Hydrogen Fueling Infrastructure Research and Station Technology

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Fuel Cell Technologies Office
Question and Answer

- Please type your question into the question box

hydrogenandfuelcells.energy.gov
Hydrogen Fueling Infrastructure Research and Station Technology

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November 18, 2014
Objective: Ensure that FCEV customers have a positive fueling experience relative to conventional gasoline/diesel stations as vehicles are introduced (2015-2017), and transition to advanced refueling technology beyond 2017.

- Co-led by NREL and SNL
- Leverages lab core capabilities
- Supports goals and objectives of H2USA

Existing Project Tasks:

**Hydrogen Station Equipment Performance (HyStEP) Device**
- Goal: Develop hydrogen station test device to validate dispenser fueling protocol
- September 2014 – August 2015

**Hydrogen Contaminant Detector**
- Goal: Develop requirements for inline fuel quality system for installation at stations
- Timeframe under development

**Reference Station Design**
- Goal: Develop station designs based on state-of-the-art components and characterize cost, throughput, reliability, and footprint using DOE models
- June 2013 - December 2014
The mission of H₂ USA is to promote the commercial introduction and widespread adoption of FCEVs across America through creation of a public-private collaboration to overcome the hurdle of establishing hydrogen infrastructure.
Goals

- Establishing necessary hydrogen infrastructure and leveraging multiple energy sources, including natural gas and renewables
- Deploying FCEVs across America
- Improving America’s energy and economic security
- Significantly reducing greenhouse gas emissions
- Developing domestic sources of clean energy and creating jobs in the United States
- Validating new technologies and creating a strong domestic supply base in the clean energy sector
Signatories on the Letter of Understanding

- U.S. Department of Energy
- State of California
- Northeast States for Coordinated Air Use Management
- Air Liquide
- American Gas Association
- American Honda Motor Company
- Argonne National Laboratory
- Association of Global Automakers
- California Fuel Cell Partnership
- Chrysler Group LLC
- Electric Drive Transportation Association
- Argonne National Laboratory
- General Motors Holding LLC
- Hawaii Natural Energy Institute
- Hydrogenics
- Hyundai Motor America
- Intelligent Energy Ltd.
- Fuel Cell & Hydrogen Energy Association
- ITM Power
- Linde North America
- Massachusetts Hydrogen Coalition
- Mercedes-Benz USA, LLC
- National Association of Convenience Stores
- Fuel Cell & Hydrogen Energy Association
- KobeKo Compressors (America), Inc.
- Linde North America
- Massachusetts Hydrogen Coalition
- Mercedes-Benz USA, LLC
- Pacific Northwest National Laboratory
- General Motors
- Linde North America
- Mitsubishi
- National Renewable Energy Laboratory
- Nuvera
- Pacific Northwest National Laboratory
- NISsAN
- National Association of Convenience Stores
- Plug Power Inc.
- Volkswagen Group of America
- Proton Onsite
- National Association of Convenience Stores
- SCRA
- Toyota Motor North America
H2FIRST Long-term Objectives

- Reduce the installation cost of a hydrogen fueling station to be competitive with conventional liquid fuel stations.
- Improve the availability, reliability, and cost while ensuring the safety of high-pressure components.
- Focus a flexible and responsive set of technical experts and facilities to help solve today’s urgent challenges and the future unpredicted needs.
- Enable distributed generation of renewable hydrogen in a broader energy ecosystem.
H2FIRST Project Coordination

H2USA HFSWG Coordination Activity

Hydrogen Fueling Station WG
- Station Analysis Core
  - Cost & Utilization modeling
  - Performance needs
  - Customer specific
  - Technology options
  - Utilization impacts
  - etc.
- Technology Challenge Solutions Core
- Hydrogen Fueling Infrastructure Research & Station Technology Coordination Panel (H2FIRST)
- Component R&D Core
- Operation Knowledge Core
- Reg., Code, Stds & Permit Core

Needs, Ideas, Feedback
- Pre-Proposal
- Full Proposal
- Add key external partners

Project Status & Results

H2FIRST Project(s)

DOE FCTO Decision Authority

Brian Somerday
SNL Lead

Chris Ainscough
NREL Lead

H2FIRST Project Partners Activity
Task Overview

**HyStEP** Hydrogen Station Equipment Performance Device
HyStEP Task Overview

Objective – Accelerate commercial hydrogen station acceptance by developing and validating a prototype performance test device.

