Hydrogen Internal Combustion Engine (ICE) Vehicle Testing Activities

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Presentation Outline

Background and goal

APS Alternative Fuel (Hydrogen) Pilot Plant - design and operations

Fuel dispensing and prototype dispenser

Hydrogen (H2) and HCNG (compressed natural gas) internal combustion engine (ICE) vehicle testing

WWW Information
Background

Advanced Vehicle Testing Activity (AVTA) is part of DOE’s FreedomCAR and Vehicle Technologies Program.

These activities are conducted by the Idaho National Laboratory (INL) and the AVTA testing partner Electric Transportation Applications (ETA).
AVTA Goal

Provide benchmark data for technology modeling, research and development programs, and help fleet managers and other vehicle purchasers make informed purchase and operations decisions.
AVTA History

Full-size EVs: 40 models, 5 million miles
Neighborhood EVs: 15 models, 200k miles
Urban EVs: 3 models, 1.75 million miles
Hybrid EVs: 9 models, 1.7 million miles
H2 ICE vehicles: 18 vehicles, 300k miles
APS Alternative Fuel Pilot Plant

Station partners include Arizona Public Service (APS), ETA, DOE and INL

First U.S. H2 station in operation (June 2002)
Pilot Plant & Vehicle Testing Objectives

Evaluate safety and reliability of operating vehicles on 100% H2 and HCNG blended fuels (15 to 50% H2)

Evaluate fueling infrastructure and vehicle costs, performance, and emissions
Pilot Plant Layout

Hydrogen Fuel Cell

2 H2 High psi tanks

H2 Low psi tank

H2 Compressor

2 CNG Compressors

6 CNG Tanks (3 psi levels)
H2 Subsystem

- Oxygen
- Water
- Electricity

H2 Generator → Dryer → Low Pressure Storage

Compressor → Filter → High Pressure Storage → H2 Out
Major H2 Subsystem Components

Proton Energy Systems’ HOGEN PEM stationary fuel cell operating in reverse

Lectrodryer H2 dryer: -80°F

Pdc Machines H2 compressor: 6,000 psi

Norman H2 filter 8 locations

H2: 99.9997% purity
H2 Storage

Low pressure H2 storage (lower tank):
8,955 SCF @ 150 psi

High pressure H2 storage (upper 2 tanks):
17,386 SCF @ 6,000 psi (both tanks)
H2 Gas and Flame Detectors

Six combustible H2 detectors
Six IR/UV flame detectors (1 more at dispensing island)
Tied to automated shutdown system
CNG Subsystem

Street Service Low Pressure Natural Gas → Boost Compressor → Main Compressor → High Pressure Storage (3 levels) → CNG Output

CNG Output
CNG Subsystem

Boost Compressor: 60 psi
CNG Main Compressor: 5,000 psi
CNG Storage/Pressure: 6 tanks, 22,500 scf
• 3 Low: 3,600 psi
• 2 Medium: 4,500 psi
• 1 High: 5,000 psi
H2 & HCNG Fueling Dispensers
Metering and electronic billing interface
Fully permitted for motor fuel dispensing
Public access
Pilot Plant Monitoring

H2 kg energy costs based on historical (26% to 49%) and projected (70%) plant factors $3.43 (26% PF) to $2.39 per kg (70% PF)

- DOE 2005 energy cost target $2.47

Water cost per kg of hydrogen $0.10
Pilot Plant Monitoring

6,000 fueling events

7,200 kg of H2 produced at 6,000 psi
Prototype Dispenser Testing

Real-time ratio control of blended fuels
Uses 1 nozzle to deliver 100% H2 at 5,000 psig
Uses 1 nozzle for 100% CNG and blends of HCNG fuels (15, 20, 30, and 50% H2 by volume) at 3,600 psi
Brassboard design
Initial H2 & HCNG vehicle testing

Dodge van on 15% HCNG (continues)
Ford F150 up to 30% HCNG (continues)
Ford F150 up to 50% HCNG (completed)
100% H2 Mercedes Benz van (completed)
15% HCNG Dodge Van

5.2 L CNG V8 (no modifications)

71k HCNG test miles: no problems

15% HCNG, 27k data miles: 15.5 miles/GGE

<table>
<thead>
<tr>
<th>Percentage change in 15% HCNG emissions compared to 100% CNG</th>
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</thead>
<tbody>
<tr>
<td>Total hydrocarbons</td>
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<tr>
<td>Carbon monoxide</td>
</tr>
<tr>
<td>Oxides of nitrogen</td>
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<tr>
<td>Carbon dioxide</td>
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### 30% HCNG F150

