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U.S. Department of Energy

FreedomCAR & Vehicle Technologies Program

Advanced Vehicle Testing Activity

Hydrogen/CNG Blended Fuels Performance Testing in a Ford F-150

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Idaho National Engineering and Environmental Laboratory
Bechtel BWXT Idaho, LLC

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ABSTRACT

Federal regulation requires energy companies and government entities to utilize alternative fuels in their vehicle fleets. To meet this need, several automobile manufacturers are producing compressed natural gas (CNG)-fueled vehicles. In addition, several converters are modifying gasoline-fueled vehicles to operate on both gasoline and CNG (Bifuel). Because of the availability of CNG vehicles, many energy company and government fleets have adopted CNG as their principle alternative fuel for transportation. Meanwhile, recent research has shown that blending hydrogen with CNG (HCNG) can reduce emissions from CNG vehicles. However, blending hydrogen with CNG (and performing no other vehicle modifications) reduces engine power output, due to the lower volumetric energy density of hydrogen in relation to CNG. Arizona Public Service (APS) and the U.S. Department of Energy's Advanced Vehicle Testing Activity (DOE AVTA) identified the need to determine the magnitude of these effects and their impact on the viability of using HCNG in existing CNG vehicles.

To quantify the effects of using various blended fuels, a work plan was designed to test the acceleration, range, and exhaust emissions of a Ford F-150 pickup truck operating on 100% CNG and blends of 15 and 30% HCNG. This report presents the results of this testing conducted during May and June 2003 by Electric Transportation Applications (Task 4.10, DOE AVTA Cooperative Agreement DE-FC36-00ID-13859).

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ACRONYMS

APG	Arizona Proving Grounds
APS	Arizona Public Service
ATL	Automotive Testing Laboratories
CH_4	Methane
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
DOE AVTA	U.S. Department of Energy Advanced Vehicle Testing Activity
ETA	Electric Transportation Applications
FTP-75	Federal Emissions Test Procedure
gge	Gasoline gallon equivalent
HC	Total hydrocarbons
HCNG	Hydrogen blended with natural gas
ICE	Internal combustion engine
IM240	Inspection and Maintenance Driving Cycle
kph	Kilometers per hour
LEV	Low-emission vehicles
MDV	Medium duty vehicle
mpg	Miles per gallon
mph	Miles per hour
NMCH	Nonmethane hydrocarbons
NMOG	Nonmethane organic gases
NOx	Oxides of nitrogen
psi	Pounds per square inch
psig	Pounds per square inch, gauge
kPa	Kilopascals
SULEV	Super ultra low-emission vehicle
ULEV	Ultra low-emission vehicle

Hydrogen/CNG-Blended Fuels Performance Testing in a Ford F-150

1. BACKGROUND

1.1 Test Program

Federal regulation requires energy companies and government entities to utilize alternative fuels in their vehicle fleets. As a result, several automobile manufacturers are producing compressed natural gas (CNG)-fueled vehicles. In addition, several converters are modifying gasoline-fueled vehicles to operate on both gasoline and CNG (Bifuel). Because of the availability of CNG vehicles, many energy company and government fleets have adopted CNG as their principle alternative fuel for transportation. Meanwhile, recent research has shown that blending hydrogen with CNG (HCNG) can reduce emissions from CNG vehicles. However, blending hydrogen with CNG (and performing no other vehicle modifications) reduces engine power output, due to the lower volumetric energy density of hydrogen in relation to CNG. Arizona Public Service (APS) and the U.S. Department of Energy's (DOE's) Advanced Vehicle Testing Activity (AVTA) identified the need to determine the magnitude of these effects and their impact on the viability of using HCNG in existing CNG vehicles.

To perform this evaluation, a work plan was designed to test the acceleration, range, and exhaust emissions of a Ford F-150 pickup truck (Figure 1) operating on 100% CNG and blends of 15 and 30% HCNG. This work program was conducted by Electric Transportation Applications, as Task 4.10 under the DOE Cooperative Agreement DE-FC36-00ID-13859. The Ford F-150 was previously tested in fleet operation using a blend of 30% HCNG (DOE Cooperative Agreement DE-FC36-00ID-13859, Task 4.6). Results of the previous Task 4.6 testing are documented in the report: *Low Percentage Hydrogen/CNG Blend Ford F-150 Truck Operating Summary* (INEEL/EXT-03-00008, September 2002).

Figure 1. Low-percentage blend Ford F-150 pickup.

1.2 Test Vehicle

The test vehicle is a model year 2000, F-150 regular cab pickup truck equipped with a factory CNG engine (Table 1) and 3600 psig carbon steel fuel tanks with an 85-liter capacity. It was modified by NRG Tech in Reno, Nevada to run on a blend of CNG and up to 30% hydrogen (by volume). NRG Tech modifications (Figure 2) include supercharging, ignition modifications, and exhaust gas recirculation. The F-150 was placed in service in the APS fleet in June 2001. Fleet testing of the vehicle was conducted from June 2001 through September 2002. Subsequent to the formal performance testing with blended fuels, the vehicle was again placed in the APS fleet. F-150 parametric performance testing with hydrogen/CNG-blended fuels was conducted in May and June 2003. At the beginning of this test program, the vehicle had accumulated 31,678 miles, operating with HCNG fuel.

Table 1. Ford F-150 original factory specifications.

Engine	5.4 L V8
Factory HP	230 HP
Curb weight	5,170 lb
GVWR	7,650 lb

Figure 2. Low-percentage blend Ford F-150 engine compartment.

1.3 Emission Test Procedures

During the previous fleet testing (Task 4.6) of the Ford F-150, emissions from the test vehicle were periodically measured. Two different emission test procedures were performed on the vehicle, the IM240 and the FTP-75.

1.3.1 IM240

The Inspection and Maintenance Driving Cycle (IM240) test is used by several states for emissions testing of light duty vehicles. The test consists of a single phase, which spans 240 seconds and 1.96 miles of travel; it reaches a top speed of 56.7 mph, at an average speed of 29.4 mph. The test fails to account for cold starts, when automobile emissions are typically the highest.

1.3.2 FTP-75

The Federal Test Procedure (FTP-75) is a more thorough emissions test than the IM240. The test consists of three phases, which span 1,874 seconds and 11.04 miles of travel, at an average speed of 21.2 mph. The three phases are cold start, transient, and hot start that occurs 10 minutes after completion of the transient phase.

Emissions tests performed under the current work program were conducted using the FTP-75 test cycle at the Automotive Testing Laboratories, Inc. (ATL) facilities, located in Mesa, Arizona. ATL is certified by the State of Arizona to conduct the Federal Test Procedure.

California emission standards are used in this report as a reference point for vehicle emissions. Currently, Low-Emission Vehicles I (LEV I) emission standards are in effect. However, a more stringent set of emission standards, LEV II, will come into effect in 2004. The California LEV II emission standards categorize emissions into the following groups: low-emission vehicles (LEVs), ultra low-emission vehicles (ULEVs), and super ultra low-emission vehicles (SULEVs). The standards are based on weight class and emissions are measured over the FTP-75 test. The F-150 test vehicle used for this work program is classified by California emission standards as an MDV3.[c] Some of the California emission standards for the MDV3 class are shown in Table 2.

Table 2. California LEV II emission standards.

	NMOG (gram/mile)	CO (gram/mile)	NOx (gram/mile)
LEV	0.09	4.2	0.07
ULEV	0.055	2.1	0.07
SULEV	0.01	1	0.02

NMOG = nonmethane organic gases.
CO = carbon monoxide.
NOx = oxides of nitrogen.

1.4 Acceleration and Range Test Procedures

Hydrogen internal combustion engine (ICE) test procedures were developed to conduct acceleration and range testing of the F-150 test vehicle, fueled using 100% CNG and blends of 15 and 30% HCNG. The acceleration test procedure (Attachment 1) requires that the vehicle be accelerated from rest to a speed of 100 mph, and speed versus time data are collected. The hydrogen ICE range test procedure (Attachment 2) requires that the vehicle be operated at a constant speed of 45 mph, and distance versus time data are collected.

[c] MDV = medium duty vehicle; MDV3 is the class of MDVs with a test weight between 5751 and 8500 lb. *Test weight* by the California definition is analogous to the federal definition of *adjusted loaded vehicle weight* (ALVW); Test weight = (curb weight + GVWR)/2.

2. CONDUCT OF TESTING

2.1 Emissions Testing

Emissions from the F-150 were measured at ATL using both FTP-75 and IM240 test cycles during the June 2001 through September 2002 vehicle fleet testing (Task 4.6). During this test, the F-150 was fueled exclusively with a blend of 30% HCNG. The vehicle was tested several times to validate the results. As Table 3 shows, carbon monoxide emissions from the low percentage blend F-150 averaged 0.26 gram/mile over the FTP-75 tests, well under the California SULEV standard of 1 gram/mile. Nitrogen oxide emissions averaged 0.078 gram/mile, near the California ULEV standard of 0.07. However, the first NO_x testing result (0.063) was under the 0.07 standard, which is based on emissions when a vehicle is new. Non-methane organic gases (NMOG) were not measured.

To provide an additional point of reference for F-150 emissions test results, emissions testing of a randomly selected Ford F-150 equipped with a factory gasoline engine was also conducted at ATL (Table 4).

Table 3. Fleet testing F-150 emissions test results (gram/mile) operating on 30% HCNG.

Test Date	Mileage	NMHC	CH_4	HC	CO	NO_X	CO_2
FTP-75							
5/2/2001	1592	0.011	0.075	0.094	0.237	0.063	440.606
5/3/2001	1613	0.019	0.084	0.118	0.249	0.094	441.442
5/4/2001	1636	0.024	0.082	0.121	0.267	0.094	437.370
5/8/2001	1657	0.017	0.099	0.133	0.257	0.084	439.940
6/14/2001	2148	0.028	0.091	0.136	0.223	0.104	435.899
8/30/2001	3890	0.028	0.074	0.116	0.348	0.051	442.515
8/31/2001	3915	0.028	0.067	0.107	0.210	0.053	437.009
Average		0.022	0.081	0.117	0.255	0.078	439.254
IM240							
5/2/2001	1592	0.062	0.050	0.124	0.135	0.040	392.720
5/3/2001	1625	0.008	0.042	0.057	0.118	0.025	402.205
5/4/2001	1647	0.014	0.054	0.078	0.146	0.023	410.147
5/8/2001	1670	0.016	0.069	0.098	0.101	0.022	411.302
8/30/2001	3901	0.014	0.054	0.078	0.077	0.089	397.635
8/30/2001	3903	0.016	0.028	0.049	0.125	0.051	402.614
8/31/2001	3928	0.013	0.045	0.066	0.101	0.019	397.634
8/31/2001	3931	0.013	0.026	0.045	0.095	0.033	396.020
Average		0.019	0.046	0.074	0.112	0.037	401.285

NMHC = nonmethane hydrocarbons
CH_4 = methane
HC = total hydrocarbons
CO = carbon monoxide
NO_x = oxides of nitrogen
CO_2 = carbon dioxide

Table 4. Gasoline-fueled F-150 emission test results (gram/mile).

Test	Vehicle	Emission Species					
Date	Mileage	NMHC	CH_4	HC	CO	NO_X	CO_2
FTP-75							
6/20/2001	23497	0.122	0.013	0.136	1.644	0.170	620.7
6/21/2001	23519	0.107	0.011	0.119	1.457	0.163	623.0
Average		0.115	0.012	0.128	1.551	0.167	621.9
IM240							
6/20/2001	23509	0.015	0.008	0.023	0.127	0.565	585.172
6/21/2001	23531	0.006	0.011	0.017	0.046	0.440	578.728
Average		0.011	0.010	0.020	0.087	0.503	581.95

NMHC = nonmethane Hydrocarbons
CH_4 = methane
HC = total hydrocarbons
CO = carbon monoxide
NO_x = oxides of nitrogen
CO_2 = carbon dioxide

Table 5 illustrates the emissions comparison between the average emissions of the F-150 during fleet testing at 30% HCNG (Table 3) and the random gasoline-fueled F-150 (Table 4). Reductions were achieved for all emission species except for methane, which is typical of vehicles operating on CNG.

Table 5. Percentage reduction in emissions (30% HCNG fuel versus gasoline-fueled F-150).

HC	CO	NO_X	CO_2
7.6%	83.5%	53.4%	29.4%

HC = total hydrocarbons.
CO = carbon monoxide.
NO_x = oxides of nitrogen.
CO_2 = carbon dioxide.

The baseline of data obtained from the previous F-150 emissions testing during the fleet testing (Tables 3 and 4) was supplemented in the current work program by conducting additional FTP-75 emissions testing for the F-150 test vehicle using fuels of 100% CNG, 15 and 30% HCNG (Table 6). Each time fuel was changed in the test vehicle, it was driven at least 100 miles using the new fuel to allow the engine management computer to make any automatic adjustments necessary to optimize use of the new fuel. The FTP-75 test cycle emissions testing was conducted by ATL using the procedures certified by the State of Arizona.

Table 6. Emissions test results (gram/mile) for blended HCNG fuels and 100% CNG.

Fuel	Vehicle	Emission Species (gram/mile)					
Blend	Mileage	NMHC	CH_4	HC	CO	NO_X	CO_2
CNG	30,045	0.023	0.128	0.173	0.567	0.110	473.1
15% HCNG	29,915	0.025	0.132	0.179	0.467	0.124	452.2
30% HCNG	28,814	0.013	0.138	0.175	0.423	0.126	448.1

CO = carbon monoxide
NO_x = oxides of nitrogen
CO_2 = carbon dioxide
NMHC = nonmethane Hydrocarbons
CH_4 = methane
HC = total hydrocarbons.

2.2 Acceleration Testing

Acceleration testing of the F-150 was conducted at DaimlerChrysler's Arizona Proving Grounds (APG) in accordance with the Hydrogen ICE (Internal Combustion Engine) Vehicle Acceleration Test Procedures (Attachment 1), for fuels of 100% CNG, and blends of 15 and 30% HCNG. Tests were performed using a 2.4-mile-long straight track at the APG. For each of the three blends of fuel, two sets of acceleration runs were conducted. Each set consisted of one acceleration run in each direction (east and west) on the straight track. Data sheets from these tests (12 runs total) are presented in Attachment 3. Results of acceleration testing conducted with the F-150 test vehicle are presented as speed versus distance in Figures 3, 4, and 5 and speed versus time in Figures 6, 7, and 8 for each fuel type. Table 7 presents the times to accelerate to 60 mph for each fuel type.

