U.S. Department of Energy - FreedomCAR & Vehicle Technologies Program

Hydrogen Fuel Pilot Plant and Hydrogen ICE Vehicle Testing

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2004 Fuel Cell Seminar – San Antonio Session 5B - Hydrogen
Advanced Vehicle Testing Activity (AVTA)-Background

• AVTA part of DOE’s FreedomCAR and Vehicle Technologies Program

• AVTA Goal - Benchmark & validate the performance of light-, medium-, & heavy-duty vehicles that feature one or more advanced technologies, including:
  – ICE’s burning advanced fuels, such as 100% hydrogen and hydrogen/CNG-blended fuels
  – Hybrid electric, pure electric, & hydraulic drive systems
  – Advanced batteries & engines
  – Advanced climate control, power electronic, & other ancillary systems
APS Alternative Fuel (Alt-Fuel) Pilot Plant & Vehicle Testing - Partners

- Electric Transportation Applications (ETA)
- Arizona Public Service (APS)
- DOE’s AVTA
- Idaho National Engineering and Environmental Laboratory (INEEL) – manages these activities for the AVTA
APS Alt-Fuel Pilot Plant & Vehicle Testing - Objectives

- Evaluate the safety & reliability of operating ICE vehicles on hydrogen & H/CNG blended fuels
- Evaluate hydrogen fueling infrastructure costs
- Quantify hydrogen & H/CNG ICE vehicle costs, performance, & emissions
APS Alt-Fuel 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
APS Alt-Fuel Pilot Plant - Hydrogen System

H₂ Generator -> Dryer -> Low Pressure Storage

H₂ Generator -> Compressor -> Filter -> High Pressure Storage

Oxygen

Water

Electricity

H₂ Out
APS Alt-Fuel Pilot Plant – Hydrogen System

- Proton Energy Systems’ HOGEN PEM stationary fuel cell operating in reverse
  - Model – HOGEN 300
  - 20 cells
  - Uses 57 kW, 480 V, 150 A, 3 phase
  - 300 SCFH hydrogen output @ 150 psi
  - 17 kWh per 100 SCF hydrogen
- Hydrogen dryer
  - Lectrodryer model GAS-B12
  - 300 SCFH
  - -80°F dew point
  - 120-V
APS Alt-Fuel Pilot Plant – Hydrogen System

• Hydrogen compressor
  – Pressure Dynamic Consultants - Pdc Machines
  – Model: Pdc-4
  – 5 hp, 480 V, 10 A, 3 phase
  – Oil-free triple diaphragm
  – Two-stage compression
  – 300 SCFH @ 6,100 psi

• Norman hydrogen filter locations
  – High- & low-pressure storage outlets
  – Dryer inlet & outlet
  – Compressor outlets

• Hydrogen - 99.9997% purity
APS Alt-Fuel Pilot Plant - Hydrogen System

- Low pressure hydrogen storage (lower tank)
  - 8,955 SCF @ 150 psi
- High pressure hydrogen storage (upper 2 tanks)
  - 17,386 SCF @ 6,000 psi
Low Pressure Hydrogen Storage Tank

- 8,955 SCF @ 150 psi
- Rated for 250 psi @ 125°F
- Carbon steel, 6 ft. 11 in. inside diameter, 19 ft. long
- Water volume of 6,565 gal.
- Manufactured by Trinity Industries under ASME Pressure Vessel Code, Section VIII, Division 22
- ASME safety relief valve rated @ 165°F piped to vent stack
High Pressure Hydrogen Storage Tanks

• 17,386 SCF @ 6,000 psi (total both tanks)
• Rated for 6,667 psi @ 200°F
• Seamless horizontal carbon steel, 16 in. outside diameter, 28 ft. long
• Water volume of 405 gal. (total both tanks)
• Manufactured by CP Industries under 1998 ASME Pressure Vessel Code, Section VIII, Division 1, Addendum 1999, Appendix 22 (SF3)
• ASME safety relief valve rated @ 6,667°F piped to vent stack
APS Alt-Fuel Pilot Plant - Auxiliary Systems