5.4 L V8 CNG engine, added supercharger, ignition mods & exhaust gas recirculator

54k 30% HCNG miles: 17.5 miles/GGE

<table>
<thead>
<tr>
<th>Fuel Blend</th>
<th>0 to 60 mph (secs.)</th>
<th>Miles/GGE</th>
<th>Range (miles)</th>
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<tr>
<td>CNG</td>
<td>10.10</td>
<td>23.3</td>
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<tr>
<td>15% HCNG</td>
<td>10.97</td>
<td>22.6</td>
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<td>30% HCNG</td>
<td>12.68</td>
<td>23.5</td>
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### 30% HCNG F150 Emissions

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Percentage Change in Emissions Testing</th>
<th>NMHC</th>
<th>CH₄</th>
<th>HC</th>
<th>CO</th>
<th>NOₓ</th>
<th>CO₂</th>
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<td>Base</td>
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<td>CNG</td>
<td>-80</td>
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<td>+35</td>
<td>-63</td>
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<tr>
<td>15% HCNG</td>
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<td>+40</td>
<td>-70</td>
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<tr>
<td>30% HCNG</td>
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<td>+1050</td>
<td>+37</td>
<td>-73</td>
<td>-25</td>
<td>-28</td>
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</table>

NMHC=Non-Methane Hydrocarbons  
CH₄=Methane  
HC=Total Hydrocarbons  
CO=Carbon Monoxide  
NOₓ=Oxides of Nitrogen  
CO₂=Carbon Dioxide
50% HCNG F150

Modifications: SVO heads, supercharger, exhaust intercooler, ignition system, and exhaust gas recirculator

Three 3,600 psi tanks with 3 kg H2 storage

Percent reduction in emissions (HCNG versus gasoline-fueled F-150)

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<tr>
<th></th>
<th>HC</th>
<th>CO</th>
<th>NO\textsubscript{x}</th>
<th>CO\textsubscript{2}</th>
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<tr>
<td>HC</td>
<td>-3.5%</td>
<td>-43.3%</td>
<td>-97.0%</td>
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HCNG ICE Vehicle Testing

APS meter reader fleet 12 Bifuel vehicles

- 1,600 fueling events, 190k miles using 10,600 GGE of 15% HCNG

Public Fleet - private Bifuel conversions

- 350 fueling events, 36k miles (estimated), 1,800 GGE of HCNG blends (mostly 15%)
5.4L 16-valve 100% H2 ICE Pickup

5.4L V-8, 100% H2, 16-valve pickup, converted by ETEC

5 speed manual, supercharged (3 psi boost), H2 fuel injectors, and air-to-water intercooler

Hardened valves and seats, and forged pistons with 12:1 compression

Motec fuel and spark controllers

Lean-burn mode
5.4L 16-valve 100% H2 ICE Pickup
6.5 kg onboard H2 storage
3 Dynetek tanks (aluminum vessel and fiberglass wrap) @ 3,000 psi
1,365 lbs payload
5.4L 16-valve 100% H2 ICE Pickup
Max speed 1 mile: 81 mph ¼ mile: 58 mph
Acceleration (0 to 50 mph): 18.1 seconds
SAE J 1634 (AC on): 14.5 miles/GGE
SAE J 1634 (AC off): 18.0 miles/GGE
45 mph constant speed: 27.0 miles/GGE
Range - 95 to 175 miles (14.5 to 27 mi/GGE)
Fleet testing (3.5k miles) results: 17.0 miles/GGE = 110 miles range
5.4L 32-valve 100% H2 ICE Pickup

5.4L V-8, 100% H2 32-valve pickup, converted by ETEC

Automatic transmission, H2 fuel injectors, 12 lbs supercharger boost, and air-to-air intercooler

Hardened valves and seats, and forged pistons with 11.5:1 compression

Motec fuel and spark controllers

Lean-burn mode
5.4L 32-valve 100% H2 ICE Pickup
15.3 kg onboard H2 storage
3 Dynetek tanks @ 5,000 psi
Fleet testing (7.5k miles): 15.3 miles/GGE and 230 miles range
To be baseline performance tested
6L V-8 100% H2 ICE Pickup

Base vehicle: Chevrolet 1500HD crew cab (4 door) with 6L V8 CNG engine

Converted by ETEC/Roush

4-speed automatic, supercharger, electronic port fuel injection, liquid-to-air intercooler

Integration of powertrain control module and development of H2 lean-burn control strategies
6L V-8 100% H2 ICE Pickup

Implementation of J 1850 communications to maintain seamless integration with existing OEM equipment

10.5 kg onboard H2 storage @ 5,000 psi

180 Horsepower and 260 lb-ft torque

Anticipated 15 miles/GGE = 155 miles range
6L V-8 100% H2 ICE Pickup

Targeted to meet NOx requirements for 2007 Tier II, Bin 7 standards

HC<10 ppm and NOx<25 ppm on engine dynamometer

Nine vehicles being produced in 1st run

To be baseline performance tested

Track 8 unit fleet in Vancouver
Acknowledgement

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Project Leader and VSATT Lead, Lee Slezak