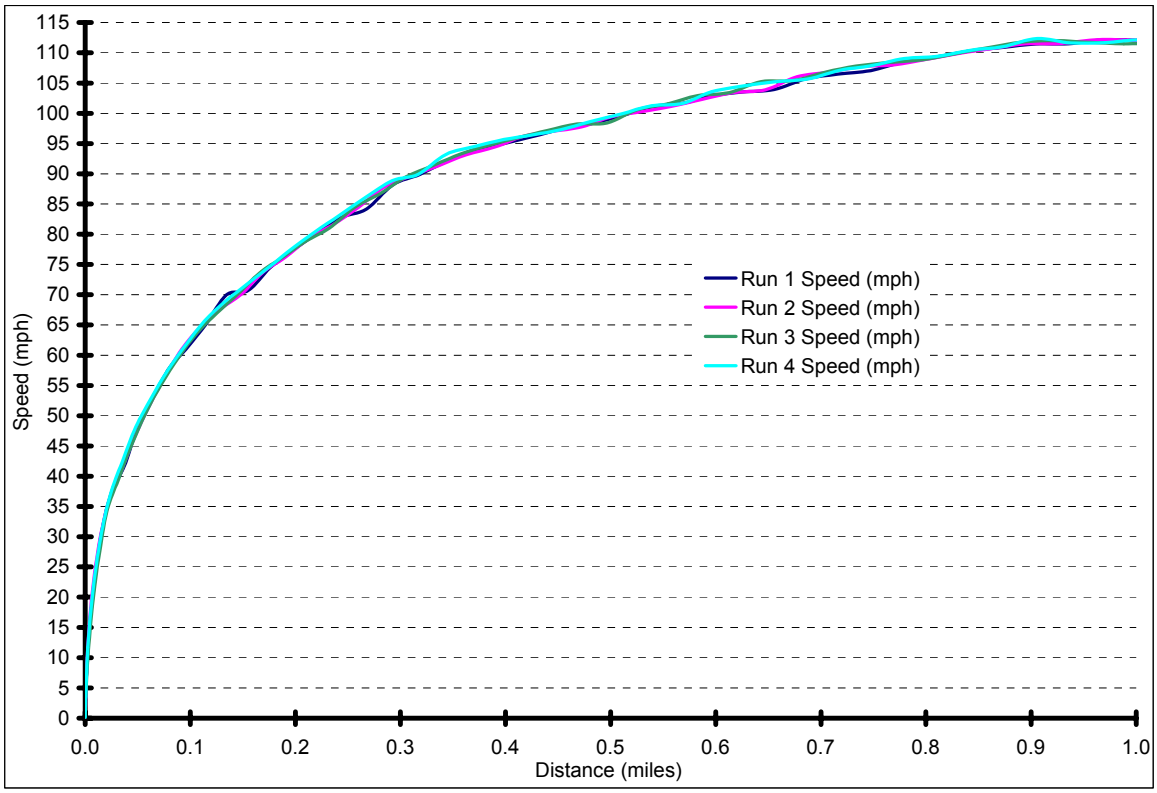

Figure 3. Speed versus distance for the F-150 test vehicle, using 100% CNG.

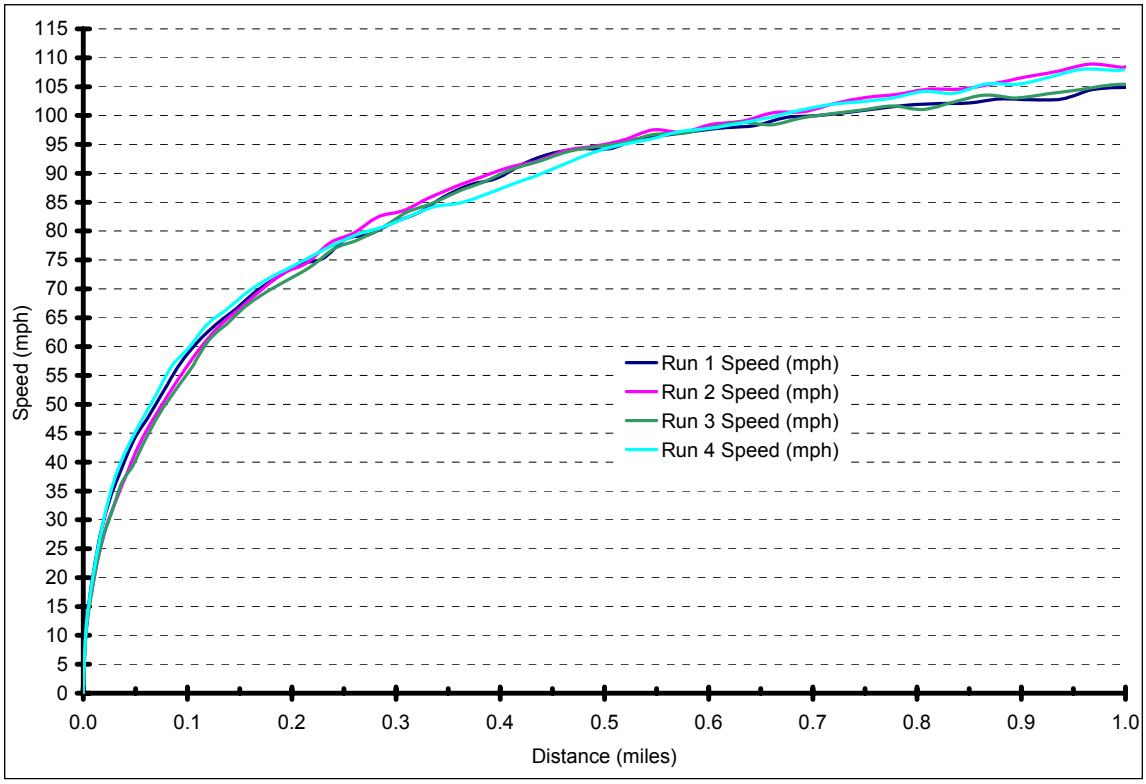

Figure 4. Speed versus distance for the F-150 test vehicle, using 15% HCNG.

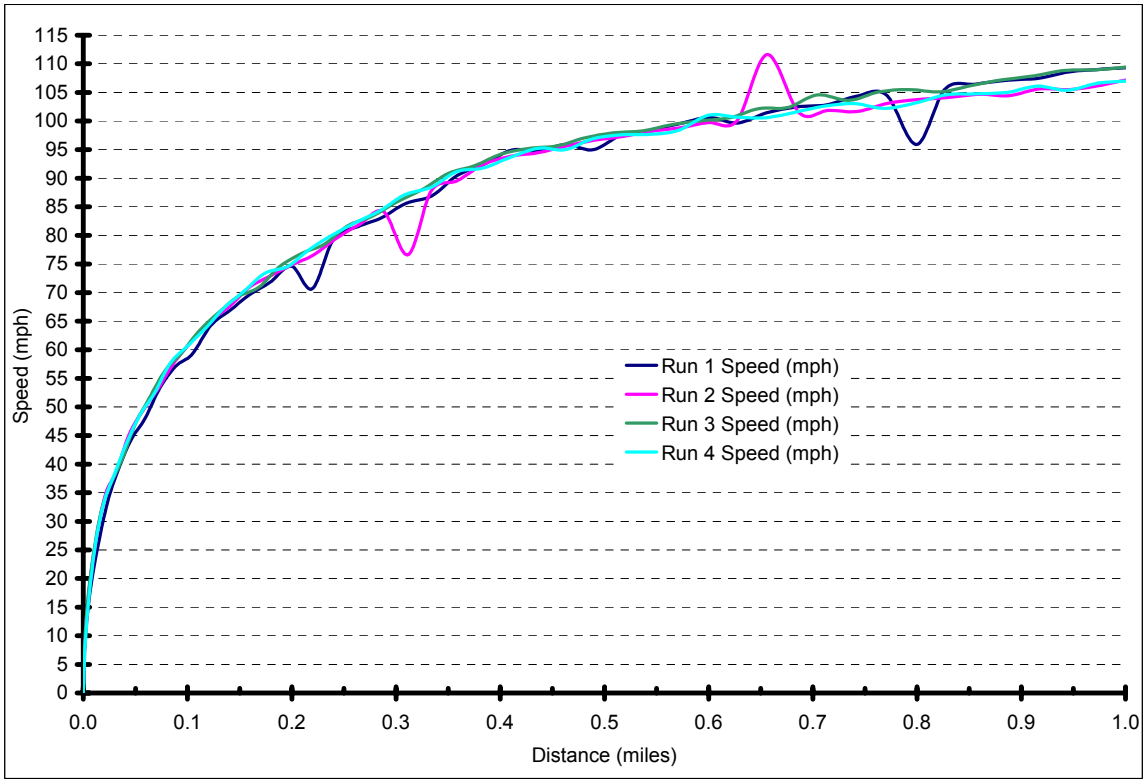

Figure 5. Speed versus distance for the F-150 test vehicle, using 30% HCNG.

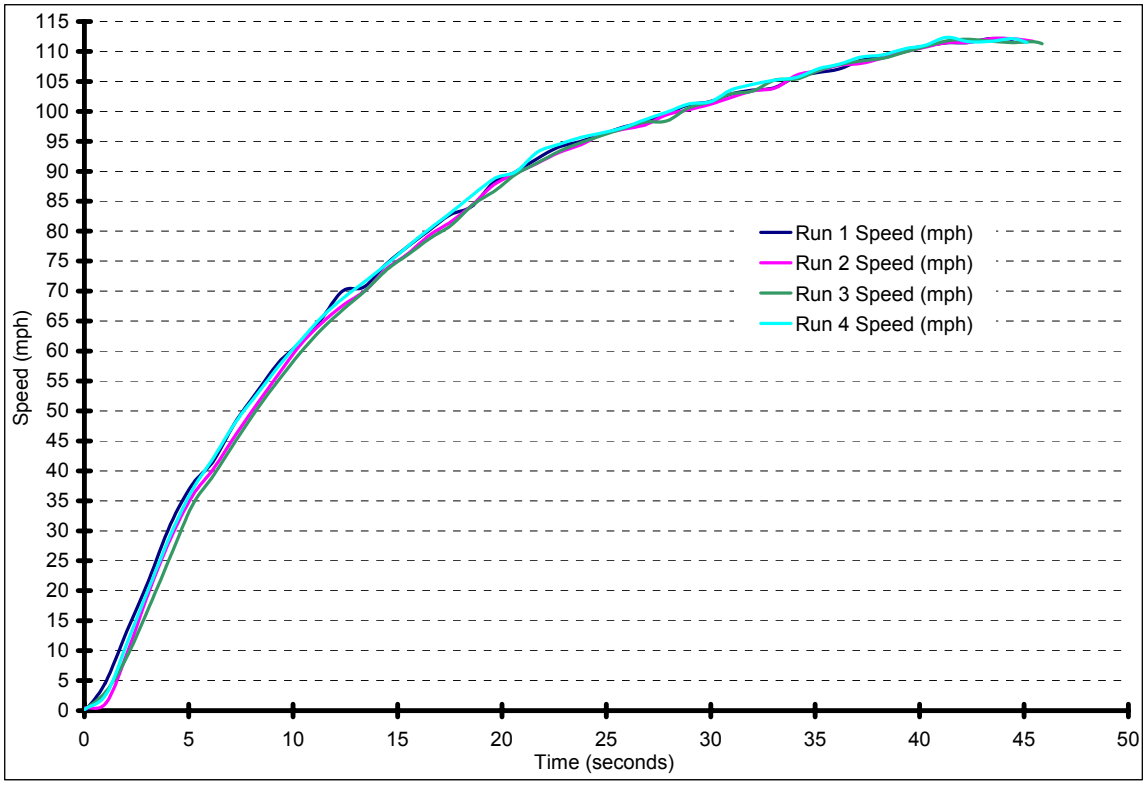

Figure 6. Speed versus time for the Ford F-150 test vehicle, using 100% CNG.

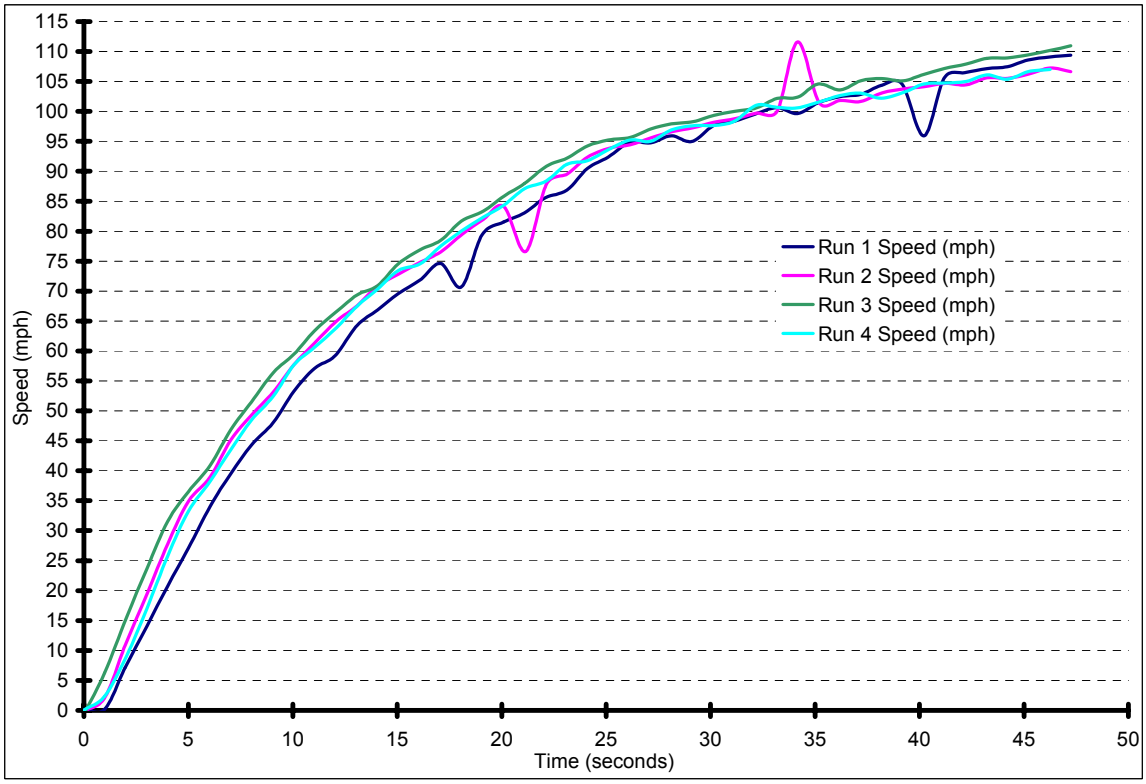

Figure 7. Speed versus time for the Ford F-150 test vehicle, using 15% HCNG.

