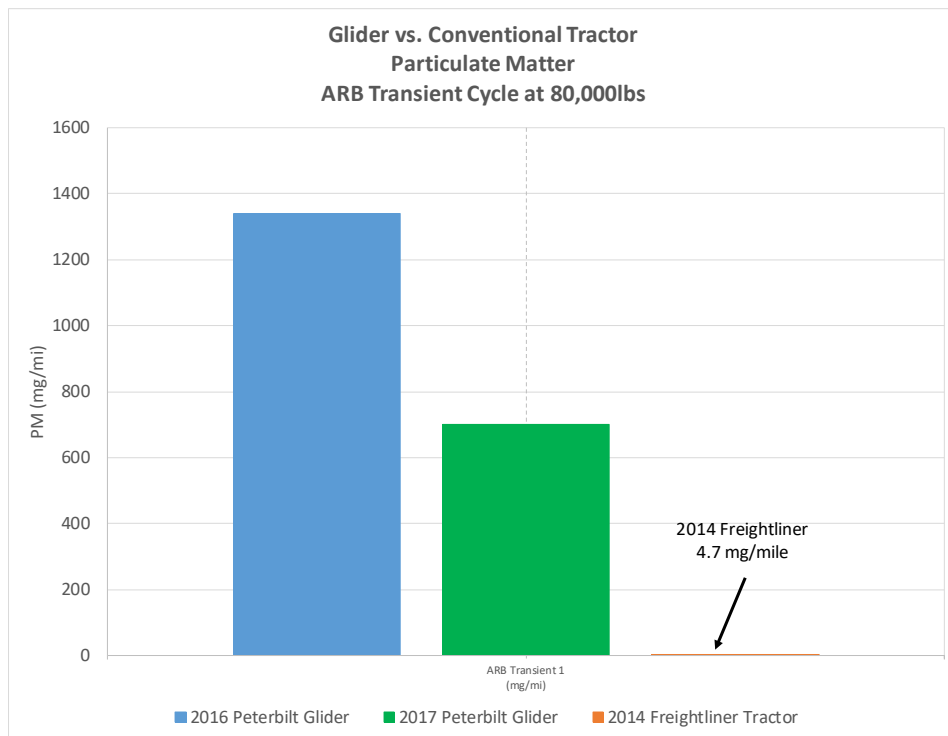


Figure 17: PM Emissions Comparison of 2014 MY Freightliner to the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2 over the ARB Transient Cycle

We also compared the CO₂ emissions of the Peterbilt 389 and Peterbilt 579 glider vehicles to the International and Freightliner conventional tractors. CO₂ emissions are directly proportional to the road load of the vehicle. Because we did not measure the actual road load of the vehicles, we used the same target road load coefficients in the two sets of comparisons (at 60,000 and 80,000 pounds). Therefore, this comparison only evaluates the performance of the powertrain and may not be representative of the difference in CO₂ emission that these vehicles would experience in-use. Figure 18 and Figure 19 show comparisons of the powertrain performance. In all cases, the CO₂ emissions were lower in the glider powertrains. This is not unexpected given the known trade-off between NO_x and CO₂ emissions with respect to injection timing and similar engine calibration techniques and the relatively higher NO_x emissions for the 2016 MY Peterbilt 389 and 2017 MY Peterbilt 579 glider vehicles shown in the previous tables and figures.

