DOE Hydrogen Codes and Standards Technology Team

Presentation to
Hydrogen Technical Advisory Committee
May 16, 2007

Patrick Davis - US DOE
Jesse Schneider - DaimlerChrysler
CSTT Key Goals

- Assess sufficiency of US and international hydrogen and fuel cell codes and standards that are established and in the process of being established. **Complete R&D to support essential Codes and Standards by 2010.**

- Identify and prioritize areas where information is needed to advance codes & standards

- Ensure that information and safety best practices are developed under the FreedomCAR and Fuel Partnership and are made available to responsible standards setting organizations as appropriate. Assist in Implementation of best practices.

**Support the Partnership Goal for demonstrated hydrogen refueling with developed commercial codes and standards** and diverse renewable and non-renewable energy sources with a cost of energy from hydrogen equivalent to gasoline at market price, assumed to be $2.00-3.00 per gallon gasoline equivalent produced and delivered to the consumer independent of pathway by 2015.
# Codes & Standards Technical Team Membership

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<tr>
<th>Energy Company</th>
<th>Auto Company</th>
<th>Government &amp; Labs</th>
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<tr>
<td>- John Lemen (Chevron)</td>
<td>- Sheral Arbuckle (Ford)</td>
<td>- Jay Keller (SNL)</td>
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<td>- Jim McGetrick (BP)</td>
<td>- Jesse Schneider (DaimlerChrysler)*</td>
<td>- Jim Ohi (NREL)</td>
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<td>- Jonathan Otero (BP)</td>
<td>- Scott Freeman (DaimlerChrysler-BPG)</td>
<td>- Cathy Gregoire Padro (LANL)</td>
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<td>- Brad Smith (Shell)</td>
<td>- Mike Steele (GM)</td>
<td>- Patrick Davis (DOE)*</td>
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<td>- Nick Burkhead (Shell)</td>
<td>- Britta Gross (GM)</td>
<td>- Phyllis Yoshida (DOE)</td>
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<td>- Michael Boyea (ExxonMobil)</td>
<td>- Jerry Rogers (GM-Triad)</td>
<td>- Barbara Hennesey (DOT)</td>
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<td>- George Mitchell (DaimlerChrysler)</td>
<td>- William Hollowell (DOT)</td>
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*CSTT Co-Leads

Dave Austgen (Shell) – FOG Liaison
How the Tech Team contributes to Codes and Standards Development

- Tech Team focuses on data required by the codes and standards process
- Members also participate in the process
  - Coordination (National Hydrogen and Fuel Cell Codes and Standards Coordinating Committee, with NHA and USFCC)
  - Members of specific committees
  - Crosscutting teams focusing on critical topics (e.g., hydrogen quality)
  - Significant progress has been made in the development of codes and standards through leveraging of limited resources
    - 9 active US Codes and Standards Organizations working on hydrogen
    - 22 C&S published, 10 of which are under revision
    - 28 draft C&S under preparation/review
    - 4 International C&S published, 13 under preparation/review
    - See www.fuelcellstandards.com
C&S Challenges

- Limited historical data / insufficient technical data to develop standards
- Large number of Authorities Having Jurisdiction
- Need for uniform training of officials
- Need for standard practices for safety assessments
- Need for integrated, coordinated approach among C&S Organizations
- Need for harmonization of domestic and international standards
- Limited government influence on C&S process
H₂ Standards & Codes Lead to Regulations & Laws

Some Standards begin as Guidelines (TIR, etc.)

US Standards: SAE/ ASTM/ CSA

US Regulations NHTSA/EPA

US Codes ICC/ NFPA

US State Codes/ State Law (can choose to adopt)

International Standards Organization (ISO)

Global Technical Regulations

Vehicle

Building/ Station

It is important to have timely implementation of performance based C&S which establish a safety baseline & enable technology.
- **Initial Version:** Completed 2004
- **Updated in May 2006** - includes detailed Gantt charts with milestones
- **Details Needs & Gaps in each Target Area to meet 2010 timeline**
Codes and Standards
Commercialization Data Timeline

- **2003**
  - Release Scenarios
  - Fundamental Jets and Flames

- **2004**
  - Materials Compatibility
  - Metal Hydride Materials, Behavior
  - H₂ Sensors

- **2005**
  - Distribution/Delivery Options
  - Fuel Quality Measurements
  - Bulk Storage/Transport, Pipelines
  - Refueling Stations Codes

- **2006**
  - Fuel Quality Specification
  - Fueling Dispensing Protocol/Testing

- **2007**
  - Fuel Quality Standard
  - Fueling Dispensing Protocol/Testing

- **2008**
  - Station Grounding

- **2009**
  - H₂ Tank Refueling Tests
  - Vehicle Demonstration Projects
  - H₂ Storage Systems, Storage Tank Testing
  - Internal Crash Testing