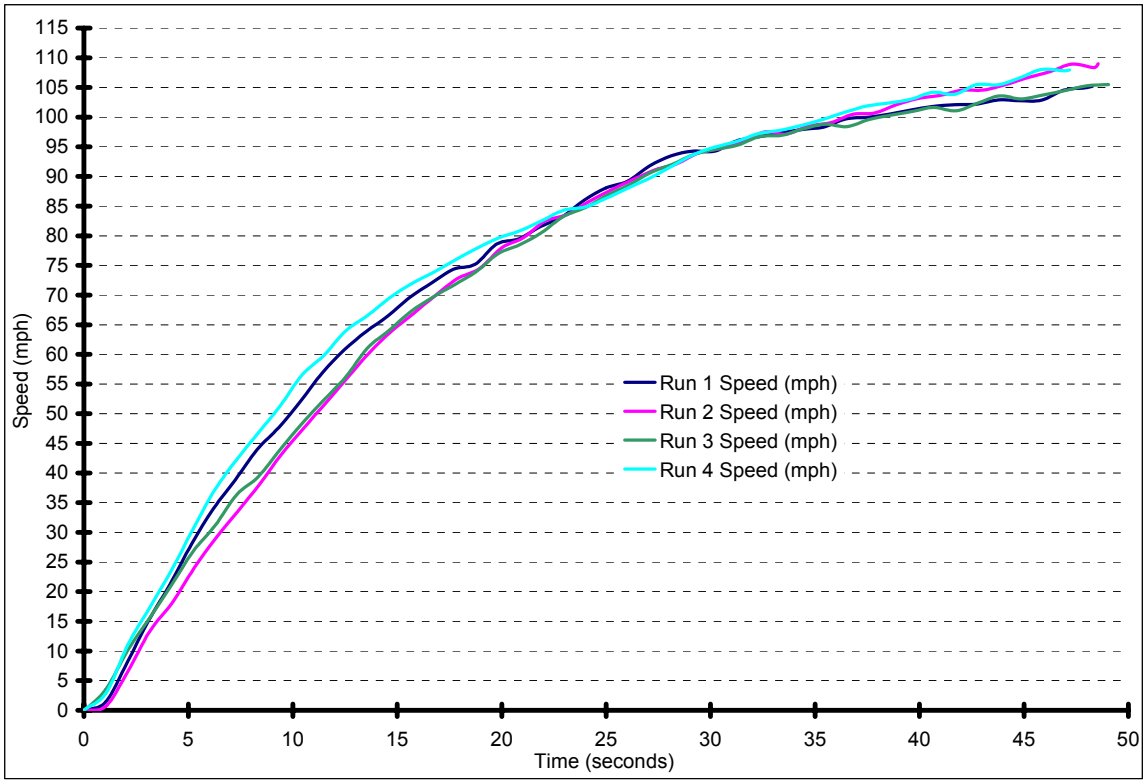

Figure 8. Speed versus time for the Ford F-150 test vehicle, using 30% HCNG.

Table 7. Time to accelerate to 60 mph for 100% CNG, 15 and 30% HCNG.

Fuel Blend	Vehicle Mileage	Time to 60 mph
100% CNG	32,452	10.10
15% HCNG	31,943	10.97
30% HCNG	31,679	12.68

2.3 Range and Fuel Economy Testing

The range of the F-150 test vehicle was also tested at the APG (Figure 9), in accordance with the Hydrogen ICE Vehicle Constant Speed Fuel Economy Tests Procedures presented in Attachment 2, for 100% CNG and blends of 15 and 30% HCNG. Tests were performed at a constant speed of 45 mph, using the 4.2-mile-long high-speed oval track at the APG. The vehicle was driven 60 miles on each fuel and the amount of fuel used was determined through the mathematical relationship between pressure, temperature, and mass for a perfect gas. From these calculations, the fuel economy in gasoline gallon equivalents (gge) was determined (see Table 8). Using the fuel economy and the capacity of the fuel tanks (85 liters) filled to 3,600 psig, the range of the F-150 test vehicle for each type of fuel was calculated, as shown in Table 8. Data sheets from these tests are presented in Attachment 4. Speed versus time testing graphs are presented in Figures 10, 11, and 12 for each fuel type. Speed was controlled manually by the driver, as the vehicle was not equipped with cruise control. Spikes in vehicle speed are the result of data acquisition system noise; they do not represent actual speed deviations.

Figure 9. Vehicle range testing at the Arizona Proving Grounds.

Table 8. F-150 test vehicle range at a constant speed of 45 mph for 100% CNG, 15 and 30% HCNG.

Fuel Blend	Vehicle Mileage	Fuel Economy (miles/gge)	Range (miles)
CNG	32,465	23.3	122
15% HCNG	31,951	22.6	110
30% HCNG	31,769	23.5	102

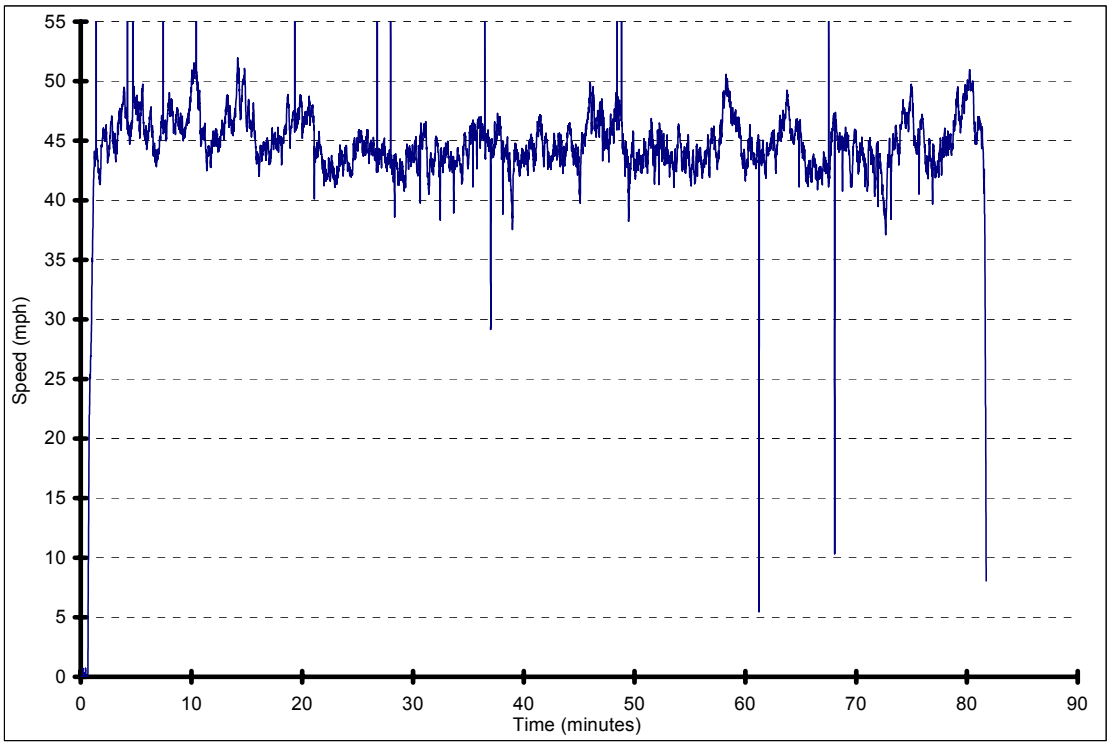

Figure 10. Speed versus time for the Ford F-150 test vehicle range test, using 100% CNG.

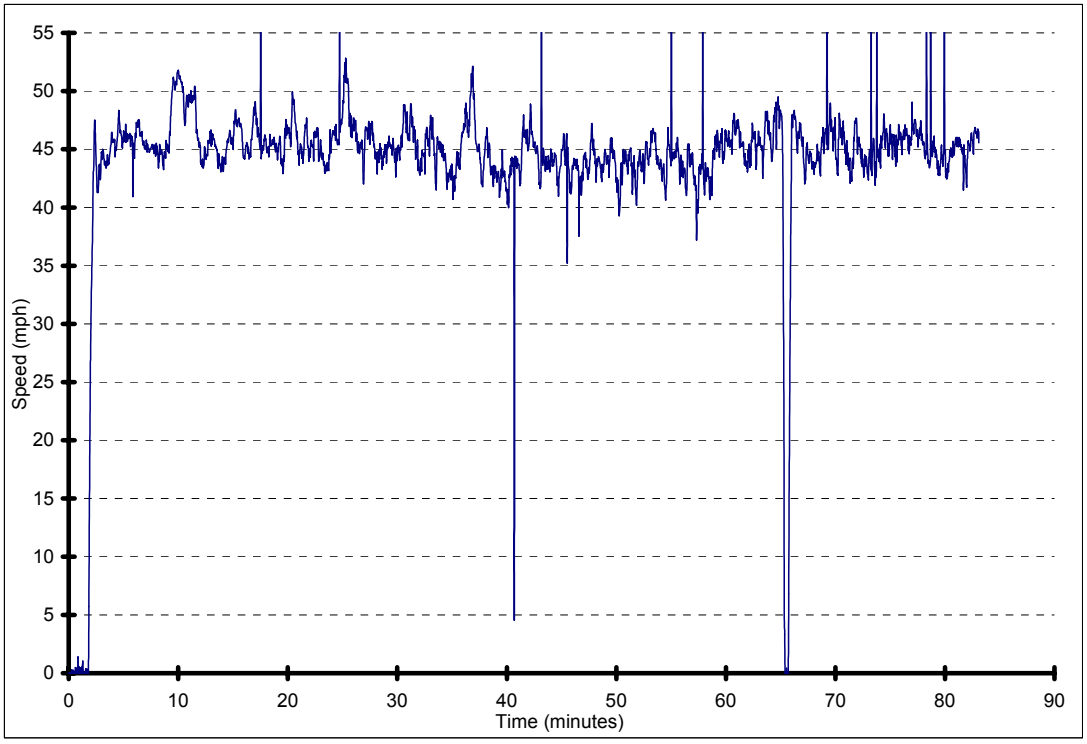

Figure 11. Speed versus time for the Ford F-150 test vehicle range test, using 15% HCNG.

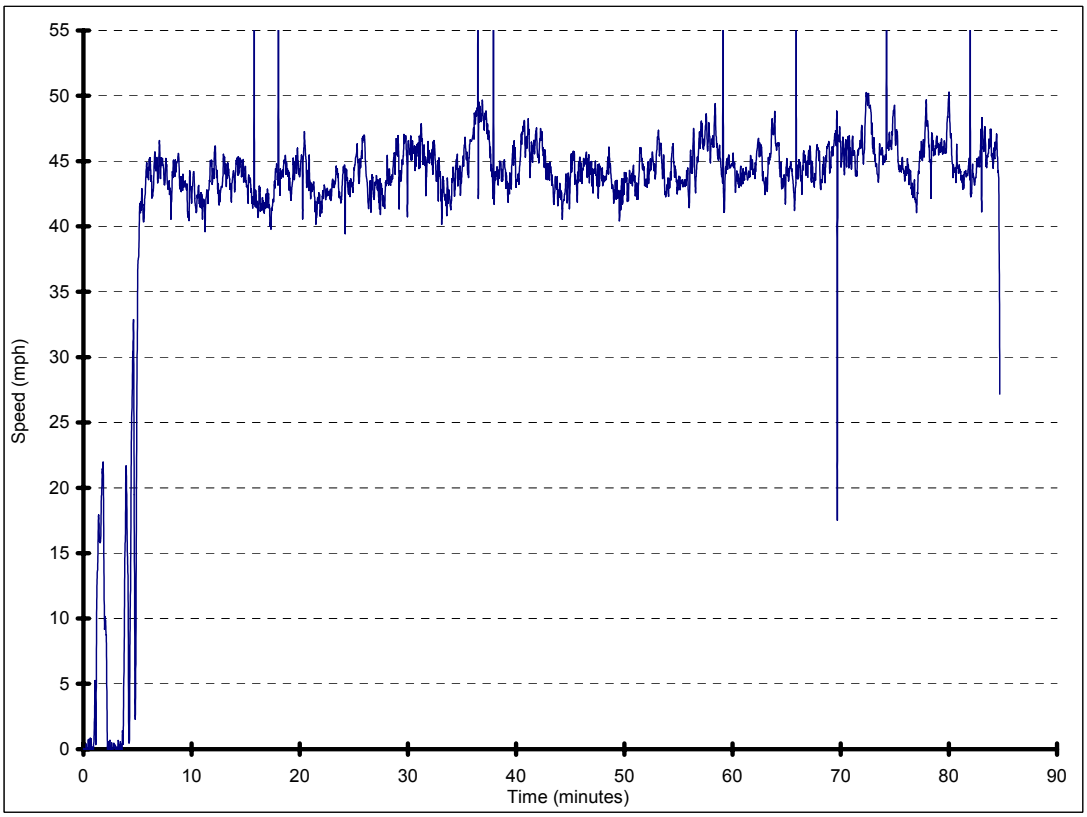

Figure 12. Speed versus time for the Ford F-150 test vehicle range test, using 30% HCNG.

3. TEST RESULTS

3.1 Emissions Testing Results

Exhaust emissions using 100% CNG, and 15 and 30% HCNG (Table 6) showed significant emission reductions over gasoline (Table 4) in NMHC, CO, NO_X, and CO_2. However, CH_4 and HC increased with the introduction of the methane-based CNG. Percentage changes are shown in Table 9. Attachment 5 summarizes the test results from Automotive Testing Laboratories.

Table 9. Emissions variations using blended fuels; comparison of the results found in Tables 4 and 6.

	Percentage Change in Emission Species					
Fuel Type	NMHC	CH_4	HC	CO	NO_X	CO_2
Gasoline	Base	Base	Base	Base	Base	Base
CNG	-80	+967	+35	-63	-34	-24
15% HCNG	-78	+1000	+40	-70	-26	-27
30% HCNG	-89	+1050	+37	-73	-25	-28

NMHC = nonmethane hydrocarbons
CH_4 = methane
HC = total hydrocarbons
CO = carbon monoxide
NOx = oxides of nitrogen
CO_2 = carbon dioxide

Much of the reductions in CO, NO_X, and CO_2 emissions are achieved by switching from gasoline to CNG. Additional CO reductions are achieved with higher percentage blends of hydrogen in CNG. However, NO_X increases with the higher-percentage blends. Note that the NO_X levels measured in the current work program are significantly higher than those measured during the fleet operation of the F-150 test vehicle using a 30% blend of hydrogen in CNG. The fleet testing was conducted with between 1,500 and 4,000 miles on the vehicle. Testing in the current work program was conducted with the vehicle use near 30,000 miles. Aging of the catalytic converter was probably the cause of the increased NO_X emissions.

Based on these results, it is apparent that reductions in CO and CO_2 emissions can be achieved by blending hydrogen with CNG for use in CNG fleets. These emission reductions come at some cost in terms of increased CH_4 and HC emissions and reduced vehicle acceleration and range. However, even at 15% HCNG, the performance reductions do not have a significant impact on vehicle drivability and offer an additional 10% decrease in CO and CO_2 emissions.

3.2 Acceleration Testing Results

As expected, the performance (in terms of acceleration [Figures 12 and 13] and range) of the F-150 test vehicle degrades with increasing amounts of hydrogen in the fuel. However, much of the performance loss results from the initial switch from a liquid fuel (gasoline) to a gaseous fuel (CNG), as shown in Table 10. The degradation in acceleration resulting from use of hydrogen in the fuel does not have a significant impact on the drivability until blends approaching 30% hydrogen are used. At a blend of 15% HCNG, the F-150 test vehicle acceleration was within 10% of that with the vehicle operating on 100% CNG (Table 10).