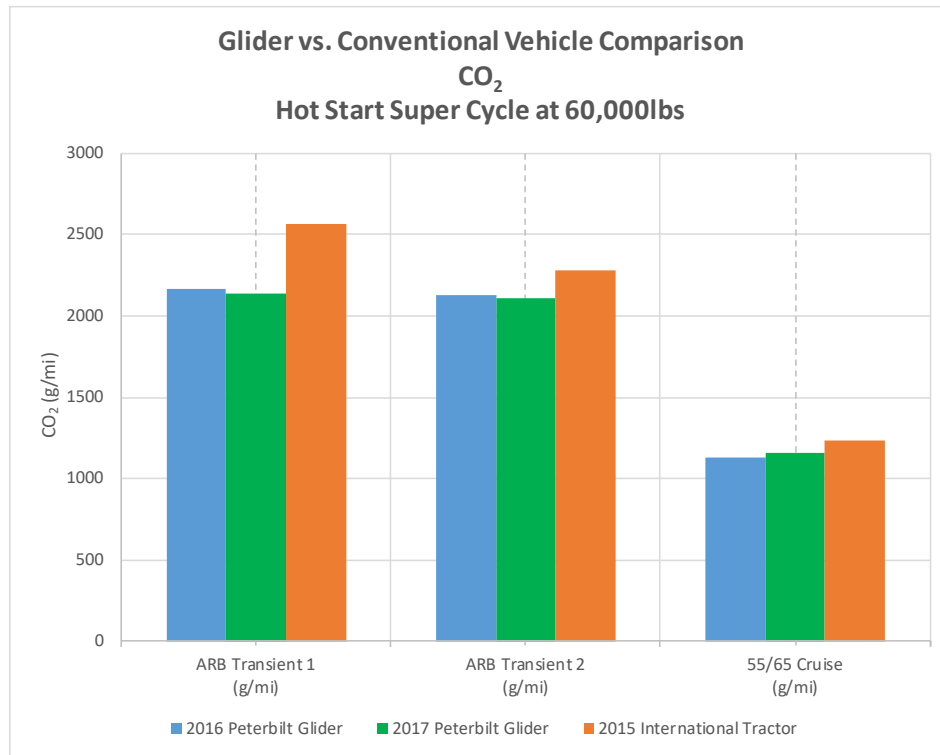


Figure 18: CO₂ Emissions Comparison of 2015 MY International to the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2 over the Super Cycle

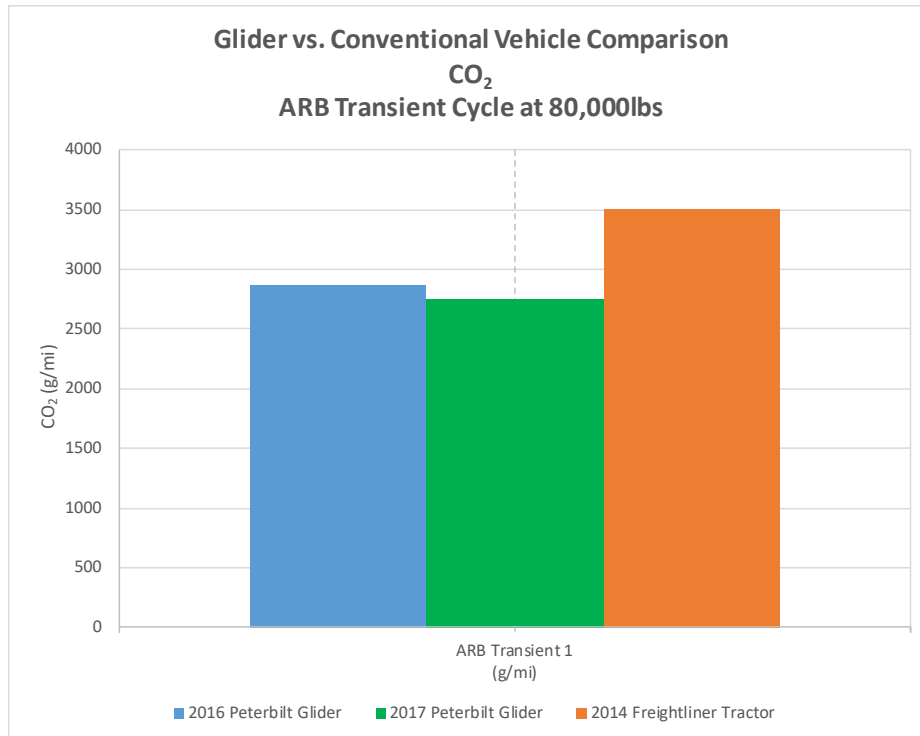


Figure 19: CO₂ Emissions Comparison of 2014 MY Freightliner to the 2016 MY Peterbilt 389 Glider #1 and 2017 MY Peterbilt 579 Glider #2 over the ARB Transient Cycle