**Legend:**
- Orange: Hydrogen Behavior
- Yellow: H₂ Fuel Infrastructure
- Green: Fuel-vehicle Interface
- Blue: H₂ Vehicles
Accomplishments
The status of all fuel cell codes and standards activities
Calendar of meetings and other significant dates
Bulletin board for posting questions and answers
70MPa Fueling Initial Results

- Developed extensive 70MPa Statement of Work
- Completed preliminary tests at Powertech, follow-on work underway (funded by broad industry participation)

Evaluate Targets:
- Time: 3 minutes
- Fill: 98-100%

25 Trials w/ & w/o
- Pre-cooling
- Communications
25 Fueling Trials at Powertech with 4 individual tanks (not system – type 3 and type 4 tanks used ranging from 34 to 130 liters)

Evaluated SAE J2601 targets regarding fill density/time changes between different fueling methods w/ and w/out pre-cooling & communications

Preliminary Results: Precooling is needed to achieve fueling in a short amount of time, in some cases also communications

Results were used to formulate the follow-on work
Purpose: Accelerate Progress of Informed Standards for Hydrogen Vehicle Fueling utilizing real vehicle and station hardware

- Not enough information currently available for standards organizations on fueling protocol and station hardware

OEMs to bring their onboard storage systems to third party organizations (Powertech & JARI) also as in-kind contribution to the project

- Participants: DCX, Ford, GM, Honda, Nissan, Toyota

Funding: Energy Companies & Government

- Air Liquide, BP, Linde, Nippon Oil, Sandia (DOE), Shell

Modeling effort at Sandia for on-board storage and hydrogen station dispensing
Hydrogen Quality
A Coordinated, Crosscutting Activity

Industry, North American
Working Group, USFCC
Japan, Europe

DOE Hydrogen Quality
Working Group

Crosscuts DOE Budget Elements

Tech Team Hydrogen Quality SOW

DOE FY2007
H2 Quality Budget
Codes and Standards: $750K
Fuel Cells: $1,500K

2010

SAE and ISO Standards
Hydrogen Quality Approach

- Investigates industry consensus critical fuel impurities from both FC and fuel provider perspective
  - Develops/refines fuel cell testing protocols and develops essential, standardized analytical methodologies
  - Conducts R&D and testing to find the balance between requirements of both sides of the vehicle-station interface
  - Addresses fuel cell FCV operational effects and empirical cell modeling

- Parallel effort to evaluate cost implications of meeting specified hydrogen quality level

- Data sharing/report-outs major factor in refining existing fuel quality guidelines
To date, the North American industry-government team has identified the following as critical constituents around which near-term R&D and testing should be focused:

- CO
- S compounds
- He
- CH4 and inerts
- NH3
- Particulate Matter (<10µ diameter)

This list may change and other critical constituents may be identified as R&D and testing proceed.
Increased material strength lowers threshold for H₂-assisted crack growth

Increased H₂ gas pressure lowers threshold for H₂-assisted crack growth

H₂ compatibility of 316 stainless steel can be optimized by controlling composition, particularly nickel content. Carbon content seems to be less important.
Hydrogen Combustion and Release Scenarios

Flame Characterization

Experimentally Measure Heat Flux

Impinging jet, 10 ft impingement diameter

Flammability Limits & Ignition Probabilities

Thermal Radiation Models

Experimentally Measure Heat Flux

Impinging jet, 10 ft impingement diameter
Quantitative risk assessment (QRA) provides a framework for making risk-informed decisions. We are applying QRA to help define refueling setbacks.

- Likelihood of events is estimated from component reliability and architecture-based FMEA studies.

- Event consequences are quantified using engineering models from the research program and published data.

- Consequences are integrated and evaluated relative to acceptable risk metrics.

- Site-specific mitigation strategies should be identified where appropriate.
Compendium of Permitting Tools for Hydrogen Fueling Stations

- **Information Repository**
  - Fact sheet(s)
    - Basic information on hydrogen fueling stations (examples, codes/standards typically used, information sources)
  - Network chart
    - Contact list of code officials whose jurisdictions have issued permits for hydrogen fueling stations
  - Flowchart of permitting requirements
    - Web-based map to navigate requirements
    - Database of key standards and codes
  - Hydrogen fueling station permitting information repository
    - Web-based information and database of code and standards requirements
  - Case studies of hydrogen fueling stations

- **Education/outreach**
  - Workshops for code officials (nationally and regionally)
  - Web-based training
Compendium – Case Study Activity:
A collaboration with NASFM

**Goal:** To compile case studies of hydrogen fueling stations (HFS) that have been vetted by the building code and fire safety community

Provides a reference for local code officials to consult at their discretion.