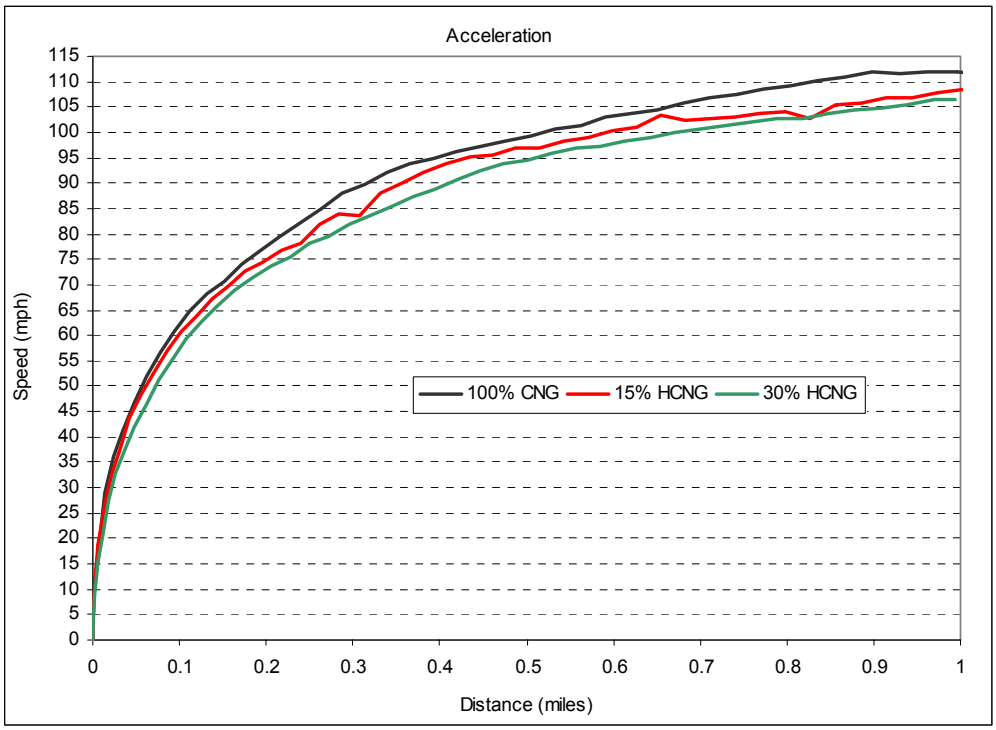

Figure 13. Average speed versus distance for F-150 test vehicle range test, 100% CNG, 15% HCNG and 30% HCNG.

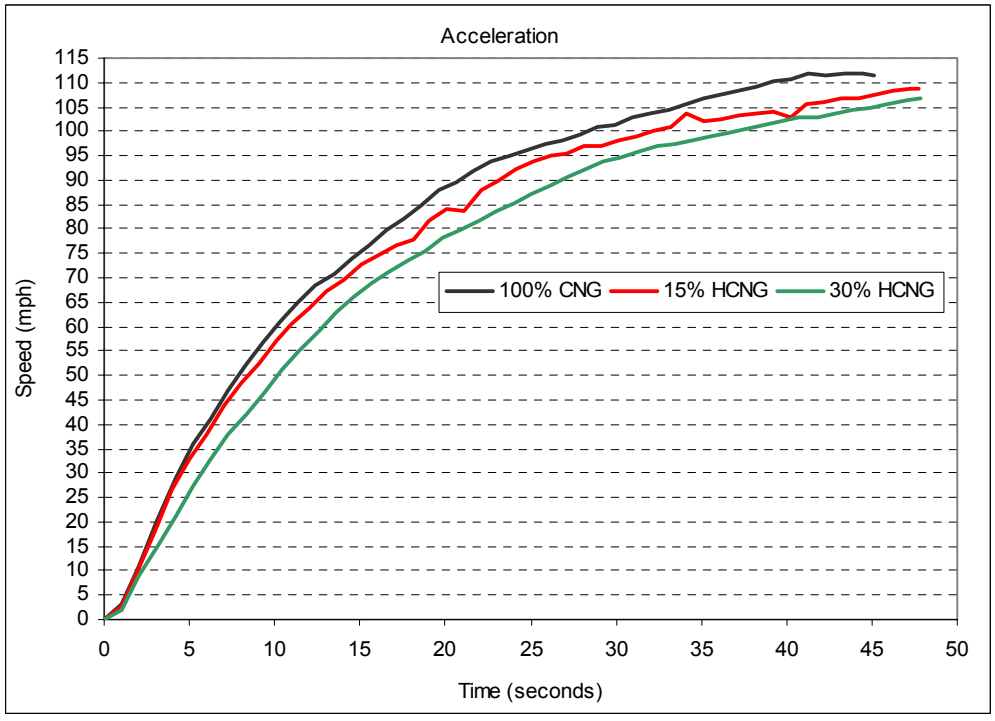

Figure 14. Average speed versus time for F-150 test vehicle range test, 100% CNG, 15% HCNG and 30% HCNG.

Table 10. Acceleration to 60 mph for various fuels.

Fuel Blend	Time to 60 mph (seconds)	Degradation from CNG F-150	Degradation from Gasoline F-150
Gasoline[1]	8.6 (1)	---	Base
CNG	10.10	Base	17.4 %
15% HCNG	10.97	8.6 %	27.6 %
30% HCNG	12.68	25.5 %	47.4 %

[1] 2001 Ford F-150 with 5.4L V-8 engine and automatic transmission, as reported by edmunds.com.

Degradation of acceleration can be remedied by either increasing the amount of fuel and air entering the engine cylinders, or by directly injecting hydrogen into the cylinder to avoid the displacement of air by the hydrogen fuel. However, this requires additional vehicle modifications, which does not appear to be economically practical for introducing blended fuel into existing CNG fleets.

3.3 Range and Fuel Economy Test Results

As shown in Table 11, degradation of vehicle range was significant with the 30% HCNG fuel. The decrease is based on the lower energy content of hydrogen when compared to CNG on a volumetric basis. The decrease in range between 100% CNG and 30% HCNG would require a 16.4 % increase in onboard fuel storage to maintain vehicle range similar to that achievable with 100% CNG. In the case of the F-150 test vehicle, this would require the addition of a 14-liter fuel tank. With a fuel of 15% HCNG, the range degradation was less than 10%, which should have a negligible impact on vehicle utility in fleet operation.

Table 11. Range decrease from use of various fuels.

Fuel Blend	Range (miles)	Decrease from CNG
CNG	122	Base
15% HCNG	110	9.8 %
30% HCNG	102	16.4 %

Note that no significant change in efficiency (within the accuracy of the test methods) was noted for the fuels tested. Fuel economy for the constant speed of 45 mph range test was 23.3 mile/gge for 100% CNG, 22.6 mile/gge for 15% HCNG, and 23.5 mile/gge for 30% HCNG.

Attachment 1 - Hydrogen ICE Vehicle Acceleration Test Procedure

ETA-YTP001

Revision 0

Effective May 15, 2003

Implementation of SAE Standard J1666 AUG99

Prepared by

Electric Transportation Applications

Appendix 1

ETA-YTP001

Revision 0

Effective May 15, 2003

Implementation of SAE Standard J1666 AUG99

"Hydrogen ICE Vehicle Acceleration Test Procedure"

Prepared by

Electric Transportation Applications

Prepared by: _____ **Date:** _____
Bill Short

Approved by: _____ **Date:** _____
Don Karner

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Hydrogen ICE Vehicle Acceleration Test Procedure

1.0 Objective

The objective of this procedure is to identify proper methods for the control of acceleration testing pursuant to the requirements of SAE J1666 AUG99, "Electric Vehicle Acceleration, Gradeability and Deceleration Test Procedure", as such methods are applied to hydrogen fueled internal combustion engine powered (ICE) Vehicles (HFVs). These methods are not meant to supersede those of the testing facility, those specifically addressed by SAE Test Standards, nor of any regulatory agency who may have or exercise control over the covered activities.

2.0 Purpose

The purpose of this procedure is to identify acceptable methods for the implementation of an acceleration test. SAE-J1666 AUG99 establishes uniform procedures for testing electric vehicles. Testing conducted in accordance with this procedure is similar to that identified in SAE J1666 AUG99, with the exception of using an internal combustion powered vehicle. This procedure collects and retains test data as specified in the "HFV America Technical Requirements."

3.0 Documentation

Documentation addressed by this procedure shall be consistent, easy to understand, easy to read and readily reproducible. This documentation shall contain enough information to "stand alone"; that is, be self-contained to the extent that all individuals qualified to review it could be reasonably expected to reach a common conclusion, without the need to review additional documentation. Review and approval of test documentation shall be in accordance with ETA-YAC004, "Review of Test Results." Storage and retention of records during and following testing activities shall be completed as described in Procedure ETA-YAC001, "Control, Close-out and Storage of Documentation."

4.0 Initial Conditions and Prerequisites

Prior to conduct of any portion of the testing, the following initial conditions and prerequisites shall be met. Satisfactory completion of these items should be verified as complete and recorded on the Test Data Sheet.

4.1 Personnel conducting testing under this procedure shall be familiar with the requirements of this procedure, and when applicable the appropriate SAE Test Instructions, Administrative Control Procedures, and be certified by the Program Manager, Test Manager or specific Test Engineer prior to commencing any testing activities.

4.2 All documentation required to complete the testing shall be completed, approved and issued (past it's effective date) prior to commencing the testing it addresses.

4.3 Test Conditions

4.3.1 The test road must be an open course consisting of dry, clean and smooth roads not exceeding 1.0% grade. Tests shall be run in pairs in opposite directions on the test road.

4.3.2 Ambient temperature during road testing shall be within the range of 50°F to 100°F (5°C to 38°C) - Note this is a deviation from SAE J1666 AUG99.

4.3.3 The average wind speed at the test site during the test shall not exceed 10 mph (16 km/h). Wind gusts shall not exceed 20 mph (32 kph) during the test.

4.4 Test Vehicle Preparation

4.4.1 The vehicle should have accumulated a minimum of 2,000 miles (3,200 km) of operation prior to test. At least 1,000 (1,600 km) of these miles must have been driven at speeds above 40 mph (64 kph).

4.4.2 Tires shall have been operated for at least 100 miles (160 km) prior to test and shall have at least 75% of the tread remaining and in good condition. Tires provided with the vehicle shall be the standard tire offered by the vehicle manufacturer, and shall be inflated to the manufacturer's (placard) recommended cold inflation pressures prior to test. This pressure shall not exceed the maximum allowable pressure imprinted upon the tire's sidewall.

4.4.3 Vehicle shall be tested in its normal configuration with normal appendages (mirrors, bumpers, hubcaps, etc.).

4.4.4 Vehicles shall be tested at curb weight plus 332 pounds. - Note this is a deviation from SAE J1666 AUG99. Consideration should be given to how adding instrumentation will affect the test weight and balance of the vehicle.

4.4.5 Normal manufacturer's recommended lubricants shall be employed.

4.5 The following data shall be collected during conduct of the various tests specified by this procedure suing an onboard Data Acquisition System (DAS). Overall error in recording or indicating instruments shall not exceed ±2% of the maximum value of the variable being measured, unless otherwise excepted and noted. Periodic calibration shall be performed and documented to ensure compliance with this requirement.

4.6.1 Vehicle speed versus time;

4.6.2 Distance versus time;

4.6 Environmental conditions during the testing shall be recorded and include, at a minimum, the following:

4.7.1 Range of ambient temperature during the test;

4.7.2 Range of wind velocity during the test;

4.7.3 Range of wind direction during the test.

Bounding values shall be recorded in Appendix A.

4.7 A description of the test route, road surface type and condition (SAE J688, "Truck Ability Prediction Procedure"), and lengths and grades of test route, shall be recorded in Appendix A.

4.8 The date and starting and ending times shall be recorded in Appendix A

4.9 The starting and ending vehicle odometer readings shall be recorded in Appendix A.

4.10 The type of fuel used for the test shall be recorded in Appendix A.

NOTE

When switching fuels, the vehicle shall be operated for a minimum of 20 miles under varying load conditions to allow the fuel management system to adapt to the new fuel.

4.11 All instrumentation used in the test shall be listed on Appendix B, attached to the test data sheets/results, and shall include the following information:

4.12.1 Manufacturer

4.12.2 Model Number

4.12.3 Serial Number

4.12.4 Last Calibration date

4.12.5 Next Calibration date

4.12 The speed-time measuring device and other necessary equipment shall be installed so that they do not hinder vehicle operation or alter the operating characteristics of the vehicle. Mounting will nominally be at the rear of the vehicle.

4.13 Any deviation from the test procedure, and the reason for the deviation, shall be recorded in accordance with ETA-YAC002.

4.14 All documentation required to complete the testing shall be completed, approved and issued prior to commencing the testing it addresses.

4.15 During data reduction, the time to specific speeds and the speed at a distance of one mile shall be determined and recorded.

5.0 Test Activity Requirements

This section selectively implements portions of SAE J1666 AUG99 to determine vehicle acceleration on a level road

NOTE

Activities necessary to complete the test are identified in the following sections. All items shall be completed, whether they are required by J1666 or not. Any section which cannot be completed shall be so annotated, along with the appropriate justification in accordance with ETA-YAC002, “Control of Test Conduct,” on Appendix A.

NOTE

In this section, vehicles will be tested twice, with each test consisting of two acceleration runs (one in each direction on the test road).

5.1 Record information concerning the vehicle being tested in Appendix A.

5.2 Instrument the vehicle to obtain, at a minimum, the data identified in Section 4.6. Calibrate the fifth wheel, as necessary.

5.3 Determine the maximum speed to be achieved and record this value in Appendix A.

5.4 Adjust the vehicle's cold tire pressures to match the manufacturer's placard value, or the maximum cold inflation pressure imprinted upon the tire's sidewall, whichever is less.

5.5 Operate the vehicle for a minimum of 10 miles to allow the engine and fluids to reach operating temperature.

5.6 Record time of test commencement and the vehicle's odometer reading on Appendix A and start the onboard DAS. Accessories shall not be used during testing activities.

NOTE

At least the last 3000 feet of the track for this test shall be straightaway.

5.7 From a standing start, accelerate the vehicle at its maximum attainable acceleration or the manufacturer's maximum permissible acceleration rate(s) (whichever is less) until the target speed has been exceeded or the vehicle has traveled one mile, whichever occurs first. Note the speed achieved and the time required to achieve it on Appendix A. [If the data is being accumulated into a DAS, this data may be transcribed subsequent to the data download.]

5.8 Reverse the direction of travel on the test track.

5.9 The maximum time interval between the completion of the acceleration portion of one run to the beginning of the next successive run shall not exceed 5 minutes. Record elapsed time on Appendix A. [If the data is being accumulated into a DAS, this time interval may be transcribed subsequent to the data download.]

5.10 From a standing start, accelerate the vehicle at its maximum attainable acceleration or the manufacturer's maximum permissible acceleration rate(s) (whichever is less) until the target speed has been exceeded or the vehicle has traveled one mile, whichever occurs first. Note the speed achieved and the time required to achieve it on Appendix A. [If the data is being accumulated into a DAS, this data may be transcribed subsequent to the data download.]

5.11 Record completion of this test portion on Appendix A and reverse the direction of travel on the test track.

5.12 From a standing start, accelerate the vehicle at its maximum attainable acceleration or the manufacturer's maximum permissible acceleration rate(s) (whichever is less) until the target speed has been exceeded or the vehicle has traveled one mile, whichever occurs first. Note the speed achieved and the time required to achieve it in Appendix A. [If the data is being accumulated into a DAS, this data may be transcribed subsequent to the data download.]