5. Appendix A
HD UDDS Results for the Glider Vehicles

Glider #1 2016 MY Peterbilt 389

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	Total HC			NMHC		
				Glider #1 Cold UDDS (g/mi)	Glider #1 Inter. UDDS (g/mi)	Glider #1 Hot UDDS (g/mi)	Glider #1 Cold UDDS (g/mi)	Glider #1 Inter. UDDS (g/mi)	Glider #1 Hot UDDS (g/mi)
Cold Start UDDS	Glider #1 60,000 lb Test Wt.	1	10/6	0.630	0.664	0.487	0.561	0.606	0.491
		2	10/10	0.551	0.608	0.501	0.476	0.590	0.508
		3*	10/16	0.402	0.417	0.415	0.407	0.422	0.421
		4*	10/17	0.443	0.447	0.481	0.447	0.452	0.488
Cold Start UDDS	Glider #1 80,000 lb Test Wt.	1	10/12	0.569	0.527	0.427	0.545	0.509	0.435
		2	10/13	0.399	0.411	0.379	0.407	0.421	0.389
		3*	10/18	0.437	0.431	0.414	0.445	0.439	0.424
		4*	10/19	0.400	0.413	0.438	0.407	0.420	0.448
* Check Engine Light issue resolved prior to this test									

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	CH ₄			CO		
				Glider #1 Cold UDDS (g/mi)	Glider #1 Inter. UDDS (g/mi)	Glider #1 Hot UDDS (g/mi)	Glider #1 Cold UDDS (g/mi)	Glider #1 Inter. UDDS (g/mi)	Glider #1 Hot UDDS (g/mi)
Cold Start UDDS	Glider #1 60,000 lb Test Wt.	1	10/6	0.051	0.045	0.001	36.4	28.5	16.2
		2	10/10	0.050	0.022	0.000	36.0	23.8	14.2
		3*	10/16	0.000	0.000	0.000	13.9	11.1	10.3
		4*	10/17	0.000	0.000	0.000	13.3	10.7	11.2
Cold Start UDDS	Glider #1 80,000 lb Test Wt.	1	10/12	0.034	0.028	0.000	31.1	30.6	16.7
		2	10/13	0.002	0.000	0.000	19.7	16.1	17.4
		3*	10/18	0.000	0.000	0.000	16.1	15.2	15.4
		4*	10/19	0.000	0.000	0.000	18.9	16.3	14.4
* Check Engine Light issue resolved prior to this test									

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	NO _x			N ₂ O		
				Glider #1 Cold UDDS (g/mi)	Glider #1 Inter. UDDS (g/mi)	Glider #1 Hot UDDS (g/mi)	Glider #1 Cold UDDS (g/mi)	Glider #1 Inter. UDDS (g/mi)	Glider #1 Hot UDDS (g/mi)
Cold Start UDDS	Glider #1 60,000 lb Test Wt.	1	10/6	33.4	31.6	24.2	0.016	0.014	0.014
		2	10/10	32.3	31.5	20.6	0.016	0.014	0.013
		3*	10/16	28.4	20.0	20.3	0.019	0.017	0.014
		4*	10/17	27.2	20.5	19.8	0.018	0.016	0.015
Cold Start UDDS	Glider #1 80,000 lb Test Wt.	1	10/12	42.5	35.1	28.1	0.020	0.021	0.018
		2	10/13	36.5	28.3	28.2	0.017	0.016	0.015
		3*	10/18	36.2	27.7	27.2	0.020	0.017	0.017
		4*	10/19	36.2	27.7	26.9	0.019	0.017	0.016
* Check Engine Light issue resolved prior to this test									
Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	CO ₂			Fuel Economy		
				Glider #1 Cold UDDS (g/mi)	Glider #1 Inter. UDDS (g/mi)	Glider #1 Hot UDDS (g/mi)	Glider #1 Cold UDDS (mpg)	Glider #1 Inter. UDDS (mpg)	Glider #1 Hot UDDS (mpg)
Cold Start UDDS	Glider #1 60,000 lb Test Wt.	1	10/6	2002	1838	1807	4.94	5.40	5.55
		2	10/10	2066	1881	1854	4.79	5.30	5.42
		3*	10/16	1990	1818	1779	5.05	5.54	5.67
		4*	10/17	1991	1804	1816	5.05	5.58	5.54
Cold Start UDDS	Glider #1 80,000 lb Test Wt.	1	10/12	2595	2493	2447	3.85	4.00	4.11
		2	10/13	2664	2425	2413	3.77	4.15	4.17
		3*	10/18	2602	2465	2449	3.87	4.09	4.11
		4*	10/19	2677	2478	2432	3.76	4.06	4.14
* Check Engine Light issue resolved prior to this test									

