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

Advanced Vehicle Testing Activity

Advanced Technology Vehicle Testing – 41st Power Sources Conference

Jim Francfort
Presentation Outline

- AVTA Goal
- AVTA Testing Partners
- Light-Duty Hybrid Electric Vehicle Testing
- Hydrogen Fuel Pilot Plant
- Hydrogen Internal Combustion Engine (ICE) Vehicle Testing
- Neighborhood & Urban Electric Vehicles
- WWW Information Address
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
AVTA Testing Partners

- Qualified Vehicle Testers (50 – 50 cost share)
  - Electric Transportation Applications (lead)
  - Arizona Public Service
  - Bank One
  - Ford Motor Company
  - Luke AFB
  - New York Power Authority
  - Red Cross
  - Southern California Edison
  - Salt River Project
  - Cites of Palm Springs, Palm Valley, Phoenix, Vacaville, and San Diego
Hybrid Electric Vehicle Testing

- Honda Insight
- Honda Civic
- MY ’02 & ’03 Toyota Prius
- MY ’04 Toyota Prius
- Fleet & accelerated reliability testing
  - Bank One, Red Cross, Arizona Public Service, ETA
  - Fuel use, maintenance, repairs & driver experience
- Baseline Performance testing (dynamometer & closed track testing)
  - Fuel economy, acceleration, max speed, braking, & handling
## Hybrid Electric Vehicle Specifications

<table>
<thead>
<tr>
<th>Manufacturer / Model</th>
<th>Battery Technology</th>
<th>System Voltage</th>
<th>Pack Capacity (C/2)</th>
<th>Electric Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honda Civic</td>
<td>NiMH</td>
<td>144 V</td>
<td>6.0 Ah</td>
<td>10 kW</td>
</tr>
<tr>
<td>Honda Insight</td>
<td>NiMH</td>
<td>144 V</td>
<td>6.0 Ah</td>
<td>10 kW</td>
</tr>
<tr>
<td>Toyota Prius ('02 &amp; '03)</td>
<td>NiMH</td>
<td>274 V</td>
<td>6.5 Ah</td>
<td>33 kW</td>
</tr>
<tr>
<td>Toyota Prius ('04)</td>
<td>NiMH</td>
<td>202 V</td>
<td></td>
<td>50 kW</td>
</tr>
</tbody>
</table>
Hybrid Electric Vehicle Testing

• Baseline Performance testing results
Hybrid Electric Vehicle Testing

- Fleet & accelerated reliability testing (1+ million miles)
  - 6 Honda Insights (347,000 miles) 46.0 mpg
  - 4 Honda Civics (284,000 miles) 38.0 mpg
  - 6 MY 02 & 03 Toyota Prius (380,000 miles) 41.1 mpg
  - 2 MY 04 Toyota Prius (16,000 miles) 44.6 mpg
Hybrid Electric Vehicle Testing

- Fleet and accelerated reliability testing

**Monthly Fuel Economy**

- Insight (347,000 miles) - 46.0 mpg
- Civic (284,000 miles) - 38.0 mpg
- Prius '02 & '03 (380,000 miles) - 41.1 mpg
- Prius '04 (16,000 miles) - 44.6 mpg
Hybrid Electric Vehicle Testing

- Baseline Performance, fleet and accelerated reliability, and EPA testing results

Drive Cycle (SAE J1634) and Fleet/AR Testing

- Civic
- Insight
- Prius

Miles per gallon

- Fleet/AR Testing
- With Air - J1634
- Without Air - J1634
- EPA City
- EPA Highway
Hybrid Electric Vehicle Testing

• 2004 HEV candidate test vehicles
  – MY 04 Toyota Prius (started testing)
  – General Motors Sierra pickup
  – Toyota Highlander SUV
  – Lexus RX400 SUV
  – Honda Accord
  – Ford Escape SUV
Arizona Public Service Hydrogen Fuel Pilot Plant (APS – HFPP)

- Onsite electrolytic hydrogen production, hydrogen & CNG (H/CNG) compression, & vehicle fueling
- Objectives:
  - Evaluate the safety & reliability of operating ICE vehicles on hydrogen & blended hydrogen fuels
  - Evaluate hydrogen vehicle fueling infrastructure
  - Quantify hydrogen ICE vehicle costs, performance, & emissions
APS – HFPP: Hydrogen Sub-System

H₂ Generator → Dryer → Low Pressure Storage

Compressor → Filter → High Pressure Storage

Oxygen → H₂

Water → Electricity → H₂
APS – HFPP: Hydrogen Sub-System

- Proton Energy Systems’ HOGEN PEM stationary fuel cell operating in reverse
- Hydrogen generator
  - PEM fuel cell, 57 kW, 20 cells
  - 300 SCFH hydrogen output, 150 psi
  - 17 kWh per 100 SCF hydrogen
- Hydrogen dryer
  - 300 SCFH
- Hydrogen compressor
  - Oil free diaphragm compressor
  - Three stage compression
  - 6,100 psi output
- Hydrogen - 99.9997% purity
APS – HFPP: Hydrogen Sub-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