5.13 Reverse the direction of travel on the test track.

5.14 The maximum time interval between the completion of the acceleration portion of one run to the beginning of the next successive run shall not exceed 5 minutes.

Record elapsed time on Appendix A. [If the data is being accumulated into a DAS, this time interval may be transcribed subsequent to the data download.]

5.15 From a standing start, accelerate the vehicle at its maximum attainable acceleration or the manufacturer's maximum permissible acceleration rate(s) (whichever is less) until the target speed has been exceeded or the vehicle has traveled one mile, whichever occurs first. Note speed achieved and time required to achieve in Appendix A.

5.16 Record completion of this test section in Appendix A.

6.0 Data Reduction and Acceptability Criteria

6.1 The requirements for data reduction are specifically addressed in Section 9 of SAE J1263. Refer to that standard for these techniques.

6.2 Acceptability requirements are presented in Section 9.4 of SAE J1634.

6.3 Distribution, retention and destruction of all test documents shall be in accordance with the requirements identified in Procedure ETA-YAC001, "Control, Close-out and Storage of Documentation."

7.0 Glossary

7.1 Curb Weight - The total weight of the vehicle including fuel tanks, lubricants and other expendable supplies, but excluding the driver, passengers, and other payloads.

7.2 Effective Date - The date, after which a procedure has been reviewed and approved, that the procedure can be utilized in the field for official testing.

7.3 Fifth Wheel - A calibrated mechanical instrument used to measure a vehicle's speed and distance independent of the vehicles on-board systems.

7.4 Gross Vehicle Weight Rating - The maximum design loaded weight of the vehicle specified by the manufacturer.

7.5 Initial Conditions - Conditions that shall exist prior to an event occurring.

7.6 Prerequisites - Requirements that shall be met or resolved prior to an event occurring.

7.7 Program Manager - As used in this procedure, the individual within Electric Transportation Applications responsible for oversight of the HFV America Performance Test Program. [Subcontract organizations may have similarly titled individuals, but they are not addressed by this procedure.]

7.8 Shall - Items which require adherence without deviation. Shall statements identify binding requirements. A go, no-go criterion.

7.9 Should - Items which require adherence if at all possible. Should statements identify preferred conditions.

7.10 Test Director - The individual within Electric Transportation Applications responsible for all testing activities associated with the HFV America Performance Test Program.

7.11 Test Director's Log - A daily diary kept by the Test Director, Program Manager, Test Manager or Test Engineer to document major activities and decisions that occur during the conduct of a Performance Test Evaluation Program. This log is normally a running commentary, utilizing timed and dated entries to document the days activities. This log is edited to develop the Daily Test Log published with the final report for each vehicle.

7.12 Test Engineer - The individual(s) assigned responsibility for the conduct of any given test. [Each contractor/subcontractor should have at least one individual filling this position. If so, they shall be responsible for adhering to the requirements of this procedure.]

7.13 Test Manager - The individual within Electric Transportation Applications responsible for the implementation of the test program for any given vehicle(s) being evaluated to the requirements of the HFV America Performance Test Program. [Subcontract organizations may have similarly titled individuals, but they are not addressed by this procedure.]

8.0 References

8.1 SAE Recommended Practice - "Electric Vehicle Acceleration, Gradeability, and Deceleration Test Procedure" SAE J1666, AUG99

8.2 "HFV America Technical Requirements," dated May 15, 2001

8.3 ETA-YAC001, "Control, Close-out and Storage of Documentation"

8.4 ETA-YAC002, "Control of Test Conduct"

8.5 ETA-YAC004, "Review of Test Results"

8.6 ETA-YAC005, "Qualifications, Certifications & Training of Test Personnel"

8.7 ETA-YAC006, "Vehicle Verification"

8.8 ETA-YAC007, "Control of Measuring and Test Equipment"

8.9 ETA-YTP004, "Constant Speed Range Test"

8.10 ETA-YTP011, "Receipt Inspection"

APPENDIX-A

Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet

(Page 1 of 4)

VIN Number: _____

Project No.:	Test Date(s):
Root File No.:	
Test Driver: (Initials) (Date)	
Test Engineer: (Initials) (Date)	

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Curb weight plus 332 pounds)			
Left Front: (lbs or kg)	Right Front: (lbs or kg)	Total Front: (lbs or kg)	Percent Front: %
Left Rear: (lbs or kg)	Right Rear: (lbs or kg)	Total Rear: (lbs or kg)	Percent Rear: %
		Total Weight: (lbs or kg)	

INSTALLED TIRES (Placard or sidewall whichever is less)			
Preparation Area Temperature: (°F or °C)			
Left Front		Right Front	
Pressure: (psi or kPa)		Pressure: (psi or kPa)	
Left Rear		Right Rear	
Pressure: (psi or kPa)		Pressure: (psi or kPa)	

Track/Weather Conditions

Test Track Location:	Track Grade: % (Within 1%)
Ambient Temperature (initial): (40-90°F or 5-32°C)	Ambient Temperature (final): (40-90°F or 5-32°C)
Track Temperature (initial): (°F or °C)	Track Temperature (final): (°F or °C)
Wind Velocity (initial): (<10 mph or 16 km/h)	Wind Velocity (final): (<10 mph or 16 km/h)
Wind Direction (initial): °	Wind Direction (completion): °

APPENDIX-A

Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet

(Page 2 of 4)

VIN Number:_____

Sequence No: 1	File No.:	Direction of Travel:
Time (initial):	Time (final):	
Odometer (initial): (miles or kilometers)	Odometer (final): (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		% H_2
Comments (initials/date):		
Sequence No: 2	File No.:	Direction of Travel:
Time (initial):	Time (final):	
Odometer (initial): (miles or kilometers)	Odometer (final): (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		% H_2
Comments (initials/date):		

APPENDIX-A

Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet

(Page 3 of 4)

VIN Number:_____

Sequence No: 3	File No.:	Direction of Travel:
Time (initial):	Time (final):	
Odometer (initial): (miles or kilometers)	Odometer (final): (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		% H_2
Comments (initials/date):		
Sequence No: 4	File No.:	Direction of Travel:
Time (initial):	Time (final):	
Odometer (initial): (miles or kilometers)	Odometer (final): (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		% H_2
Comments (initials/date): *s*		

APPENDIX-A

Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet

(Page 4 of 4)

VIN Number:_____

General Comments (initials/date):

Completed By:	(Printed Name)	(Signature)	(Date)
Reviewed By:	(Printed Name)	(Signature)	(Date)
Approved By:	(Printed Name)	(Signature)	(Date)

APPENDIX-B

Vehicle Metrology Setup Sheets

(Page 1 of 1)

VIN Number: _____

Instrument/Device:	Calibration Due Date:	Initials / Date:
Fifth Wheel S/N:		
Fifth Wheel Calibrator S/N:		
DAS S/N:		
DAS Set-up Sheet S/N		
Tire Pressure Gauge S/N:		
Misc:		
Misc:		
Misc:		
Misc:		

Comments (initials/date):

Completed By:

(Printed Name) (Signature) (Date)

Reviewed By (QA):

(Printed Name) (Signature) (Date)

Attachment 2 - Hydrogen ICE Vehicle Constant Speed Fuel Economy Tests

ETA-YTP002
Revision 0
Effective May 15, 2003

Prepared by

Electric Transportation Applications

Appendix 2

ETA-YTP002

Revision 0

Effective May 15, 2003

Hydrogen ICE Vehicle Constant Speed Fuel Economy Tests

Prepared by

Electric Transportation Applications

Prepared by: _____ **Date:**_____
Bill Short

Approved by: _____ **Date:** _____
Don Karner

TABLE OF CONTENTS

1.0 Objective

The objective of this procedure is to identify proper methods for the control of constant speed fuel economy testing, pursuant to SAE-J1082 JUN95. These methods are not meant to supersede those of the testing facility, those specifically addressed by SAE Test Standards, nor of any regulatory agency who may have or exercise control over the covered activities.

2.0 Purpose

The purpose of this procedure is to identify acceptable methods for the implementation of a constant speed range test. SAE J1082 JUN95 establishes uniform procedures for testing internal combustion vehicle fuel economy. Testing conducted in accordance with this procedure is similar to that identified in SAE J1082 JUN95, with the exception of using a constant speed driving schedule. This procedure shall collect and retain test data as specified in the HFV America Technical Requirements.

3.0 Documentation

Documentation addressed by this procedure shall be consistent, easy to understand, easy to read and readily reproducible. This documentation shall contain enough information to "stand alone"; that is, be self-contained to the extent that all individuals qualified to review it could be reasonably expected to reach a common conclusion, without the need to review additional documentation. Review and approval of test documentation shall be in accordance with ETA-YAC004, "Review of Test Results." Storage and retention of records during and following testing activities shall be completed as described in Procedure ETA-YAC001, "Control, Close-out and Storage of Documentation."

4.0 Initial Conditions and Prerequisites

Prior to conduct of any portion of the testing, the following initial conditions and prerequisites shall be met. Satisfactory completion of these items shall be verified as complete and recorded on the Vehicle Test Data Sheet.

4.1 Personnel conducting testing under this procedure shall be familiar with the requirements of this procedure, and when applicable the appropriate SAE Test Instructions, Administrative Control Procedures, and be certified by the Program Manager, Test Manager or specific Test Engineer prior to commencing any testing activities.

4.2 All documentation required to complete the testing shall be completed, approved and issued (past it's effective date) prior to commencing the testing it addresses.

4.3 Test Conditions

4.3.1 The test road must be a closed course consisting of dry, clean and smooth roads not exceeding 1.0% grade

4.3.2 Ambient temperature during road testing shall be within the range of 50°F to 100°F (-1°C to 38°C) - Note this is a deviation from SAE J1082 JUN95.

4.3.3 The average wind speed at the test site during the test shall not exceed 10 mph (16 km/h). Wind gusts shall not exceed 20 mph (32 kph) during the test.

4.4 Test Vehicle Preparation

4.4.1 The vehicle should have accumulated a minimum of 2,000 miles (3,200 km) of operation prior to test. At least 1,000 (1,600 km) of these miles must have been driven at speeds above 40 mph (64 kph).

4.4.2 Tires shall have been operated for at least 100 miles (160 km) prior to test and shall have at least 75% of the tread remaining and in good condition. Tires provided with the vehicle shall be the standard tire offered by the vehicle manufacturer, and shall be inflated to the manufacturer's (placard) recommended cold inflation pressures prior to test. This pressure shall not exceed the maximum allowable pressure imprinted upon the tire's sidewall.

4.4.3 Vehicle shall be tested in its normal configuration with normal appendages (mirrors, bumpers, hubcaps, etc.).

4.4.4 Vehicles shall be tested at curb weight plus 332 pounds. - Note this is a deviation from SAE J1082 JUN95. Consideration should be given to how adding instrumentation will affect the test weight and balance of the vehicle.

4.4.5 Normal manufacturer's recommended lubricants shall be employed.

4.5 The following data shall be collected during conduct of the test specified by this procedure. Overall error in recording or indicating instruments shall not exceed ±2% of the maximum value of the variable being measured. Periodic calibration shall be performed and documented to ensure compliance with this requirement.

4.5.1 Fuel pressure and fuel temperature prior to testing

4.5.2 Vehicle speed versus time

4.5.3 Distance versus time

4.5.4 Fuel pressure and fuel temperature after testing

Vehicle speed and distance versus time data shall be collected using an onboard Data Acquisition System (DAS).

4.6 Environmental conditions during the testing shall be recorded and include, at a minimum, the following:

4.6.1 Range of ambient temperature during the test;

4.6.2 Range of wind velocity during the test;

4.6.3 Range of wind direction during the test.

Bounding values shall be recorded in Appendix A.

4.7 Verify that Procedures ETA-YAC006, "Vehicle Verification," and ETA-YTP011, "Receipt Inspection," have been completed. This requirement shall be waived if the vehicle is being tested outside the HFV America Program.

4.8 A description of the test route, road surface type and condition (SAE J688, "Truck Ability Prediction Procedure"), and lengths and grades of test route, shall be recorded in Appendix A.

4.9 The date and starting and ending times shall be recorded in Appendix A

4.10 The starting and ending vehicle odometer readings shall be recorded in Appendix A.

4.11 The type of fuel used for the test shall be recorded in Appendix A.

NOTE

When switching fuels, the vehicle shall be operated for a minimum of 20 miles under varying load conditions to allow the fuel management system to adapt to the new fuel.

4.12 All instrumentation used in the test shall be listed on Appendix B, attached to the test data sheets/results, and shall include the following information:

4.12.1 Manufacturer

4.12.2 Model Number

4.12.3 Serial Number

4.12.4 Last Calibration date

4.12.5 Next Calibration date

4.13 The speed-time measuring device and other necessary equipment shall be installed so that they do not hinder vehicle operation or alter the operating characteristics of the vehicle. Mounting will nominally be at the rear of the vehicle.

4.14 Any deviation from the test procedure, and the reason for the deviation, shall be recorded in accordance with ETA-YAC002.

4.15 All documentation required to complete the testing shall be completed, approved and issued prior to commencing the testing it addresses.

4.16 During data reduction, the actual distance traveled and the corresponding fuel consumption shall be determined.

4.17 Each Fuel Economy Test shall be terminated when the specific requirements of section 5.9 have been reached. However, if the manufacturer's instructions provide guidance about when to stop driving the vehicle, this guidance shall take precedence in all circumstances.

5.0 Testing Activities Requirements

5.1 Range at 45 mph Constant Speed

The purpose of this section is to determine fuel economy with the vehicle loaded at curb weight plus 332 pounds, and operated at a constant 45 mph.

This testing shall be completed subject to the initial conditions and prerequisites stated in Section 4 of this procedure.

NOTE

All steps shall be completed in the order written. Deviations from any step or requirement shall have the approval of the Program Manager or Test Manager in accordance with Procedure ETA-YAC002, "Control of Test Conduct."

5.1 Record information concerning the vehicle being tested in Appendix A.

5.2 Instrument the vehicle to obtain, at a minimum, the data identified in Section 4.5. Calibrate the fifth wheel, as necessary.

5.3 Record fuel pressure and temperature of the fuel tank to be used for constant speed fuel economy testing after soaking the vehicle for 6 hours in a constant temperature area. Tank temperature shall be measured by a thermocouple attached to the tank exterior approximately mid tank (long dimension). The temperature of the tank shall be within 1˚C of the air temperature in the immediate vicinity of the tank and the air temperature approximately four (4) feet from the tank. Isolate the fuel tank to be used for constant speed fuel economy testing until commencement of step 5.7.

5.4 Adjust the vehicle's cold tire pressures to match the manufacturer's placard value, or the maximum cold inflation pressure imprinted upon the tire's sidewall, whichever is less.

5.5 Operate the vehicle for a minimum of 10 miles to allow the engine and fluids to reach operating temperature.

5.6 Switch the vehicle fuel supply to the tank isolated in step 5.3. Record time of test commencement and the vehicle's odometer reading on Appendix A and start the onboard DAS. Accessories shall not be used during testing activities.