Glider #2 2017 MY Peterbilt 579

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	Total HC			NMHC		
				Glider #2 Cold UDDS (g/mi)	Glider #2 Inter. UDDS (g/mi)	Glider #2 Hot UDDS (g/mi)	Glider #2 Cold UDDS (g/mi)	Glider #2 Inter. UDDS (g/mi)	Glider #2 Hot UDDS (g/mi)
Cold Start UDDS	Glider #2 60,000 lb Test	1	11/3	0.603	0.363	0.377	0.605	0.370	0.384
		2	11/6	0.621	0.401	0.405	0.621	0.406	0.411
Cold Start UDDS	Glider #2 80,000 lb Test	1	11/7	0.236	0.056	0.064	0.241	0.063	0.073

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	CH ₄			CO		
				Glider #2 Cold UDDS (g/mi)	Glider #2 Inter. UDDS (g/mi)	Glider #2 Hot UDDS (g/mi)	Glider #2 Cold UDDS (g/mi)	Glider #2 Inter. UDDS (g/mi)	Glider #2 Hot UDDS (g/mi)
Cold Start UDDS	Glider #2 60,000 lb Test	1	11/3	0.004	0.000	0.000	11.4	11.1	9.4
		2	11/6	0.005	0.000	0.000	13.2	11.2	12.3
Cold Start UDDS	Glider #2 80,000 lb Test	1	11/7	0.006	0.000	0.000	15.5	15.1	15.2

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	NO _x			N ₂ O		
				Glider #2 Cold UDDS (g/mi)	Glider #2 Inter. UDDS (g/mi)	Glider #2 Hot UDDS (g/mi)	Glider #2 Cold UDDS (g/mi)	Glider #2 Inter. UDDS (g/mi)	Glider #2 Hot UDDS (g/mi)
Cold Start UDDS	Glider #2 60,000 lb Test	1	11/3	32.8	25.3	23.5	0.018	0.022	0.013
		2	11/6	32.0	24.7	23.6	0.014	0.010	0.010
Cold Start UDDS	Glider #2 80,000 lb Test	1	11/7	40.3	33.5	32.0	0.013	0.010	0.010

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	CO ₂			Fuel Economy		
				Glider #2 Cold UDDS (g/mi)	Glider #2 Inter. UDDS (g/mi)	Glider #2 Hot UDDS (g/mi)	Glider #2 Cold UDDS (mpg)	Glider #2 Inter. UDDS (mpg)	Glider #2 Hot UDDS (mpg)
Cold Start UDDS	Glider #2 60,000 lb Test	1	11/3	1962	1868	1801	5.13	5.39	5.60
		2	11/6	2035	1855	1856	4.95	5.43	5.42
Cold Start UDDS	Glider #2 80,000 lb Test	1	11/7	2640	2493	2460	3.82	4.04	4.10

PM Results

The values in the table represent an average of the PM collected on three filters. The PM emission data was not collected for all tests due to power issues in the laboratory during the time of testing which affected the PM sampler. Those tests for which the PM sample system was not operating are indicated with a “N/A”.

Test Type	Vehicle Test Weight (lbs)	Test Number	Date	PM		
				Cold UDDS (mg/mi)	Inter. UDDS (mg/mi)	Hot UDDS (mg/mi)
Cold Start UDDS	Glider #1 60,000 lb	1	10/6	1472	1491	813
		2	10/10	N/A	N/A	N/A
		3*	10/16	479	580	542
		4*	10/17	521	554	662
	Glider #2 60,000 lb	1	11/3	323	363	310
		2	11/6	375	379	431
		3	11/14	N/A	N/A	N/A
Cold Start UDDS	Glider#1 80,000 lb	1	10/12	1419	1622	916
		2*	10/13	706	706	674
		3*	10/18	N/A	N/A	N/A
		4*	10/19	778	849	800
	Glider #2 80,000 lb	1	11/7	490	473	466
		2	11/8	413	433	402
		3	11/13	450	427	432
* Check Engine Light issue resolved prior to these tests						