- Team consists of vehicle OEMs, station providers, state and government agencies and lab teams (SNL and NREL)
- Highest priority: Device to test fueling protocol (SAE J2601/CSA HGV 4.3)
HyStEP Task Overview

• Why we need HyStEP:
  – As hydrogen is compressed into a vehicle tank, it heats up.
  – Hydrogen is pre-cooled as low as -40°C, and the fill rate is controlled.
  – Carbon fiber vehicle tanks have thermal limits that must not be exceeded.
  – The fueling protocol standards SAE J2601 and CSA HGV 4.3 specify how to fill hydrogen vehicles safely.
  – Vehicle manufacturers, consumers, station operators, and state stakeholders all want to know that stations are filling safely.
**HyStEP Task Overview**

- Specifications for HyStEP
  - Device is mobile: Mounted in truck bed or trailer
  - Type IV 70 MPa tank(s) with 4-7 kg capacity
  - Designed to perform subset of CSA HGV 4.3 tests, may add others in the future (e.g. MC fill)
  - SAE J2799 IrDA for communication tests and fills
  - Tank and receptacle instrumented with multiple P, T sensors to monitor pressure ramp rate, ambient, tank, and gas conditions.
  - Leak simulation to check dispenser response
HyStEP Device scheduled for completion September 2015

- Issue RFQ
- Negotiate contract
- Design review and safety analysis
- Initial checkout and testing
- Testing at Air Liquide CA station

- Review proposals
- Develop design
- Procurement, fabrication and assembly
- Validation testing and Gauge R&R at NREL
Task Overview

*Hydrogen Contaminant Detector*
Hydrogen Contaminant Detector (HCD) Task Overview

Objective – Develop requirements for inline fuel quality system for installation at stations.

Current Activity

<table>
<thead>
<tr>
<th>Market Survey</th>
<th>Requirements Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perform a market survey of current detection technology characteristics including detector availability, capabilities, cost and maintenance</td>
<td>Incorporate input from industry and government experts with research from the market survey to develop a set of engineering requirements for a detector</td>
</tr>
</tbody>
</table>
### Hydrogen Contaminant Detector Challenges

<table>
<thead>
<tr>
<th>Desired Characteristics</th>
<th>Challenges</th>
</tr>
</thead>
</table>
| Ease of station integration | • Multiple station configurations  
|                        | • Extreme gas pressure and temperature           |

Near term solutions will likely be tailored to individual station technologies based on probable contaminants.
Hydrogen Station Integration
Risk Based Approach

Delivered
- Depends on Quality

Reformer
- CO, H2O, S, HC
- O2, Part

Electrolyzer
- H2O, K, H2O, O2, Part

Compressor
- HC, S, H2O

Outside Sources
- All, including part

Storage
- Inert, H2O, O2

Chiller
- H2O

Possible HCD Location

Location 1

Hoses and Piping
- HC, Inert, Part, H2O

Location 2

*Constituents are examples

Location 3

Credit: Spencer Quong
Hydrogen Station Integration

Risk Based Approach

• Delivered Hydrogen (SMR Production)
  – Gaseous
  – Liquid

• On-site Hydrogen Production
  – Water Electrolysis
  – Steam Methane Reformation

• Pros
  – L1: low pressure requirements
  – L2: captures most contaminant sources
  – L3: captures all contaminant sources

• Cons
  – L1: misses potential contaminants from downstream sources
  – L2: must be integrated with <87.5 MPa and > -40°C gas
  – L3: burden on vehicle OEM; many more cars than stations

Possible HCD Location
- Location 1
- Location 2
- Location 3
Critical Contaminants

CO is the most critical constituent in the specification

Technical Accomplishments: Fuel Quality-Relative Tradeoff Drivers Identified

<table>
<thead>
<tr>
<th>Impact on Fuel Cell</th>
<th>Difficulty to Attain and Verify Level</th>
</tr>
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<tbody>
<tr>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Low Impact</td>
<td>Low</td>
</tr>
<tr>
<td>Medium Impact</td>
<td>Medium</td>
</tr>
<tr>
<td>High Impact</td>
<td>High</td>
</tr>
</tbody>
</table>

- Ammonia
- Aromatic & Aliphatic HCs
- Carbon Monoxide
- Sulfur species
- Carbon Dioxide
- Oxygen
- Methane
- Nitrogen
- Helium
Contaminants Detected and Levels

Current station data: Field observations

23 of 33 samples (70%) met the SAE J2719 guidelines. Consecutive samples may be for a single issue.

Values are in micromole/mole. Only values that exceed SAE J2719 guideline are shown in text.
Market Survey

• Study of available hydrogen contaminant detectors. Task elements include:
  – Gather data on relevant technologies
  – Prioritize detectors for most impactful contaminants
  – Prioritize commercial technologies for station deployment
  – Define engineering requirements for a deployable HCD
  – Identify gaps