5.7 From a standing start, accelerate the vehicle under its own power to a speed of 45 mph ±1 mph (72 km/h ±1.6 km/h).

5.8 Each time the vehicle passes the lap marker, record the odometer reading. Each reading shall be recorded in the smallest increment displayed by its respective indicator.

NOTE

All vehicle's tested will be operated in accordance with the requirements of the Manufacturer's operating manuals/instruction cards/placards. Should the manufacturer's requirements for stopping the vehicle be met prior to reaching the criteria in Step 5.9, the test shall be terminated. The Official Range will be the range achieved at that point, regardless of remaining capability.

5.9 Maintain this speed without interruption until the vehicle travels at least 60 miles (100 km).

5.10 Pull the vehicle off to the side of the test track Record the final odometer reading and time on Appendix A. (This may be recorded via a DAS).

5.11 The vehicle shall not be driven more than 0.3 miles or 0.5% of the test distance, whichever is greater, prior to completing step 5.12. As an alternative, the fuel

tank used for the constant speed range test may be isolated and the vehicle driven using a supplemental fuel supply.

5.12 Record fuel pressure and temperature of the fuel tank to be used for constant speed fuel economy testing after soaking the vehicle for 6 hours in a constant temperature area. Tank temperature shall be measured by a thermocouple attached to the tank exterior approximately mid tank (long dimension). The temperature of the tank shall be within 1˚C of the air temperature in the immediate vicinity of the tank and the air temperature approximately four (4) feet from the tank.

5.13 Calculate the quantity (moles) of fuel consumed using the following formula.

$$\Delta n = (P_{initial} * V_{initial}) / (\zeta * R * T_{initial}) - (P_{final} * V_{final} / \zeta * R * T_{final})$$

where;

R = Universal Gas Constant

ζ = Compressibility Factor

5.14 Calculate the quantity (gge) of fuel consumed using the following formula.

$$Q = \Delta n * EMW / ACC$$

where;

EMW = Effective Molecular Weight of the fuel

ACC = Average Conversion Constant for the fuel

5.15 Calculate the constant speed fuel economy (miles/gge) using the following formula.

$$FE = (ODOMETER_{initial} - ODOMETER_{final}) / Q$$

5.16 For convenience and accuracy, the equations used in Sections 5.13 through 5.15 have been incorporated into a MicroSoft Excel® spreadsheet. The file name for this spreadsheet is "ETA-YTP002 (Fuel Use Calculator)" and is marked as Revision 0. A sample print from this spreadsheet is attached as Appendix C.

6.0 GLOSSARY

6.1 Curb Weight - The total weight of the vehicle including fuel tanks, lubricants and other expendable supplies, but excluding the driver, passengers, and other payloads.

6.2 Effective Date - The date, after which a procedure has been reviewed and approved, that the procedure can be utilized in the field for official testing.

6.3 Fifth Wheel - A calibrated instrument used to measure a vehicle's speed and distance independent of the vehicles on-board systems.

6.4 Gross Vehicle Weight Rating (GVWR) - The maximum design loaded weight of the vehicle specified by the manufacturer.

6.5 Initial Conditions - Conditions that shall exist prior to an event occurring.

6.6 Prerequisites - Requirements that must be met or resolved prior to an event occurring.

6.7 Program Manager - As used in this procedure, the individual within Electric Transportation Applications responsible for oversight of the HFV America Performance Test Program. [Subcontract organizations may have similarly titled individuals, but they are not addressed by this procedure.]

6.8 Shall - This word is used to indicate an item which requires adherence without deviation. Shall statements identify binding requirements. A go, no-go criterion.

6.9 Should - This word is used to identify an item which requires adherence if at all possible. Should statements identify preferred conditions.

6.10 Test Director - The individual within Electric Transportation Applications responsible for all testing activities associated with the HFV America Performance Test Program.

6.11 Test Director's Log - A daily diary kept by the Test Director, Program Manager, Test Manager or Test Engineer to document major activities and decisions that occur during the conduct of a Performance Test Evaluation Program. This log is normally a running commentary, utilizing timed and dated entries to document the day's activities. This log is edited to develop the Daily Test Log published with the final report for each vehicle.

6.12 Test Engineer - The individual(s) assigned responsibility for the conduct of any given test. [Each contractor/subcontractor should have at least one individual filling this position. If so, they shall be responsible for adhering to the requirements of this procedure.]

6.13 Test Manager - The individual within Electric Transportation Applications responsible for the implementation of the test program for any given vehicle(s) being evaluated to the requirements of the HFV America Performance Test Program. [Subcontract organizations may have similarly titled individuals, but they are not addressed by this procedure.]

7.0 REFERENCES

7.1 HFV America Vehicle Technical Specifications

7.2 ETA-YAC001, Revision 0 - "Control, Close-out and Storage of Documentation"

7.3 ETA-YAC002, Revision 0 - "Control of Test Conduct"

7.4 ETA-YAC004, Revision 0 - "Review of Test Results"

7.5 ETA-YAC006, Revision 0 - "Vehicle Receipt"

7.6 ETA-YAC007, Revision 0 - "Control of Measuring and Test Equipment"

7.7 ETA-YTP002, Revision 0 - "Implementation of SAE Standard J1666 May 93, Electric Vehicle Acceleration, Gradeability and Deceleration Test Procedure"

7.8 ETA-YTP011, Revision 0 - "Receipt Verification"

7.9 SAE Standard J1082 JUN95

7.10 SAE Standard J1515 JUN95

APPENDIX-A

45 mph Constant Speed Fuel Economy Test Data Sheet

(Page 1 of 2)

VIN Number: _____

Project No.:	Test Date(s):
Root File No.:	
Test Driver: (Initials) (Date)	
Test Engineer: (Initials) (Date)	

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Test Weight is Curb Weight plus 332 pounds)			
Left Front: (lbs or kg)	Right Front: (lbs or kg)	Total Front: (lbs or kg)	Percent Front: %
Left Rear: (lbs or kg)	Right Rear: (lbs or kg)	Total Rear: (lbs or kg)	Percent Rear: %
		Total Weight: (lbs or kg)	

INSTALLED TIRES (Placard or sidewall whichever is less)			
Preparation Area Temperature: (°F or °C)			
Left Front		Right Front	
Pressure: (psi or kPa)		Pressure: (psi or kPa)	
Left Rear		Right Rear	
Pressure: (psi or kPa)		Pressure: (psi or kPa)	

Track/Weather Conditions

Test Track Location:	Track Grade: %
Ambient Temperature (initial): (40-100°F or 5-38°C)	Ambient Temperature (final): (40-100°F or 5-38°C)
Track Temperature (initial): (°F or °C)	Track Temperature (final): (°F or °C)
Wind Velocity (initial): (<10 mph or 16 km/h)	Wind Velocity (final): (<10 mph or 16 km/h)
Wind Direction (initial): °	Wind Direction (completion): °

APPENDIX-A

45 mph Constant Speed Fuel Economy Test Data Sheet

(Page 2 of 2)

VIN Number _____

Sequence No:	File No.:	Direction of Travel:
Time (initial):	Time (final):	
Odometer (initial): (miles or kilometers)	Odometer (final): (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		% H_2
Tank Pressure (initial):	Tank Pressure (final):	
Tank Temperature (initial):	Tank Temperature (final):	
Comments (initials/date):		
Completed By: (Printed Name)	(Signature)	(Date)
Reviewed By: (Printed Name)	(Signature)	(Date)
Approved By: (Printed Name)	(Signature)	(Date)

APPENDIX-B

Vehicle Metrology Setup Sheets

(Page 1 of 1)

VIN Number: _____

Instrument/Device:	Calibration Due Date:	Initials / Date:
Fifth Wheel S/N:		
Fifth Wheel Calibrator S/N:		
DAS S/N:		
DAS Set-up Sheet S/N		
kWh Meter S/N:		
Shunt S/N:		
Tire Pressure Gauge S/N:		
Fuel Pressure Gauge S/N:		
Fuel Temperature Meter S/N:		
Misc:		
Misc:		
Comments (initials/date):		
Completed By: (Printed Name)	(Signature)	(Date)
Reviewed By (QA): (Printed Name)	(Signature)	(Date)
Approved By: (Printed Name)	(Signature)	(Date)

APPENDIX-C

Fuel Use Calculation Using Spreadsheet ETA-YTP002 (Fuel Use Calculator)

SAMPLE

File Name: ETA-YTP002 (Fuel Use Calculator) **Revision; 0**
Calculations for Fuel Economy

Assumptions		
Assumed LHV for H2	51,608	Btu/lb (LHV)
Assumed LHV for CH4	21,480	Btu/lb (LHV)
Assumed curve fit of Z for H2 (pressure in psi	Z=2E-12P^3+2E-8P^2+1E-5P+.9974	
Assumed curve fit of Z for CH4 (pressure in p	Z=3E-8P^2-1E-4P+.9914	

Test Number	ETA-06-002
Test Date	6/3/2003
Test Engineer	B.S.

Input Parameters

Input Gasoline Energy per Gallon	122,000	Btu/gallon (LHV)		
Input Molar Percentage H2	0.3	%		
Input Tank Volume	85	liters	3.00	ft^3
Input Initial Pressure	3220	psig		
Input Initial Temperatue	81.0	Fahrenheit	541.0	Rankine
Input Final Pressure	1520	psig		
Input Final Temperature	74.1	Fahrenheit	534.1	Rankine
Input Distance Traveled	60	Miles		

Output Parameters

Initial Gasoline Gallons Equivalent	3.92	GGE
Final Gasoline Gallons Equivalent	1.65	GGE
Gasoline Gallons Equivalent Used	2.27	GGE
Miles Per Gasoline Gallon Equival	26.48	Miles per GGE

Claculations

H2 Mass Percentage	0.050847	%			
Initial Pressure	3220	psig	465796.8	psf	
Z for H2	1.021526				
Z for CH4	0.918415				
Molar Ratio (H2/CH4)	0.428571				
Pressure Ratio (H2/CH4)	0.476687				
Partial Pressure of H2	1044.189	psi	150363.2	psf	966 Perfect gas partial pressure (used for calculating Z)
Partial Pressure of CH4	2190.511	psi	315433.6	psf	2254 Perfect gas partial pressure (used for calculating Z)
Total Initial Pound Moles	1.760966				
Initial H2 Weight	1.05658	lbs			
Initial CH4 Weight	19.72282	lbs			
Initial Energy of H2	54527.97	Btu			
Initial Energy of CH4	423646.2	Btu			
Initial Total Energy	478174.2	Btu			
Final Pressure	1520	psig	220996.8	psf	
Z for H2	1.006308				
Z for CH4	0.885032				
Molar Ratio (H2/CH4)	0.428571				
Pressure Ratio (H2/CH4)	0.487299				
Partial Pressure of H2	502.8294	psi	72407.43	psf	456 Perfect gas partial pressure (used for calculating Z)
Partial Pressure of CH4	1031.871	psi	148589.4	psf	1064 Perfect gas partial pressure (used for calculating Z)
Total Final Pound Moles	0.742973				
Initial H2 Weight	0.445784	lbs			
Final CH4 Weight	8.321302	lbs			
Final Energy of H2	23006.02	Btu			
Final Energy of CH4	178741.6	Btu			
Final Total Energy	201747.6	Btu			

Attachment 3 - Hydrogen ICE Vehicle Acceleration Testing Data Sheets

Test Data Sheets Form
Conduct of ETA-YTP001, Revision 0

Implementation of
SAE Standard J1666 AUG99

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 1 of 4)

VIN Number: 1FTPF17m8YKB39272

Project No.: ETA-06-25-01	Test Date(s): 6/25/03
Root File No.:	
Test Driver: Biel Short BS (Initials)	(Date) 6/25/03
Test Engineer: BS (Initials)	(Date) 6/25/03

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Curb weight plus 332 pounds)			
Left Front: 1363 lbs. (lbs or kg)	Right Front: 1441 lbs. (lbs or kg)	Total Front: 2804 lbs. (lbs or kg)	Percent Front: 53.7%
Left Rear: 1228 lbs. (lbs or kg)	Right Rear: 1203 lbs. (lbs or kg)	Total Rear: 2431 lbs. (lbs or kg)	Percent Rear: 46.3%
		Total Weight: 5235 lbs (lbs or kg)	

INSTALLED TIRES (Placard or sidewall whichever is less)			
Preparation Area Temperature: (°F or °C)			
Left Front		Right Front	
Pressure: 65 psi (psi or kPa)		Pressure: 65 psi (psi or kPa)	
Left Rear		Right Rear	
Pressure: 65 psi (psi or kPa)		Pressure: 65 psi (psi or kPa)	

Track/Weather Conditions

Test Track Location: DC APG Straightaway		Track Grade: ± 1 % (Within 1%)	
Ambient Temperature (initial):	72.3 °F (40-90°F or 5-32°C)	Ambient Temperature (final):	75.4 °F (40-90°F or 5-32°C)
Track Temperature (initial):	76.3 °F (°F or °C)	Track Temperature (final):	76.9 °F (°F or °C)
Wind Velocity (initial):	2.5 mph (<10 mph or 16 km/h)	Wind Velocity (final):	2.2 °F (<10 mph or 16 km/h)
Wind Direction (initial):	328 °	Wind Direction (completion):	314 °

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 2 of 4)

VIN Number: 1FTPF17M8YKB39272

Sequence No: 1	File No.: ETA-06-25-01	Direction of Travel: E
Time (initial): 6:31 a.m.	Time (final): 6:33 a.m.	
Odometer (initial): 32451.9 miles (miles or kilometers)	Odometer (final): 32454.4 miles (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		0 % H_2
Comments (initials/date):		

Sequence No: 2	File No.: ETA-06-25-01	Direction of Travel: W
Time (initial): 6:37 a.m.	Time (final): 6:40 a.m.	
Odometer (initial): 32454.4 miles (miles or kilometers)	Odometer (final): 32456.8 miles (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		0 % H_2
Comments (initials/date):		

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 3 of 4)

VIN Number: 1FTPF17M8YKB39272

Sequence No: 3	File No.: ETA-06-25-01	Direction of Travel: E
Time (initial): 6:41 a.m.		Time (final): 6:44 a.m.
Odometer (initial): 32456.8 miles (miles or kilometers)		Odometer (final): 32459.3 miles (miles or kilometers)
Vehicle Fuel (% Hydrogen by Volume):		0 % H_2
Comments (initials/date):		

Sequence No: 4	File No.: ETA-06-25-01	Direction of Travel: W
Time (initial): 6:45 a.m.		Time (final): 6:48 a.m.
Odometer (initial): 32459.3 miles (miles or kilometers)		Odometer (final): 32461.7 miles (miles or kilometers)
Vehicle Fuel (% Hydrogen by Volume):		0 % H_2
Comments (initials/date):		

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 4 of 4)

VIN Number: 1FTPF17M8YKB39272

General Comments (initials/date):			
Completed By:	Bill Short (Printed Name)	Bill Short (Signature)	6/26/03 (Date)
Reviewed By:	DBLarner (Printed Name)	DBL (Signature)	8/27/03 (Date)
Approved By:	DBLarner (Printed Name)	DBL (Signature)	8/27/03 (Date)