6. Appendix B

World Harmonized Vehicle Cycle (WHVC) Results for the Glider Vehicles

Glider #1 2016 MY Peterbilt 389

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	Total HC (g/mi)	NMOG (g/mi)	NMHC (g/mi)	CH4 (g/mi)	CO (g/mi)	Nox (g/mi)	N2O (g/mi)	CO2 (g/mi)	Fuel Economy (mpg)
Hot Start WHVC	Glider #1 60,000 lb Test Wt.	1	10/5	0.431	0.435	0.435	0.000	8.65	17.3	0.0123	1505	6.69
		2	10/6	0.391	0.397	0.397	0.000	10.21	16.9	0.0109	1561	6.45
		3	10/10	0.410	0.397	0.397	0.004	16.82	25.4	0.0099	1506	6.63
		4*	10/16	0.373	0.377	0.377	0.000	8.94	16.8	0.0128	1560	6.46
		5*	10/17	0.392	0.395	0.395	0.000	9.55	16.8	0.0130	1577	6.38
Hot Start WHVC	Glider #1 80,000 lb Test	1	10/11	0.332	0.336	0.336	0.000	13.14	24.2	0.0128	2105	4.78
		2*	10/13	0.347	0.350	0.350	0.000	14.70	22.7	0.0145	2132	4.72

Glider #2 2017 MY Peterbilt 579

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	Total HC (g/mi)	NMOG (g/mi)	NMHC (g/mi)	CH4 (g/mi)	CO (g/mi)	Nox (g/mi)	N2O (g/mi)	CO2 (g/mi)	Fuel Economy (mpg)
Hot Start WHVC	Glider #2 60,000 lb Test	1	11/3	0.285	0.288	0.288	0.000	8.79	20.0	0.0068	1553	6.49
		2	11/6	0.289	0.291	0.291	0.000	9.12	20.2	0.0076	1552	6.49
Hot Start WHVC	Glider #2 80,000 lb Test	1	11/7	0.298	0.300	0.300	0.000	12.85	26.4	0.0082	2157	4.67
		2	11/8	0.313	0.316	0.316	0.000	10.87	27.1	0.0101	2152	4.69

PM Results

The values in the table represent an average of the PM collected on three filters. The PM emission data was not collected for all tests due to power issues in the laboratory during the time of testing which affected the PM sampler. Those tests for which the PM sample system was not operating are indicated with a “N/A”.

Test Type	Vehicle Test Weight (lbs)	Test Number	Date	PM
				WHVC (mg/mi)
Hot Start WHVC	Glider #1 60,000 lb	1	10/5	543
		2	10/6	622
		3	10/10	N/A
		4*	10/16	530
		5*	10/17	591
	Glider #2 60,000 lb	1	11/3	367
		2	11/6	331
Hot Start WHVC	Glider #1 80,000 lb	1	10/11	627
		2*	10/13	745
Hot Start WHVC	Glider #2 80,000 lb	1	11/7	433
		2	11/8	419

* Check Engine Light issue resolved prior to these tests

7. Appendix C
Super Cycle (SC) Results for the Glider Vehicles

Glider #1 2016 MY Peterbilt 389

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	Total HC			NMHC		
				Glider #1 ARB Transient 1 (g/mi)	Glider #1 ARB Transient 2 (g/mi)	Glider #1 55/65 Cruise (g/mi)	Glider #1 ARB Transient 1 (g/mi)	Glider #1 ARB Transient 2 (g/mi)	Glider #1 55/65 Cruise (g/mi)
Hot Start SC	Glider #1 60,000 lb Test Wt.	1	10/5	0.822	0.753	0.207	0.823	0.756	0.214
		2	10/6	0.611	0.723	0.201	0.611	0.726	0.208
		3	10/10	0.794	0.740	0.201	0.765	0.742	0.208
		4*	10/16	0.683	0.753	0.197	0.682	0.757	0.204
		5*	10/17	0.727	0.758	0.207	0.727	0.762	0.214
Hot Start SC	Glider #1 80,000 lb Test Wt.	1	10/11	0.608	0.648	0.168	0.609	0.653	0.178
		2	10/13	0.629	0.701	0.185	0.631	0.707	0.195
		3*	10/18	0.798	0.706	0.199	0.799	0.713	0.209