- Water Purification - 215 gal/day, 1.0-µm exit filter
- Control Air - 100 cfm compressor, 90 psi
- Chiller - 293,000 Btu/h,
- Nitrogen - Air/hydrogen buffer gas - production, piping, compression & 600 scf storage. 97% purity @ 100 psi
- Vacuum - portable pump used to reduce purge cycles
- Helium - vent stack purging
- Vents - fabricated from 0.5 in. 304 stainless steel tubing, 3 in. schedule 40 stainless steel pipe
APS Alt-Fuel Pilot Plant - Auxiliary Systems

• Emergency Shutdown System (EMS)
  – Ultra-fast IR/UV detectors
  – Combustible gas detectors
  – Manual (5) and remote trips
  – Vent stack temperature monitor
  – Alarms horns and strobe lights
  – Vent stack fire suppression
APS Alt-Fuel Pilot Plant - EMS

- Six combustible gas detectors (Det-Tronics RS 8471)
- Monitors hydrogen & natural gas in 1% increments of lower flammability limits (LFL)
- Alarm condition @ 25% of LFL reached
- Emergency shutdown when 50% of LFL reached
APS Alt-Fuel Pilot Plant - EMS

- Two mid-level (35 feet) & four corner IR/UV flame detectors (Spectrex 20/20LB units)
- 1 @ fuel dispenser unit
- If flame detected, emergency shutdown initiated within 3 milliseconds
APS Alt-Fuel Pilot Plant - Monitoring System

• Real-time station & component monitoring @ 50 monitoring nodes (100 @ completion)
• Fuel quantities collected and costs calculated for pure hydrogen and H/CNG blended fuels
• Electric powered equipment
  – Voltages & currents
• Select process temperatures
• Major process parameters
  – Pressures & flows
• LabVIEW-based custom system
DOE 2005 Electricity Target ($1.80) for a refueling station producing 250 kg/day. APS Hydrogen Production Electricity Cost based on APS published commercial/industry rate of $0.02/kWh for 5 MW & larger.
APS Alt-Fuel Pilot Plant - CNG System

Street Service Low Pressure Natural Gas

Boost Compressor

Main Compressor

High Pressure Storage (3 levels)

CNG Output
APS Alt-Fuel Pilot Plant - CNG System

- **CNG Boost Compressor**
  - Hy-Bon model AC-8DB
  - 300 SCFM @ 60 psi

- **CNG Main Compressor**
  - Gemini model HPSS-4
  - 350 SCFM @ 5,000 psi
  - Multi-Stage Piston

- **CNG Storage/Pressure – 6 tanks**
  - 3 Low: 11,079 SCF @ 3,600 psi
  - 2 Medium 5,711 SCF @ 4,500 psi
  - 1 High: 5,711 SCF @ 5,000 psi
  - Manufacturer: CP Industries
APS Alt-Fuel Pilot Plant – Dispenser System

CNG Sub-System

Delivered Hydrogen

Hydrogen Sub-System

H₂ and H₂/CNG Dispensers
APS Alt-Fuel Pilot Plant - Fueling Dispensers

- Dispense pure hydrogen, pure CNG fuel, or H/CNG
- Fueling Technologies Inc. - 2 fuel dispensers
  - 1 Dual dispenser: 2 nozzles, 1 hydrogen (5,000 psi) and 1 H/CNG blended fuels (3,600 psi)
    - WEH (Germany) nozzle and hose assemblies
  - 1 Dual dispenser: both nozzles CNG (3,600 psi)
    - Furon/Synflex process/vent hoses
    - Shurex NCV1 nozzle
APS Alt-Fuel Pilot Plant - Fueling Dispensers

- Includes metering and electronic billing Interface
- Permitted for motor fuel dispensing
APS Alt-Fuel Pilot Plant - Future Testing

• New Generation Hydrogen Production Unit
  – Proton PEM HOGEN 228
  – 228 scfh @ 218 psi
  – 34 cells/stack, 3 parallel stacks

• New High Pressure Compressor
  – PDC 4 frame
  – Oil-free triple diaphragm
  – Two-stage compression
  – 30 hp, 480 V, 3 phase
  – 1,250 SCFH @ 6,000 psi
Next Generation Station Design