APPENDIX-B

Vehicle Metrology Setup Sheets
(Page 1 of 1)

VIN Number: 1FTPF17M8YKB39272

Instrument/Device:	Calibration Due Date:	Initials / Date:
Fifth Wheel S/N: 01359	5-19-04	6/26/03
Fifth Wheel Calibrator S/N:	not applicable	6/26/03
DAS S/N:	not applicable	6/26/03
DAS Set-up Sheet S/N	not applicable	6/26/03
Tire Pressure Gauge S/N:	not applicable	6/26/03
Misc:		
Misc:		
Misc:		
Misc:		

Comments (initials/date):

Completed By:	Bill Short (Printed Name)	Bill Short (Signature)	6/26/03 (Date)
Reviewed By (QA):	DB Kramer (Printed Name)	DBK (Signature)	8/27/03 (Date)

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 1 of 4)

VIN Number: 1FTPF17M8YKB39272

Project No.: ETA-06-11-01	Test Date(s): 6/11/03
Root File No.:	
Test Driver: Bill Short (Initials) BS	(Date) 6/11/03
Test Engineer: (Initials) BS	(Date) 6/11/03

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Curb weight plus 332 pounds)			
Left Front: 1363 lbs (lbs or kg)	Right Front: 1441 lbs (lbs or kg)	Total Front: 2804 lbs (lbs or kg)	Percent Front: 53.7%
Left Rear: 1228 lbs (lbs or kg)	Right Rear: 1203 lbs (lbs or kg)	Total Rear: 2431 lbs (lbs or kg)	Percent Rear: 46.3%
		Total Weight: 5235 lbs (lbs or kg)	

INSTALLED TIRES (Placard or sidewall whichever is less)			
Preparation Area Temperature: (°F or °C)			
Left Front		Right Front	
Pressure: 65 psi (psi or kPa)		Pressure: 65 psi (psi or kPa)	
Left Rear		Right Rear	
Pressure: 65 psi (psi or kPa)		Pressure: 65 psi (psi or kPa)	

Track/Weather Conditions

Test Track Location: DCAPG Straightaway		Track Grade: ±1 % (Within 1%)	
Ambient Temperature (initial):	74°F (40-90°F or 5-32°C)	Ambient Temperature (final):	75°F (40-90°F or 5-32°C)
Track Temperature (initial):	78.9 F (°F or °C)	Track Temperature (final):	80.5°F (°F or °C)
Wind Velocity (initial):	3.6 mph (<10 mph or 16 km/h)	Wind Velocity (final):	4.3 mph (<10 mph or 16 km/h)
Wind Direction (initial):	— °	Wind Direction (completion):	— °

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 2 of 4)

VIN Number: 1FTPF17M8YKB39272

Sequence No: 1	File No.: ETA-06-11-01	Direction of Travel: W
Time (initial): 6:47	Time (final): 6:48	
Odometer (initial): 31943.3 (miles or kilometers)	Odometer (final): 31945.4 (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		15 % H_2
Comments (initials/date):		
Sequence No: 2	File No.: ETA-06-11-01	Direction of Travel: E
Time (initial): 6:49	Time (final): 6:52	
Odometer (initial): 31945.4 (miles or kilometers)	Odometer (final): 31946.6 (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		15% H_2
Comments (initials/date):		

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 3 of 4)

VIN Number: 1FTPF17M8YKB39272

Sequence No: 3	File No.: ETA-06-11-01	Direction of Travel: W
Time (initial): 6:40	Time (final): 6:41	
Odometer (initial): 31940.0 (miles or kilometers)	Odometer (final): 31941.2 (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		15 % H_2
Comments (initials/date):		
Sequence No: 4	File No.: ETA-06-11-01	Direction of Travel: E
Time (initial): 6:43	Time (final): 6:44	
Odometer (initial): 31941.3 (miles or kilometers)	Odometer (final): 31942.4 (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		15 % H_2
Comments (initials/date):		

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 4 of 4)

VIN Number: 1FTPF17M8YKB39272

General Comments (initials/date):

	(Printed Name)	(Signature)	(Date)
Completed By:			
Reviewed By:			
Approved By:	DB Kamer		8/27/03

APPENDIX-B

Vehicle Metrology Setup Sheets
(Page 1 of 1)

VIN Number: 1FTPF17M8YKB39272

Instrument/Device:	Calibration Due Date:	Initials / Date:
Fifth Wheel S/N: 01359	5-19-04	6/12/03
Fifth Wheel Calibrator S/N:	not applicable	6/12/03
DAS S/N:	not applicable	6/12/03
DAS Set-up Sheet S/N	not applicable	6/12/03
Tire Pressure Gauge S/N:	not applicable	6/12/03
Misc:		
Misc:		
Misc:		
Misc:		

Comments (initials/date):

Completed By:	Bill Short (Printed Name)	Bill Short (Signature)	6/12/03 (Date)
Reviewed By (QA):	D B Karner (Printed Name)	D B (Signature)	8/27/03 (Date)

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 1 of 4)

VIN Number: 1FTPF17M8YKB39272

Project No.: ETA-05-21-01	Test Date(s): 5-21-03
Root File No.:	
Test Driver: William Short W.S (Initials)	(Date) 5/21/03
Test Engineer: (Initials)	(Date) 5/21/03

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Curb weight plus 332 pounds)			
Left Front: 1363 lbs (lbs or kg)	Right Front: 1441 lbs (lbs or kg)	Total Front: 2804 lbs (lbs or kg)	Percent Front: 53.7%
Left Rear: 1228 lbs (lbs or kg)	Right Rear: 1203 lbs (lbs or kg)	Total Rear: 2431 lbs (lbs or kg)	Percent Rear: 46.3 %
		Total Weight: 5235 lbs. (lbs or kg)	

INSTALLED TIRES (Placard or sidewall whichever is less)			
Preparation Area Temperature: (°F or °C)			
Left Front		Right Front	
Pressure: 65 (psi or kPa)		Pressure: 65 (psi or kPa)	
Left Rear		Right Rear	
Pressure: 65 (psi or kPa)		Pressure: 65 (psi or kPa)	

Track/Weather Conditions

Test Track Location: DC APG Straightaway		Track Grade: ± 1 % (Within 1%)	
Ambient Temperature (initial): 91.2 (40-90°F or 5-32°C)		Ambient Temperature (final): 91.7 (40-90°F or 5-32°C)	
Track Temperature (initial): 109.4 (°F or °C)		Track Temperature (final): 113.6 (°F or °C)	
Wind Velocity (initial): 9.9 (≤10 mph or 16 km/h)		Wind Velocity (final): 9.9 (≤10 mph or 16 km/h)	
Wind Direction (initial): — °		Wind Direction (completion): — °	

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 2 of 4)

VIN Number: 1FTPF17m8YKB39272

Sequence No: 1	File No.: ETA-05-21-01	Direction of Travel: E
Time (initial): 9:51	Time (final): 9:53	
Odometer (initial): 31678.9 (miles or kilometers)	Odometer (final): 31679.2 (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		30% H_2
Comments (initials/date):		

Sequence No: 2	File No.: ETA-05-21-01	Direction of Travel: W
Time (initial): 9:57	Time (final): 9:59	
Odometer (initial): 31681.5 (miles or kilometers)	Odometer (final): 31682.7 (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		30% H_2
Comments (initials/date):		

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 3 of 4)

VIN Number: 1FTPF17M8YKB39272

Sequence No: 3	File No.: ETA-05-21-01	Direction of Travel: E
Time (initial): 9:36	Time (final): 9:40	
Odometer (initial): 31675.4 (miles or kilometers)	Odometer (final): 31676.5 (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		30% H_2
Comments (initials/date):		

Sequence No: 4	File No.: ETA-05-21-01	Direction of Travel: W
Time (initial): 9:45	Time (final): 9:48	
Odometer (initial): 31676.6 (miles or kilometers)	Odometer (final): 31677.7 (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		30% H_2
Comments (initials/date):		

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 4 of 4)

VIN Number: 1FTPF17M8YKB39272

General Comments (initials/date):

Completed By:	Bill Short (Printed Name)	Bill Short (Signature)	5/22/03 (Date)
Reviewed By:	DB Karner (Printed Name)	DB (Signature)	8/27/03 (Date)
Approved By:	DB Karner (Printed Name)	DB (Signature)	8/27/03 (Date)

APPENDIX-B

Vehicle Metrology Setup Sheets
(Page 1 of 1)

VIN Number: 1FTPF17M8YKB39272

Instrument/Device:	Calibration Due Date:	Initials / Date:
Fifth Wheel S/N: 01359	5-19-04	BS 6/01/03
Fifth Wheel Calibrator S/N:	not applicable	BS 6/01/03
DAS S/N:	not applicable	BS 6/01/03
DAS Set-up Sheet S/N	not applicable	BS 6/01/03
Tire Pressure Gauge S/N:	not applicable	BS 6/01/03
Misc:		
Misc:		
Misc:		
Misc:		

Comments (initials/date):

Completed By: Bill Short (Printed Name) Bill Short (Signature) 6/01/03 (Date)

Reviewed By (QA): DB Karner (Printed Name) (Signature) 8/27/03 (Date)

Attachment 4 - Hydrogen ICE Vehicle Constant Speed Fuel Economy Testing Data Sheets

Test Data Sheets Form
Conduct of ETA-YTP002, Revision 0

APPENDIX-A
45 mph Constant Speed Fuel Economy Test Data Sheet
(Page 1 of 2)

VIN Number: 1FTPF17M8YKB39272

Project No.: ETA-06-25-02	Test Date(s): 6/25/03
Root File No.:	
Test Driver: Bill Short BS (Initials)	(Date) 6/25/03
Test Engineer: BS (Initials)	(Date) 6/25/03

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Test Weight is Curb Weight plus 332 pounds)			
Left Front: 1363 lbs. (lbs or kg)	Right Front: 1441 lbs. (lbs or kg)	Total Front: 2804 lbs. (lbs or kg)	Percent Front: 53.7 %
Left Rear: 1228 lbs. (lbs or kg)	Right Rear: 1203 lbs. (lbs or kg)	Total Rear: 2431 lbs. (lbs or kg)	Percent Rear: 46.3 %
		Total Weight: 5235 lbs (lbs or kg)	

INSTALLED TIRES (Placard or sidewall whichever is less)			
Preparation Area Temperature: (°F or °C)			
Left Front		Right Front	
Pressure: 65 psi (psi or kPa)		Pressure: 65 psi (psi or kPa)	
Left Rear		Right Rear	
Pressure: 65 psi (psi or kPa)		Pressure: 65 psi (psi or kPa)	

Track/Weather Conditions

Test Track Location: DC APG HighSpeed Oval		Track Grade: 0 %	
Ambient Temperature (initial): 78.1 °F (40-100°F or 5-38°C)		Ambient Temperature (final): 87 °F (40-100°F or 5-38°C)	
Track Temperature (initial): 81.1 °F (°F or °C)		Track Temperature (final): 96.5 °F (°F or °C)	
Wind Velocity (initial): 1.3 mph (<10 mph or 16 km/h)		Wind Velocity (final): 10.7 mph (<10 mph or 16 km/h)	
Wind Direction (initial): 289 °		Wind Direction (completion): 32 °	

APPENDIX-A
45 mph Constant Speed Fuel Economy Test Data Sheet
(Page 2 of 2)

VIN Number 1FTPF17M8YKB39272

Sequence No:	File No.: ETA-026-25-02	Direction of Travel: out
Time (initial): 7:05 a.m.	Time (final): 8:28 a.m	
Odometer (initial): 32465.6 miles (miles or kilometers)	Odometer (final): 32526.3 miles (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		0 % H_2
Tank Pressure (initial): 3060 psi	Tank Pressure (final): 1740 psi	
Tank Temperature (initial): 74.0° F	Tank Temperature (final): 73.8° F	
Comments (initials/date):		

Completed By:	Bill Short (Printed Name)	Bill Short (Signature)	(Date) 6/26/03
Reviewed By:	DBKarner (Printed Name)	DBK (Signature)	(Date) 8/24/03
Approved By:	DBKarner (Printed Name)	DBK (Signature)	(Date) 8/24/03

APPENDIX-B
Vehicle Metrology Setup Sheets
(Page 1 of 1)

VIN Number: 1FTPF17M8YKB39272

Instrument/Device:	Calibration Due Date:	Initials / Date:
Fifth Wheel S/N: 01359	5-19-04	BS 6/26/03
Fifth Wheel Calibrator S/N:	not applicable	BS 6/26/03
DAS S/N:	not applicable	BS 6/26/03
DAS Set-up Sheet S/N	not applicable	BS 6/26/03
kWh Meter S/N:	not applicable	BS 6/26/03
Shunt S/N:	not applicable	BS 6/26/03
Tire Pressure Gauge S/N:	not applicable	BS 6/26/03
Fuel Pressure Gauge S/N:	calibrators invoice: 02-01-05 D0086	BS 6/26/03
Fuel Temperature Meter S/N: 62450031	3-12-04	BS 6/26/03
Misc: Fluke 80TK Thermocouple Module	5-22-04	BS 6/26/03
Misc:		BS 6/26/03

Comments (initials/date):

Completed By:	Bill Short (Printed Name)	Bill Short (Signature)	6/26/03 (Date)
Reviewed By (QA):	D B Karner (Printed Name)	D B L (Signature)	8/24/03 (Date)
Approved By:	D B Karner (Printed Name)	D B L (Signature)	8/24/03 (Date)

APPENDIX-A
45 mph Constant Speed Fuel Economy Test Data Sheet
(Page 1 of 2)

VIN Number: 1FTPF17M8YKB39272

Project No.: ETA-06-11-02	Test Date(s): 6/11/03
Root File No.:	
Test Driver: Bill Shoe (Initials)	(Date) 6/11/03
Test Engineer: BS (Initials)	(Date) 6/11/03

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Test Weight is Curb Weight plus 332 pounds)			
Left Front: 1363 lbs. (lbs or kg)	Right Front: 1441 lbs. (lbs or kg)	Total Front: 2804 lbs. (lbs or kg)	Percent Front: 53.7%
Left Rear: 1228 lbs. (lbs or kg)	Right Rear: 1203 lbs. (lbs or kg)	Total Rear: 2431 lbs. (lbs or kg)	Percent Rear: 46.3%
		Total Weight: 5235 lbs. (lbs or kg)	

INSTALLED TIRES (Placard or sidewall whichever is less)			
Preparation Area Temperature: (°F or °C)			
Left Front		Right Front	
Pressure: 65 psi (psi or kPa)		Pressure: 65 psi (psi or kPa)	
Left Rear		Right Rear	
Pressure: 65 psi (psi or kPa)		Pressure: 65 psi (psi or kPa)	

Track/Weather Conditions

Test Track Location: DC APG High Speed Oval		Track Grade: 0 %	
Ambient Temperature (initial):	76.4 °F (40-100°F or 5-38°C)	Ambient Temperature (final):	79.7 °F (40-100°F or 5-38°C)
Track Temperature (initial):	84 °F (°F or °C)	Track Temperature (final):	97.6 °F (°F or °C)
Wind Velocity (initial):	5.9 mph (<10 mph or 16 km/h)	Wind Velocity (final):	5.2 mph (<10 mph or 16 km/h)
Wind Direction (initial):	— °	Wind Direction (completion):	— °