* Check Engine Light issue resolved prior to this test

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	CH ₄			CO		
				Glider #1 ARB Transient 1 (g/mi)	Glider #1 ARB Transient 2 (g/mi)	Glider #1 55/65 Cruise (g/mi)	Glider #1 ARB Transient 1 (g/mi)	Glider #1 ARB Transient 2 (g/mi)	Glider #1 55/65 Cruise (g/mi)
Hot Start SC	Glider #1 60,000 lb Test Wt.	1	10/5	0.000	0.000	0.000	16.20	18.45	1.69
		2	10/6	0.000	0.000	0.000	20.12	21.34	1.76
		3	10/10	0.022	0.002	0.000	38.94	20.84	1.86
		4*	10/16	0.000	0.000	0.000	16.13	15.01	1.50
		5*	10/17	0.000	0.003	0.000	17.23	17.49	1.61
Hot Start SC	Glider #1 80,000 lb Test Wt.	1	10/11	0.000	0.000	0.000	22.84	24.34	2.99
		2	10/13	0.000	0.000	0.001	22.43	22.15	2.70
		3*	10/18	0.000	0.000	0.002	21.15	20.05	2.58

* Check Engine Light issue resolved prior to this test

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	NO _x			N ₂ O		
				Glider #1 ARB Transient 1 (g/mi)	Glider #1 ARB Transient 2 (g/mi)	Glider #1 55/65 Cruise (g/mi)	Glider #1 ARB Transient 1 (g/mi)	Glider #1 ARB Transient 2 (g/mi)	Glider #1 55/65 Cruise (g/mi)
Hot Start SC	Glider #1 60,000 lb Test Wt.	1	10/5	24.4	23.8	13.3	0.016	0.014	0.005
		2	10/6	23.2	23.3	13.4	0.015	0.016	0.006
		3	10/10	35.5	26.6	13.4	0.020	0.018	0.008
		4*	10/16	22.0	22.4	13.6	0.020	0.020	0.008
		5*	10/17	22.5	22.2	13.5	0.021	0.019	0.008
Hot Start SC	Glider #1 80,000 lb Test Wt.	1	10/11	29.6	30.1	25.3	0.022	0.020	0.009
		2	10/13	29.2	28.8	25.2	0.023	0.023	0.010
		3*	10/18	29.1	28.6	25.2	0.023	0.021	0.010

* Check Engine Light issue resolved prior to this test

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	CO ₂			Fuel Economy		
				Glider #1 ARB Transient 1 (g/mi)	Glider #1 ARB Transient 2 (g/mi)	Glider #1 55/65 Cruise (g/mi)	Glider #1 ARB Transient 1 (g/mi)	Glider #1 ARB Transient 2 (g/mi)	Glider #1 55/65 Cruise (g/mi)
Hot Start SC	Glider #1 60,000 lb Test Wt.	1	10/5	2188	2181	1121	4.59	4.60	9.05
		2	10/6	2158	2172	1141	4.64	4.61	8.90
		3	10/10	2172	2104	1139	4.55	4.76	8.90
		4*	10/16	2138	2110	1132	4.70	4.76	8.97
		5*	10/17	2200	2146	1134	4.57	4.68	8.95
Hot Start SC	Glider #1 80,000 lb Test Wt.	1	10/11	2814	2827	1750	3.57	3.55	5.80
		2	10/13	2843	2817	1757	3.53	3.57	5.77
		3*	10/18	2863	2783	1749	3.51	3.61	5.80
* Check Engine Light issue resolved prior to this test									