• Driven by commercial fueling station design requirements
  – Reduced setbacks to allow siting on a commercial corner
  – Reduced operator training to allow operation by service station personnel or vehicle operators
  – Reduced hazards to minimize the maximum potential accident
  – Multiple layers of safety to significantly reduce operating risk
Next Generation Station Design

• Coaxial Containment System™
• Expandable modular design
• Envelopes most severe environmental conditions
• Exhaustive safety analysis to support permitting
• Zero setback requirements for flexible siting
• Shop assembled skid design
  – Assembly by ASME shop
  – Field welding minimized
Next Generation Station Design - Coaxial Containment System™

• Double wall piping system
  – Shields process piping within a pressure containing pipe
  – Contains pressure waves resulting from any gas ignitions
  – Redirects any detonations to benign location
  – Allows inerting of annulus to prevent gas ignition
  – Eliminates need for blast setback
  – Protects process pipe from vandalism
Hydrogen & H/CNG ICE Vehicle Testing

- Initial ICE hydrogen & H/CNG vehicle testing
  - Ford F150 up to 30% H/CNG (continues testing)
  - Ford F150 up to 50% H/CNG
  - 100% hydrogen Mercedes Benz van (operating)
  - Dodge van on 15% H/CNG (continues testing)
Hydrogen/CNG ICE Vehicle Testing

- Ongoing hydrogen & H/CNG ICE vehicle testing
  - 8 APS fleet vehicles on 15% H/CNG - S-10s, Sierra pickups, Blazers, Dodge Ram van
  - 16+ City of Phoenix (including Phoenix Fire Department) fleet vehicles on 15% H/CNG
  - Ford F150 30% H/CNG (tested @ 100% CNG, 15%H/CNG, and 30% H/CNG)
Hydrogen/CNG ICE Vehicle Testing

- Ongoing hydrogen ICE vehicle testing (cont’d)
  - Ford F150 - 100% hydrogen, 5.6 liter, 32 valve
  - Ford F150 – 100% hydrogen, 5.4 liter 16 valve
  - Adding F150 100% hydrogen, 5.4 liter 24 valve engine
  - Baseline, fleet & emissions testing
  - 250,000+ hydrogen test miles, 3,000+ successful fueling events
Hydrogen Vehicle Fuel Storage

- 100% Hydrogen, 32 Valve, F150
  - 100% hydrogen Dynetek tanks
  - aluminum inner vessel, carbon wrap
  - 5,000 psi tanks
  - 15 kilograms
Hydrogen Vehicle Fuel Storage

- 100% Hydrogen, 16 Valve, F150
  - 100% hydrogen Dynetek tanks
  - aluminum inner vessel, fiberglass wrap
  - 3,000 psi
  - 6 kilograms
## 30% H/CNG F150 Performance Testing

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<th>Fuel Blend</th>
<th>Time to 60 mph (seconds)</th>
<th>Fuel Economy (miles/gge)</th>
<th>Range (miles)</th>
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<tbody>
<tr>
<td>CNG</td>
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<td>23.3</td>
<td>122</td>
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<tr>
<td>15% H/CNG</td>
<td>10.97</td>
<td>22.6</td>
<td>110</td>
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<tr>
<td>30% H/CNG</td>
<td>12.68</td>
<td>23.5</td>
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## 50% H/CNG F150 Emissions Testing

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<th>Ave. FTP</th>
<th>Ave. Hwy</th>
<th>ULEV</th>
<th>SULEV</th>
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<tbody>
<tr>
<td>CO (g/mi)</td>
<td>0.864</td>
<td>0.097</td>
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<td>CO2 (g/mi)</td>
<td>373.85</td>
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<td>THC (g/mi)</td>
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<tr>
<td>NOx (g/mi)</td>
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<td>0.017</td>
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<td>MPG</td>
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<tr>
<td>PM (g/mi)</td>
<td>0.0003</td>
<td>0.0006</td>
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Hydrogen Station Report, vehicle reports, this presentation, and the online hydrogen monitoring system are all available via:

http://avt.inel.gov

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