• NREL and SRNL developing work plan, timeline and milestones

• Output: market survey and engineering requirements
<table>
<thead>
<tr>
<th>Market Survey</th>
<th>Technologies Investigated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gas Chromatograph Technologies</strong></td>
<td><strong>Mass Spectrometry</strong></td>
</tr>
<tr>
<td>• GC/PDID – Pulsed Discharge Ionization Detector</td>
<td>• APIMS – Atmospheric Pressure Ion Mobility Spectrometry</td>
</tr>
<tr>
<td>• GC/DID – Discharge Ionization Detector</td>
<td></td>
</tr>
<tr>
<td>• GC/ECD – Electron Capture Detector</td>
<td></td>
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<tr>
<td>• GC/PFPD – Pulsed Flame Photometric Detector</td>
<td></td>
</tr>
<tr>
<td><strong>Piezoelectric</strong></td>
<td><strong>Optical</strong></td>
</tr>
<tr>
<td>• QCM – Quartz Crystal Microbalance</td>
<td>• TDL – Tunable Diode Laser</td>
</tr>
<tr>
<td></td>
<td>• ICOS – Internal Combustion Optical Sensor</td>
</tr>
<tr>
<td></td>
<td>• FTIR-Gas Cell – Fourier Transform Infrared spectroscopy</td>
</tr>
<tr>
<td></td>
<td>• CRDS – Cavity Ring Down Spectroscopy</td>
</tr>
</tbody>
</table>
Task Overview

Reference Station Design
Objective – *Develop station designs based on state-of-the-art components and characterize cost, throughput, reliability, and footprint using DOE models.*

Approach

- Develop a station design matrix.
- Identify priority options of 10-15 stations.
- Complete an external review with stakeholders.
- Develop three to five high-impact station designs.
- Report on gaps, recommendations for testing, and R&D.
- Hold a stakeholder information webinar
Station Characteristics

- Hydrogen delivery type
- Daily capacity
- Land area requirement
- Fuel cost
- Capital investment
- Compressor configuration
- Storage size
- Consecutive fill capacity
- Number of hoses

This is a highly-collaborative project between H2FIRST, H2USA, ANL, and DOE

DOE FCTO
Guidance, funding

H2USA HFSWG
Industry perspective and needs

H2FIRST Reference Station Project
• NREL
• SNL

“Now term” station design guidance

ANL
Long term station design guidance
Analysis Tools

Industry perspective and needs

Now term station design guidance

Analysis Tools
Reference Station Design Task Process

1. Define parameters and ranges
2. Specify cost data and metrics. Review.
3. Specify and simulate station concepts.
4. Station selection based on comparative economics and technical feasibility. Review.
5. Optimization of selected stations
6. Review of final stations
7. Station designs

Utilization, capacity, size, dispenser…

Compressor, land, O&M, 875 bar storage, …

HRSAM Model Development

<table>
<thead>
<tr>
<th>Station</th>
<th>Utilization</th>
<th>Capacity</th>
<th>Dispensers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20%</td>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Ramp</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Ramp</td>
<td>200</td>
<td>2</td>
</tr>
<tr>
<td>N</td>
<td>...</td>
<td>...</td>
<td>...</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Station</th>
<th>Cost per kg</th>
<th>Capital Cost</th>
<th>ROI Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$3</td>
<td>$500</td>
<td>Y</td>
</tr>
<tr>
<td>2</td>
<td>$3</td>
<td>$500</td>
<td>Y</td>
</tr>
<tr>
<td>3</td>
<td>$3</td>
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</tr>
<tr>
<td>6</td>
<td>$3</td>
<td>$500</td>
<td>Y</td>
</tr>
</tbody>
</table>

How to get involved in H2USA

- To join H2USA, email info@h2usa.org, or visit http://h2usa.org
How to get involved in H2FIRST

Contact

Bianca Kroebel Thayer, Sandia National Laboratories
925-294-1214
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OR

Alex Schroeder, National Renewable Energy Laboratory
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Alex.Schroeder@nrel.gov
Questions

• Please type questions into the chat box in the webinar software.
• For more information, please visit:
  
  http://energy.gov/eere/fuelcells/h2first

Joe Pratt, Sandia National Laboratories
  
  jwpratt@sandia.gov

Chris Ainscough, National Renewable Energy Laboratory
  
  Chris.Ainscough@nrel.gov
BACKUP
Supporting Capabilities – CIRI Materials Science & Engineering Science Focus

CIRI Capabilities

- Materials and Components
  - Materials testing in high-pressure \( \text{H}_2 \) at variable temperature
  - Customized testing on metals and non-metals
  - Weld research and development
  - Full-scale component testing in \( \text{H}_2 \)

- Systems Engineering
  - Full-scale \( \text{H}_2 \) station breadboard for system optimization
  - Real world equipment evaluation and innovation platform

Status

- Assessing HyReF (full-scale component testing and \( \text{H}_2 \) station breadboard) planned for 2015
Supporting Capabilities – ESIF & DERTF Testing & Analysis Focus

**Capabilities**
- On-site hydrogen generation (electrolyzers)
- High pressure component testing
- Flexible, renewable-ready hydrogen energy storage platform
- Advanced hydrogen sensor testing
- 700-bar and 350-bar (nom) dispensing
- Research Electrical Distribution Bus (REDB) capability for grid integration
- Physical and photo-electrochemical material characterization
- Systems integration & device under test platforms

**Research Station Status**
- 700-bar research station construction for basic system architecture started and expected completion in December 2014

Photo credit: NREL (April 2014)