APPENDIX-A
45 mph Constant Speed Fuel Economy Test Data Sheet
(Page 2 of 2)

VIN Number 1FTPF17M8YKB39272

Sequence No:	File No.: ETA-06-41-02	Direction of Travel: east
Time (initial): 7:17 a.m.	Time (final): 8:40 a.m.	
Odometer (initial): 31951.1 miles (miles or kilometers)	Odometer (final): 32011.3 miles (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):		15 % H_2
Tank Pressure (initial): 3110 psi	Tank Pressure (final): 1380 psi	
Tank Temperature (initial): 79.6 °F	Tank Temperature (final): 71.1 °F	
Comments (initials/date):		

Completed By:	Bill Shuck (Printed Name)	Bill Shuck (Signature)	6/12/03 (Date)
Reviewed By:	D B Kerner (Printed Name)	D B K (Signature)	8/27/03 (Date)
Approved By:	D B Kerner (Printed Name)	D B K (Signature)	8/27/03 (Date)

APPENDIX-B
Vehicle Metrology Setup Sheets
(Page 1 of 1)

VIN Number: 1FTPF17M8YKB39272

Instrument/Device:	Calibration Due Date:	Initials/Date:
Fifth Wheel S/N: 01359	5-19-04	BS 6/12/03
Fifth Wheel Calibrator S/N:	not applicable	BS 6/12/03
DAS S/N:	not applicable	BS 6/12/03
DAS Set-up Sheet S/N	not applicable	BS 6/12/03
kWh Meter S/N:	not applicable	BS 6/12/03
Shunt S/N:	not applicable	BS 6/12/03
Tire Pressure Gauge S/N:	not applicable	BS 6/12/03
Fuel Pressure Gauge S/N:	calibration invoice: D0086 02-01-05	BS 6/12/03
Fuel Temperature Meter S/N: 62450031	3-12-04	BS 6/12/03
Misc: Fluke 80TK Thermocouple Module	5-22-04	BS 6/12/03
Misc:		

Comments (initials/date):

Completed By:	Bill Short (Printed Name)	Bill Short (Signature)	6/12/03 (Date)
Reviewed By (QA):	DB Karner (Printed Name)	DBK (Signature)	8/27/03 (Date)
Approved By:	DB Karner (Printed Name)	DBK (Signature)	8/27/03 (Date)

APPENDIX-A
Hydrogen ICE Vehicle Acceleration to a Pre-Determined Speed Test Data Sheet
(Page 1 of 4)

VIN Number: 1FTPE17M29KB39272

Project No.: ETA-06-04-01	Test Date(s): 6/4/03
Root File No.:	
Test Driver: Bill Short BS (Initials) (Date)	
Test Engineer: (Initials) (Date)	

Vehicle Setup

VEHICLE WEIGHTS AS TESTED WITH DRIVER & INSTRUMENTATION (Curb weight plus 332 pounds)			
Left Front: 1363 lbs (lbs or kg)	Right Front: 1441 lbs (lbs or kg)	Total Front: 2804 lbs (lbs or kg)	Percent Front: 53.7%
Left Rear: 1228 lbs (lbs or kg)	Right Rear: 1203 lbs (lbs or kg)	Total Rear: 2431 lbs (lbs or kg)	Percent Rear: 46.3 %
		Total Weight: 5235 lbs. (lbs or kg)	

INSTALLED TIRES (Placard or sidewall whichever is less)			
Preparation Area Temperature: (°F or °C)			
Left Front		Right Front	
Pressure: 65 psi (psi or kPa)		Pressure: 65 psi (psi or kPa)	
Left Rear		Right Rear	
Pressure: 65 psi (psi or kPa)		Pressure: 65 psi (psi or kPa)	

Track/Weather Conditions

Test Track Location: DC APG High Speed Oval		Track Grade: 0 % (Within 1%)	
Ambient Temperature (initial): 86.4°F (40-90°F or 5-32°C)		Ambient Temperature (final): 88.4°F (40-90°F or 5-32°C)	
Track Temperature (initial): 99.3°F (°F or °C)		Track Temperature (final): 114.9°F (°F or °C)	
Wind Velocity (initial): 1.7 mph (≤10 mph or 16 km/h)		Wind Direction (initial): — °	Wind Velocity (final): 4.9 mph (≤10 mph or 16 km/h)
Wind Direction (completion): — °			

APPENDIX-A
45 mph Constant Speed Fuel Economy Test Data Sheet
(Page 2 of 2)

VIN Number 1FTP17M84KB39272

Sequence No:	File No.: ETA-06-04-01	Direction of Travel: Out
Time (initial): 8:27 a.m.	Time (final): 9:49 a.m.	
Odometer (initial): 31769.7 (miles or kilometers)	Odometer (final): 31829.8 (miles or kilometers)	
Vehicle Fuel (% Hydrogen by Volume):	30 % H_2	
Tank Pressure (initial): 3220 PSIG	Tank Pressure (final): 1240 PSIG	
Tank Temperature (initial): 81° F	Tank Temperature (final): 74.1°F	
Comments (initials/date):		

Completed By:	Bill Short (Printed Name)	Bill Short (Signature)	6/5/03 (Date)
Reviewed By:	D B Kerner (Printed Name)	D B K (Signature)	8/27/03 (Date)
Approved By:	D B Kerner (Printed Name)	D B K (Signature)	8/27/03 (Date)

APPENDIX-B
Vehicle Metrology Setup Sheets
(Page 1 of 1)

VIN Number: 1FTPF17M8YKB39272

Instrument/Device:	Calibration Due Date:	Initials / Date:
Fifth Wheel S/N: 01359	5-19-04	BS 6/5/03
Fifth Wheel Calibrator S/N:	not applicable	BS 6/5/03
DAS S/N:	not applicable	BS 6/5/03
DAS Set-up Sheet S/N	not applicable	BS 6/5/03
kWh Meter S/N:	not applicable	BS 6/5/03
Shunt S/N:	not applicable	BS 6/5/03
Tire Pressure Gauge S/N:	not applicable	BS 6/5/03
Fuel Pressure Gauge S/N:	calibrators' invoice D0086 02-01-05	BS 6/5/03
Fuel Temperature Meter S/N: 62450031	3-12-04	BS 6/5/03
Misc: Fluke 80TK Thermocouple Module	5-22-04	BS 6/5/03
Misc:		

Comments (initials/date):

Completed By:	Bill Short (Printed Name)	Bill Short (Signature)	6/5/03 (Date)
Reviewed By (QA):	DB Kasner (Printed Name)	(Signature)	8/27/03 (Date)
Approved By:	DB Kasner (Printed Name)	(Signature)	8/27/03 (Date)

Attachment 5 - Summary Emission Test Data Sheets

TEST CELL	Q-Cell
Test #	2983
Date	4/11/03
Time	9:01
Driver	KB
Operator	KB

VEHICLE...	
Model	F-150
Vehicle #	72
Odometer	30045
Dyno Inertia	6500

FUEL...	
ATL Code	CNG
FE_num	1778
CWF	0.718
Spc Grv	0.5976
HC_density	18.75

AMBIENT CONDITIONS...

Baro (inHg)	28.72		
PHASE #	**1**	**2**	**3**
Temp ('F)	76.0	76.1	76.8
Wet blb ('F)	54.3	54.3	54.6
Humidity	21.7%	21.4%	20.8%
Abs (gr/lb)	29.9	29.6	29.5
NOx K fac	0.825	0.824	0.824

Comments...

Compressed Natural Gas

Vin # 1FTPF17M8YKB39272

VARIABLES...

PHASE #	1	2	3
VMIX (ft3)	2863.7	4881.3	2845.7
Distance	3.58	3.861	3.59

Results...

Phase 1 (CT)	NMHC ppm	CH4 ppm	HC ppm	CO ppm	NOX ppm	CO2 %	DF
Sample Conc.	8.542	23.511	36.050	83.215	4.234	1.193	8.02
Ambient Conc.	4.443	1.961	6.737	1.665	0.081	0.046	
Net Conc.	4.653	21.795	30.153	81.758	4.163	1.152	
(gm)	0.233	1.179	1.619	7.719	0.533	1709.033	*mpg*
(gm/mile)	0.065	0.329	0.452	2.156	0.149	477.383	13.62

Phase 2(CS)	ppm	ppm	ppm	ppm	ppm	%	DF
Sample Conc.	4.409	3.782	8.835	5.809	2.371	0.805	11.98
Ambient Conc.	4.368	2.249	7.000	2.214	0.101	0.041	
Net Conc.	0.406	1.721	2.419	3.779	2.278	0.767	
(gm)	0.035	0.159	0.221	0.608	0.496	1940.372	*mpg*
(gm/mile)	0.009	0.041	0.057	0.158	0.129	502.557	13.05

Phase 3 (HT)	ppm	ppm	ppm	ppm	ppm	%	DF
Sample Conc.	4.589	11.564	18.119	6.877	1.360	1.054	9.15
Ambient Conc.	3.758	2.444	6.618	1.599	0.105	0.051	
Net Conc.	1.242	9.387	12.225	5.453	1.266	1.009	
(gm)	0.062	0.505	0.652	0.512	0.161	1487.364	*mpg*
(gm/mile)	0.017	0.141	0.182	0.143	0.045	414.308	15.82

Composite ...

							MPG
Grams/mile	**0.023**	**0.128**	**0.173**	**0.567**	**0.110**	**473.113**	**13.84**

TEST CELL	Q-Cell
Test #	2974
Date	4/4/03
Time	11:40
Driver	KB
Operator	KB

VEHICLE...	
Model	F-150
Vehicle #	72
Odometer	29915
Dyno Inertia	6500

FUEL...	
ATL Code	CNG
FE_num	1778
CWF	0.718
Spc Grv	0.5976
HC_density	18.75

AMBIENT CONDITIONS...

Baro (inHg)	28.75		
PHASE #	**1**	**2**	**3**
Temp ('F)	76.0	76.2	75.3
Wet blb ('F)	57.0	56.7	57.0
Humidity	29.4%	28.1%	31.1%
Abs (gr/lb)	40.7	39.1	42.0
NOx K fac	0.861	0.856	0.866

Comments...

FTP: (Hydrogen)
Preliminary Results
Pure CNG Fuel properties
Target Hydrogen conc: 15% by volume

Fuel economy correction factor: .95
Per request
Vin # 1FTPF17M8YKB39272

VARIABLES...

PHASE #	1	2	3
VMIX (ft3)	2860.8	4878.3	2843.5
Distance	3.631	3.857	3.552

Results...

	NMHC	CH4	HC	CO	NOX	CO2	
Phase 1 (CT)	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**%**	DF
Sample Conc.	7.546	24.125	35.772	67.412	3.404	1.155	8.29
Ambient Conc.	3.598	2.127	6.086	2.119	0.1217	0.043	
Net Conc.	4.382	22.254	30.420	65.548	3.297	1.117	
(gm)	0.220	1.203	1.632	6.183	0.440	1654.887	***mpg***
(gm/mile)	0.060	0.331	0.449	1.703	0.121	455.766	13.57

Phase 2(CS)	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**%**	DF
Sample Conc.	4.106	3.662	8.391	5.565	1.952	0.768	12.55
Ambient Conc.	3.958	2.085	6.397	2.037	0.106	0.045	
Net Conc.	0.463	1.744	2.503	3.690	1.854	0.727	
(gm)	0.040	0.161	0.229	0.593	0.419	1837.419	***mpg***
(gm/mile)	0.010	0.042	0.059	0.154	0.109	476.385	13.08

Phase 3 (HT)	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**%**	DF
Sample Conc.	4.813	11.949	18.794	6.262	4.221	1.016	9.48
Ambient Conc.	3.461	2.287	6.136	1.990	0.107	0.048	
Net Conc.	1.717	9.904	13.305	4.482	4.126	0.973	
(gm)	0.086	0.532	0.709	0.420	0.550	1433.595	***mpg***
(gm/mile)	0.024	0.150	0.200	0.118	0.155	403.602	15.43

Composite ...							**MPG**
Grams/mile	**0.025**	**0.132**	**0.179**	**0.467**	**0.124**	**452.197**	**13.76**

TEST CELL	Q-Cell
Test #	2966
Date	4/3/03
Time	12:14
Driver	KB
Operator	KB

VEHICLE...	
Model	F-150
Vehicle #	72 (67171X)
Odometer	29814
Dyno Inertia	6500

FUEL...	
ATL Code	CNG (CCHyN6-30%)
FE_num	1778
CWF	0.718
Spc Grv	0.5976
HC_density	18.75

AMBIENT CONDITIONS...

Baro (inHg)	28.71		
PHASE #	**1**	**2**	**3**
Temp ('F)	75.7	76.5	76.3
Wet blb ('F)	56.1	56.6	56.6
Humidity	27.6%	27.4%	27.9%
Abs (gr/lb)	37.7	38.4	38.9
NOx K fac	0.851	0.853	0.855

Comments...

FTP: (Hydrogen)
Preliminary Results
Pure CNG Fuel properties
Target Hydrogen conc: 30% by volume

Fuel economy correction factor: .95
Per request
Vin # 1FTPF17M8YKB39272

VARIABLES...

PHASE #	1	2	3
VMIX (ft3)	2861.2	4878.6	2845.2
Distance	3.585	3.859	3.586

Results...

	NMHC	CH4	HC	CO	NOX	CO2	
Phase 1 (CT)	ppm	ppm	ppm	ppm	ppm	%	DF
Sample Conc.	4.681	23.613	32.309	58.424	3.720	1.156	8.29
Ambient Conc.	2.714	1.991	5.043	2.010	0.068	0.043	
Net Conc.	2.295	21.862	27.873	56.656	3.660	1.118	
(gm)	0.115	1.182	1.495	5.345	0.483	1656.971	***mpg***
(gm/mile)	0.032	0.330	0.417	1.491	0.135	462.196	13.40

Phase 2(CS)	ppm	ppm	ppm	ppm	ppm	%	DF
Sample Conc.	2.878	3.922	7.466	5.575	1.924	0.758	12.73
Ambient Conc.	2.795	2.132	5.289	2.044	0.019	0.047	
Net Conc.	0.302	1.957	2.593	3.692	1.907	0.714	
(gm)	0.026	0.180	0.237	0.594	0.430	1805.680	***mpg***
(gm/mile)	0.007	0.047	0.061	0.154	0.111	467.914	13.32

Phase 3 (HT)	ppm	ppm	ppm	ppm	ppm	%	DF
Sample Conc.	3.652	12.707	18.519	6.775	4.024	1.018	9.47
Ambient Conc.	3.106	1.832	5.249	2.257	0.001	0.050	
Net Conc.	0.875	11.068	13.825	4.756	4.024	0.973	
(gm)	0.044	0.595	0.738	0.446	0.530	1434.796	***mpg***
(gm/mile)	0.012	0.166	0.206	0.124	0.148	400.111	15.56

Composite ...							**MPG**
Grams/mile	**0.013**	**0.138**	**0.175**	**0.423**	**0.126**	**448.114**	**13.89**

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