• Hydrogen monitoring system (150 nodes instrumented) - examining production tradeoffs
APS – HFPP: CNG Sub-System

- Street Service Low Pressure Natural Gas
- Boost Compressor
- Main Compressor
- High Pressure Storage
- CNG Output
APS – HFPP: CNG Sub-System

- CNG Boost Compressor
  - 300 SCFM @ 60 psi

- CNG Main Compressor
  - 350 SCFM @ 5,000 psi
  - Multi-Stage Piston

- CNG Storage/Pressure
  - Low: 11,079 SCF @ 3,600 psi
  - Medium 5,711 SCF @ 4,500 psi
  - High: 5,711 SCF @ 5,000 psi
APS – HFPP: Fueling System

CNG Sub-System

Delivered Hydrogen

Hydrogen Sub-System

CNG Dispenser

H₂ and H₂/CNG Dispenser
APS – HFPP: Fueling Dispenser

- Dispense pure hydrogen or pure CNG fuel
- Blend and dispense H/CNG blended fuels
- Includes metering and electronic billing Interface
Hydrogen/CNG ICE Vehicle Testing

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

- Ongoing hydrogen ICE vehicle testing
  - 8 vehicles 15% H/CNG - S-10s, Sierra pickups, Blazers, Dodge Ram van
  - Ford F150 30% H/CNG (tested at 100% CNG, 15% H/CNG, and 30% H/CNG)
  - Ford F150 - 100% hydrogen, 5.6 liter, 32 valve, 35%+ efficiency
  - Ford F150 – 100% hydrogen, 5.4 liter 16 valve, production engine
  - Emissions testing, oil analysis
  - 200,000+ hydrogen test miles
Hydrogen/CNG ICE Vehicle Testing

- F150 30% H/CNG ICE vehicle testing results

<table>
<thead>
<tr>
<th>Fuel Blend</th>
<th>Time to 60 mph (seconds)</th>
<th>Fuel Economy (miles/gge)</th>
<th>Range (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNG</td>
<td>10.10</td>
<td>23.3</td>
<td>122</td>
</tr>
<tr>
<td>15% H/CNG</td>
<td>10.97</td>
<td>22.6</td>
<td>110</td>
</tr>
<tr>
<td>30% H/CNG</td>
<td>12.68</td>
<td>23.5</td>
<td>102</td>
</tr>
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</table>
Hydrogen/CNG ICE Vehicle Testing

- F150 30% H/CNG ICE vehicle testing results

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>NMHC</th>
<th>CH₄</th>
<th>HC</th>
<th>CO</th>
<th>NOₓ</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>Base</td>
<td>Base</td>
<td>Base</td>
<td>Base</td>
<td>Base</td>
<td>Base</td>
</tr>
<tr>
<td>CNG</td>
<td>-80</td>
<td>+967</td>
<td>+35</td>
<td>-63</td>
<td>-34</td>
<td>-24</td>
</tr>
<tr>
<td>15% H/CNG</td>
<td>-78</td>
<td>+1000</td>
<td>+40</td>
<td>-70</td>
<td>-26</td>
<td>-27</td>
</tr>
<tr>
<td>30% H/CNG</td>
<td>-89</td>
<td>+1050</td>
<td>+37</td>
<td>-73</td>
<td>-25</td>
<td>-28</td>
</tr>
</tbody>
</table>

NMHC=Non-Methane Hydrocarbons  \( \text{CH}_4=\text{Methane} \)
HC=Total Hydrocarbons  \( \text{CO}=\text{Carbon Monoxide} \)
NOₓ=Oxides of Nitrogen  \( \text{CO}_2=\text{Carbon Dioxide} \)
Neighborhood Electric Vehicle Testing

- NEVAmerica Baseline Performance Testing
  - Completed NEVAmerica testing of 10 NEVs (max speed, acceleration, range, braking, charging)
  - Gel, glass mat, and flooded lead acid batteries

Range Test (@ Max Speed) - 37.8 Miles Ave.
Neighborhood Electric Vehicle Testing

- 90 NEVs in fleet testing (including fast charging)
  - San Diego Police Department
  - Luke Air Force Base
  - Palm Valley
  - Palm Springs

- 2004 NEVAmerica Baseline Performance Testing
  - 5 NEVs with lithium polymer and lead acid batteries
Urban Electric Vehicle Testing

- **UEVAmerica Baseline Performance Testing**
  - Completed TH!NK city testing
- **Fleet and accelerated reliability testing**
  - 90 TH!NK cities in New York commuter fleet demonstration (miles driven, energy use, gasoline trips avoided, driver demographics)
  - 240 TH!NK cities in national demonstration
  - 5 Nissan Hyper-mini UEVs in fleet testing
  - TH!NK in accelerated reliability testing
  - Vehicle use 225,000+ miles
Urban Electric Vehicle Testing

- Ford/TH!NK city – SAFT NiCd, 19 modules, system voltage – 114 VDC, system capacity (C/3) 100 Ah
All vehicle testing reports and fact sheets, as well as this presentation are available via:

http://avt.inel.gov