

A Report to
WaterBos™ LLC

Submitted by the
TEXAS A&M TRANSPORTATION INSTITUTE



Test Results

Project: Emissions Testing for WaterBos™ LLC

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Introduction

This report details the results of chassis dyno testing conducted on the WaterBos™ LLC PC-1 pure hydrogen generator.. The testing was conducted by the Texas A&M Transportation Institute (TTI) for WaterBos™. Testing was conducted on a chassis dynamometer located in TTI's Environmental and Emissions Research Facility (EERF), which includes a fully environmentally controlled test chamber which allows for testing to be conducted at controlled ambient conditions. This report outlines the specifications of the testing procedures used along with the results of the tests. The results from this test represent the PC-1 device's performance only under the circumstances as to which they were tested in the laboratory as documented in this report.

Test Setup

All testing for this project were conducted in the EERF test chamber. Figure 1 shows the vehicle and dyno setup in the EERF prior to the initial test. All testing was conducted at an ambient temperature of 70°F, with the vehicle A/C system turned off.



Figure 1: Test Vehicle on Dyno in Chamber

Test Vehicle

The test vehicle used for this test was a 2006 Ford Five Hundred. The vehicle details are shown below in Table 1.

Table 1: Test Vehicle Details

Make	Ford
Model	Five Hundred
Mileage (Beginning Test)	87,069
Engine Series	V-6 3.0L
Engine Type	3.0L V6 DOHC 24V

Test Drive Cycles

A total of two drive cycles were tested, one to simulate highway driving and one to simulate city driving. More information on the drive cycles can be obtained from the U.S. EPA Testing and Measuring Emissions Dynamometer Drive

Schedules page¹. The highway drive cycle tested was the Highway Fuel Economy Driving Schedule (HWFET). The HWFET is a 10.26 mile test with average speeds of 48.3 MPH. Figure 2 shows a graph of the HWFET drive schedule.

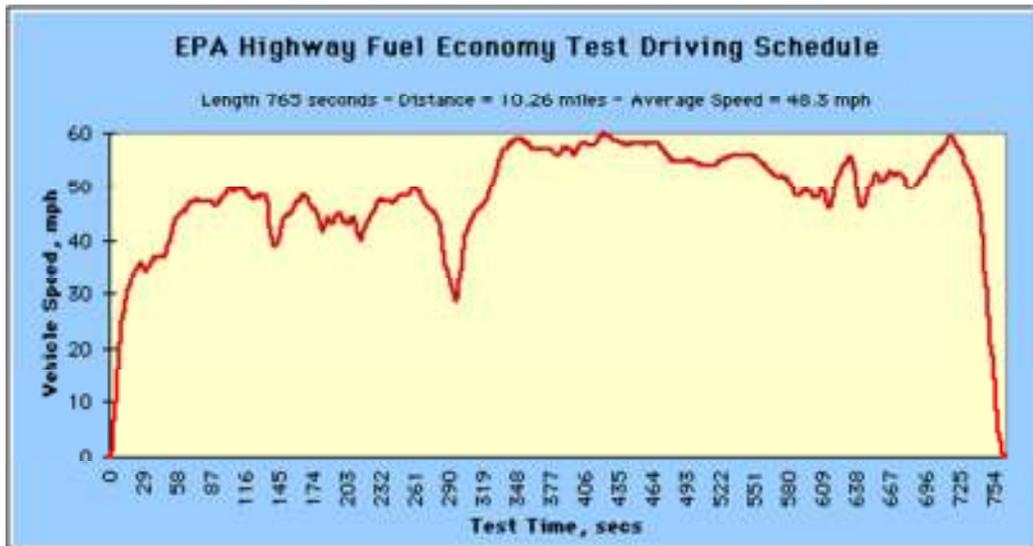


Figure 2: HWFET Drive Cycle²

For the city driving test, the Urban Dynamometer Drive Schedule (UDDS) was used. The UDDS covers a total of 7.45 miles at an average speed of 19.59 mph. Figure 3 shows the UDDS drive schedule.