Glider #2 2017 MY Peterbilt 579

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	Total HC			NMHC		
				Glider #2 ARB Transient 1 (g/mi)	Glider #2 ARB Transient 2 (g/mi)	Glider #2 55/65 Cruise (g/mi)	Glider #2 ARB Transient 1 (g/mi)	Glider #2 ARB Transient 2 (g/mi)	Glider #2 55/65 Cruise (g/mi)
Hot Start SC	Glider #2 60,000 lb Test	1	11/3	0.611	0.610	0.164	0.611	0.612	0.171
		2	11/6	0.596	0.626	0.137	0.595	0.628	0.143
Hot Start SC	Glider #2 80,000 lb Test	1	11/7	0.544	0.596	0.162	0.547	0.605	0.170
		2	11/8	0.578	0.601	0.180	0.579	0.609	0.189

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	CH ₄			CO		
				Glider #2 ARB Transient 1 (g/mi)	Glider #2 ARB Transient 2 (g/mi)	Glider #2 55/65 Cruise (g/mi)	Glider #2 ARB Transient 1 (g/mi)	Glider #2 ARB Transient 2 (g/mi)	Glider #2 55/65 Cruise (g/mi)
Hot Start SC	Glider #2 60,000 lb Test	1	11/3	0.000	0.001	0.000	15.32	16.00	1.49
		2	11/6	0.000	0.001	0.001	15.90	14.96	1.34
Hot Start SC	Glider #2 80,000 lb Test	1	11/7	0.000	0.000	0.003	17.41	18.31	2.70
		2	11/8	0.000	0.000	0.003	18.73	18.84	2.14

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	NO _x			N ₂ O		
				Glider #2 ARB Transient 1 (g/mi)	Glider #2 ARB Transient 2 (g/mi)	Glider #2 55/65 Cruise (g/mi)	Glider #2 ARB Transient 1 (g/mi)	Glider #2 ARB Transient 2 (g/mi)	Glider #2 55/65 Cruise (g/mi)
Hot Start SC	Glider #2 60,000 lb Test	1	11/3	25.0	25.0	16.4	0.014	0.013	0.005
		2	11/6	24.9	24.8	16.9	0.012	0.014	0.004
Hot Start SC	Glider #2 80,000 lb Test	1	11/7	32.1	32.7	28.6	0.015	0.013	0.005
		2	11/8	33.0	32.7	28.6	0.017	0.016	0.007

Test Type	Vehicle Number Test Weight (lbs)	Test Number	Date	CO ₂			Fuel Economy		
				Glider #2 ARB Transient 1 (g/mi)	Glider #2 ARB Transient 2 (g/mi)	Glider #2 55/65 Cruise (g/mi)	Glider #2 ARB Transient 1 (g/mi)	Glider #2 ARB Transient 2 (g/mi)	Glider #2 55/65 Cruise (g/mi)
Hot Start SC	Glider #2 60,000 lb Test	1	11/3	2177	2117	1171	4.62	4.75	8.67
		2	11/6	2106	2105	1146	4.77	4.78	8.86
Hot Start SC	Glider #2 80,000 lb Test	1	11/7	2755	2760	1765	3.66	3.65	5.75
		2	11/8	2861	2796	1777	3.52	3.60	5.71

PM Results

The values in the table represent an average of the PM collected on three filters. The PM emission data was not collected for all tests due to power issues in the laboratory during the time of testing which affected the PM sampler. Those tests for which the PM sample system was not operating are indicated with a “N/A”.

Test Type	Vehicle Test Weight (lbs)	Test Number	Date	PM		
				ARB Transient 1 (mg/mi)	ARB Transient 2 (mg/mi)	55/65 Cruise (mg/mi)
Hot Start SC*	Glider #1 60,000 lb	1	10/5	1005	839	187
		2	10/6	1112	1127	187
		3	10/10	N/A	N/A	N/A
		4*	10/16	961	905	167
		5*	10/17	1094	1089	186
	Glider #2 60,000 lb	1	11/3	682	706	88
		2	11/6	623	648	69
Hot Start SC*	Glider #1 80,000 lb	1	10/11	N/A	N/A	N/A
		2*	10/13	1340	1288	169
		3*	10/18	N/A	N/A	N/A
	Glider #2 80,000 lb	1	11/7	652	668	83
		2	11/8	749	743	98
* Check Engine Light issue resolved prior to these tests						