- Collaboration with NASFM, NCBCS, and energy suppliers to identify representative hydrogen fueling station layouts/designs
- Identify all applicable codes and standards for hydrogen fueling stations
- Gain consensus of code officials on identified fueling station designs

**Timeline:**

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<th>Purpose</th>
<th>Date and Location</th>
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| DOE workshop at NASFM annual conference | ▪ Involve key building and fire code officials  
▪ Present and discuss case studies  
▪ Demonstrate web-based information repository prototype | Atlanta  
July 10, 2007 |
| Workshop at NCBCS annual conference  | ▪ Similar purpose, agenda, format as workshop at NASFM conference       | Fall 2007             |
| Publication of case studies          | ▪ Provide building code and fire safety officials with existing examples of approved hydrogen refueling stations and the codes and standards applied | December 2007         |
Bibliographic and Incidents Databases

- **H2 Incidents Database**
  - Information on hydrogen incidents and lessons learned
  - 103 incidents documented as of February 2007
  - [www.h2incidents.org](http://www.h2incidents.org)

- **Bibliographic Database**
  - Contains approximately 400 publications related to hydrogen safety
  - [www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)
Related Education Activities:
First Responders

- **Introduction to Hydrogen Safety for First Responders**
  - 7-module, web-based basics course (includes quiz and video, animations, graphics for visual audience)
  - Print and CD versions available for free from DOE Information Center
  - Development included broad review involving hydrogen industry and emergency response community
  - Averaged 200 unique users/week since course launch in Jan 2007
  - Positive feedback from emergency response community - users include fire fighters, fire department training coordinators, fire marshals, fire plans inspectors/examiners, law enforcement personnel, industry, military, others

A “Cliffs Notes” poster is available for fire houses, free from the DOE Information Center

[www.hydrogen.energy.gov/firstresponders](http://www.hydrogen.energy.gov/firstresponders)
Related Education Activities:
First Responders and Code Officials

- **Detailed “Prop Course” for First Responders**
  - Follows intro course, designed for use with hands-on FCV training prop (focus will be vehicles but course will also cover other applications)
  - Prop will be mobile; DOE will loan prop/course to major fire fighter training centers for designated periods
  - Estimated timeline for completion: late spring/early summer 2008

- **Introduction to Hydrogen for Code Officials**
  - Like first responder course – modular, web-based (also print and CD)
  - Will provide more detailed information on technologies and equipment
  - Codes and Standards module will incorporate tools and resources developed by DOE Hydrogen Safety, Codes & Standards Program (fact sheets, network chart, flowchart of permitting requirements, refueling station permitting compendium)
  - Estimated timeline for completion: early 2008
Remaining Challenges
Future Direction

- Open Issues/Remaining Barriers
  - Difficult permitting process for retail hydrogen facilities
  - Delayed adoption of approved codes and standards
  - Synchronizing codes and standards development and adoption timeline with technology commercialization needs

- Future Direction
  - Fuel Quality: Follow R&D Timeline/ Launch collaborative international R&D testing effort.
  - 70MPa: Complete expanded cross-industry test program, demonstration project data needed
  - Materials Compatibility: Complete initial materials set and initiate investigation of composite materials
  - Provide technical support/ guidance to local code officials to facilitate permitting of retail hydrogen facilities
  - Publish Best Practices Manual/ Expand Safety Database
  - Work with Education on emergency responder and code official training
BACKUP SLIDES
H2 Quality Data Generation Timeline for Standardization

- **ASTM Analytical Techniques**
  - Compile & analyze available activities/data, determine gaps - Road Map
  - **Mechanisms Testing**
    - Contamination testing / Primary Effect (Single Cell)
    - Empirical / Kinetic Model Generation
    - Contamination testing / Secondary Effect (Single Cell)
    - Single Cell Model Validation
    - Loading Vs. Contaminant Threshold (Cost Evaluation)
    - Define/Develop Phase 2 designs of experiments
    - Stress Test Continuation with respect
    - Data Capture/Analysis / Selected Contaminants SAE J2722
    - Onboard Storage / BOP Effects / Selected contaminants & Particles

- **Production / Purity / Cost**
  - Sample current infrastructure impurities - develop database
  - Establish critical supply/costs
  - Determine economic activities to PSA purification
  - Determine canopy contaminants for analytical detection
  - Establish appropriate analytically frequency and economics
  - Establish composite range of non-H2 contaminants for further cell testing

- **Cooperative Evaluation - Costs Vs. Threshold Relationship**

- **SAE J2719 & ISO/TC197 WG12 Standardization**

- **Compromise Solution**

- **Develop SAE standard based on R&D and test data**