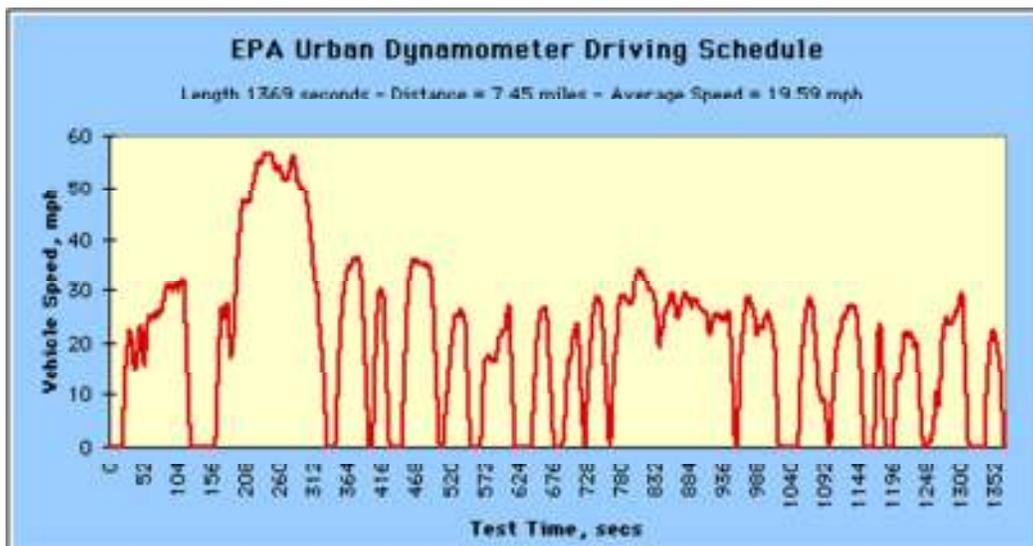


Figure 3: UDDS Drive Cycle³

Test Equipment

During all test runs the emissions from the vehicle were measured using TTI's portable emissions measurement system (PEMS), the ECOSTAR system, manufactured by Sensors-Inc. The ECOSTAR system is a 1065 complaint PEMS system that measures gaseous emissions, including carbon monoxide (CO), carbon dioxide (CO₂), oxides of nitrogen (NO_x) and total hydrocarbons (THC). The ECOSTAR system also includes an exhaust flow meter which measures the total exhaust flow,

¹ <http://www.epa.gov/nvfel/testing/dynamometer.htm>

² Image from the U.S. EPA, <http://www.epa.gov/nvfel/methods/hwfetdds.gif>

³ Image from the U.S. EPA, <http://www.epa.gov/nvfel/methods/uddsdds.gif>

which allows for the calculation of total emissions and the fuel consumption during a test. Figure 4 shows the ECOSTAR system used during the testing.



Figure 4: ECOSTAR PEMS System

Testing

In order to test the emissions and fuel economy impact of the PC-1 device the research team conducted two sets of tests for each drive schedule, a before and after set. The before set of tests were conducted on the test vehicle prior to installing the PC-1 device. The after test was conducted after the PC-1 device was installed and operating. For each set of tests a minimum of three runs, following the prescribed drive schedule, were conducted. The results from the three runs were then averaged together, to give a single number for each set of tests. The results from the before and after tests were then compared to give an overall emissions and fuel economy impact of the PC-1 device.

Installation

For this purposes of this test the PC-1 device was not permanently installed on the test vehicle, and was instead mounted on the dyno support frame. The output of the PC-1 device was connected to the vehicle according to a normal installation. The unit was installed in this manner in order to allow for easy access to power the PC-1 on and off during testing, as well as to eliminate maintenance necessary on the vehicle after removing the device. In addition the device was powered by a separate power supply, and therefore not powered by the test vehicle. The amount of power that was needed to operate the unit during operation was not part of the test, and was therefore not measured during testing. The results in this report represent the results without the PC-1 being powered by the vehicle. The PC-1 installation is shown on the left side of Figure 5 and the output of the PC-1 is shown connected to the air intake of the test vehicle on the right side of Figure 5.



Figure 5: PC-1 Temporary Installation

Test Runs

Testing was conducted in the EERF test chamber from July 30th to August 3rd, 2015. The before HWFET test was conducted on July 30th, followed by the before UDDS run which was completed on July 31st. The PC-1 was installed and both sets of after test runs were conducted on August 3rd.

Each test day begin with a vehicle warmup. The vehicle warmup consisted of starting the vehicle and allowing it to idle for approximately 15-30 minutes. Following the idle period the vehicle was driven following a HWFET drive schedule. During this warmup run no measurements were taken on the vehicle. Following the completion of the warmup run the testing was started. A minimum of three valid runs were completed for each of the drive schedules. A run was said to be valid if the driver was able to keep the vehicle within 3 MPH of the target speed of the drive cycle. At the completion of each run the vehicle would be turned off, and all equipment would be recalibrated and the data checked to ensure it was properly recorded. After validating the data and calibrating the equipment the next test run would begin. Each test was conducted approximately 20 minutes after the completion of the previous runs. Once three valid test runs were completed for each drive schedule the test was complete. The before and after test runs were completed following the same process. The only difference was that for each of the after test the PC-1 device would be started prior to beginning the test run.

Test Results

Table 2 below shows the results of the testing. All numbers shown in the table are the averages of the valid runs completed for that test.

Table 2: Test Results

Test Results						
Drive Schedule	Test Segment	CO ₂ (g/mile)	CO (g/mile)	NO _x (g/mile)	THC (g/mile)	Fuel Economy (mpg)
HWFET	Before	3960.7	2.51	0.245	0.222	23.4
	After	3182.1	2.36	0.113	0.202	29.1
	Difference	-19.7%	**	-53.7%	**	-24.3%
UDDS	Before	3719.6	1.60	0.044	0.15	18.1
	After	3071.0	1.81	0.074	0.20	21.9
	Difference	-17.4%	**	+70.1%	-30.5%	-20.8%

** Results were within the margin of error based on 95% confidence interval.