

## VIII.10 Hydrogen Safety Panel

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Project Start Date: 2004

Project End Date: Project continuation and direction determined annually in consultation with DOE

### Fiscal Year (FY) 2011 Objectives

- Provide expertise and recommendations to DOE and assist with identifying safety-related technical data gaps, best practices and lessons learned.
- Help DOE integrate safety planning into funded projects to ensure that all projects address and incorporate hydrogen and related safety practices.

### Technical Barriers

This project addresses the following technical barriers from the Hydrogen Safety section (3.8) of the Fuel Cell Technologies (FCT) Program Multi-Year Research, Development and Demonstration Plan:

- (A) Limited Historical Database
- (B) Proprietary Data
- (C) Validity of Historical Data
- (D) Liability Issues

- (E) Variation in Standard Practice of Safety Assessments for Components and Energy Systems
- (F) Safety is Not Always Treated as a Continuous Process
- (G) Expense of Data Collection and Maintenance
- (H) Lack of Hydrogen Knowledge by Authorities Having Jurisdiction
- (I) Lack of Hydrogen Training Facilities for Emergency Responders

### Contribution to Achievement of DOE Hydrogen Safety Milestones

This project contributes to achievement of the following DOE milestones from the Hydrogen Safety section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

- **Milestone 8:** Complete investigation of safe refueling protocols for high pressure systems. (1Q, 2012)
- **Milestone 20:** Update peer-reviewed Best Practices Handbook. (4Q, 2008/ongoing)

Related milestones in Task 3 (Failure Modes), Task 5 (Safety of DOE R&D Projects), Task 6 (Hydrogen Safety and Incidents), Task 7 (Best Practices Handbook) and Task 8 (Hydrogen Safety Props) of the above reference have all been achieved with support from the Hydrogen Safety Panel.

### FY 2011 Accomplishments

- Conducted Hydrogen Safety Panel meeting in Washington, D.C., April 7-8, 2010; planned Hydrogen Safety Panel meeting (September 11, 2011) in conjunction with the International Conference on Hydrogen Safety, San Francisco, CA.
- Reviewed 60 safety plans since July 1, 2010 for projects in fuel cell research and development (R&D) and American Recovery and Reinvestment Act (ARRA)-funded fuel cell deployments.
- Conducted safety review site visits for four FCT-funded projects; completed and submitted six safety evaluation reports; conducted three follow-up teleconferences for previously issued safety evaluation reports and submitted interview reports; published two issues of *H2 Safety Snapshot* (<http://www1.eere.energy.gov/hydrogenandfuelcells/codes/snapshot.html>).
- Provided technical guidance, source material and review for the Hydrogen Incident Reporting and Lessons Learned database ([www.h2incidents.org](http://www.h2incidents.org)) and Hydrogen Safety Best Practices ([www.h2bestpractices.org](http://www.h2bestpractices.org)).



## Introduction

Safety is an essential element for realizing the “hydrogen economy” – safe operation in all of its aspects from hydrogen production through storage, distribution and use; from research, development and demonstration to commercialization. As such, safety is given paramount importance in all facets of the research, development, demonstration and deployment work of the DOE FCT Program Office.

Recognizing the nature of the DOE program and the importance of safety planning, the Hydrogen Safety Panel was formed in December 2003 to bring a broad cross-section of expertise from the industrial, government and academic sectors to help ensure the success of the program as a whole. The experience of the Panel resides in industrial hydrogen production and supply, hydrogen R&D and applications, process safety and engineering, materials technology, industrial liability and facility insurance, risk analysis, accident investigation and fire protection. The Panel provides expertise and recommendations on safety-related issues and technical data gaps, reviews individual DOE-supported projects and their safety plans and explores ways to bring best practices and lessons learned to broadly benefit the DOE program.

## Approach

The Panel strives to raise safety consciousness most directly at the project level. Safety should be driven at the project level by organizational policies and procedures, safety culture and priority. Project safety plans are reviewed in order to encourage thorough and continuous attention to safety aspects of the specific work being conducted. Panel-conducted safety reviews focus on engagement, learning, knowledge-sharing and active discussion of safety practices and lessons learned, rather than as audits or regulatory exercises. Through this approach, DOE and the Hydrogen Safety Panel are trying to achieve safe operation, handling and use of hydrogen and hydrogen systems for all DOE projects.

## Results

The Hydrogen Safety Panel was formed in FY 2004 and the first meeting was held in Washington, D.C., December 11-12, 2003. The 15<sup>th</sup> Panel meeting was held in Washington, D.C., April 7-8, 2011 and included two topical themes: (1) “incident owners” discussed what was learned from specific hydrogen safety events; (2) Panel work on ARRA-funded fuel cell deployment projects, including materials handling applications, was reviewed. Planning is in progress for the 16<sup>th</sup> meeting to be held in San Francisco, CA, September 11, 2011, in conjunction with the International Conference on Hydrogen Safety.

Current Panel membership is noted in Table 1.

**TABLE 1.** Hydrogen Safety Panel

Richard A. Kallman, Chair	City of Santa Fe Springs, CA
Steven C. Weiner, Program Manager and Panel Coordinator	PNNL
Addison Bain	NASA (ret)
David J. Farese	Air Products and Chemicals, Inc.
William C. Fort	Shell Global Solutions (ret)
Don Frikken	Becht Engineering
Miguel J. Maes	NASA White Sands Test Facility
Michael Pero	Hydrogen Safety, LLC
Glenn W. Scheffler	GWS Solutions of Tolland, LLC
Andrew J. Sherman	Powdermet Inc.
Ian Sutherland	General Motors
Robert G. Zalosh	Firexplo
Nicholas F. Barilo, Technical Support	PNNL
Edward G. Skolnik, Technical Support	Energetics, Inc.

The Panel conducted safety reviews for projects as noted in Table 2 since the last reporting (safety reviews have been conducted for 45 projects since March 2004). Final reports issued to DOE with recommendations are also noted [1-6]. At the National Renewable Energy Laboratory’s invitation, a Panel team participated (September 21, 2010) in a 30% design review of a new facility, the Energy Systems Integration Facility.

In FY 2010, the Panel first established a follow-up protocol to interview project teams in order to identify actions, findings and conclusions regarding safety review recommendations as one means for measuring the value of this work. Action on report recommendations represents a rich source of safety knowledge that can have broader benefits to others. Table 2 identifies the follow-up interviews that were conducted since the last reporting [7-9] and Table 3 summarizes the conclusions for all follow-up interviews conducted to date.

The Panel concluded that all interviewees have improved the safety aspects of the work they are conducting. Overall, over 90% of the recommendations – 90 in number – have been implemented in some manner or are in progress for the 11 follow-up interviews conducted. The Panel has concluded that the mechanism used by the Panel for seamless discussion and knowledge sharing at the project level has helped augment the prime responsibility of any organization to ensure the safe conduct of work [10].

The Hydrogen Safety Panel contributes to PNNL’s ongoing work in updating and adding new technical content to two safety knowledge tools, the Hydrogen Safety

**TABLE 2.** Project Safety Reviews and Reports Since July 1, 2010

Program Area	Project Title	Contractor
Storage	* # A Joint Theory and Experimental Project in the High-Throughput Synthesis and Testing of Porous Covalent-Organic Framework and Zeolitic Imidazolate Framework Materials for On-Board Vehicular Hydrogen Storage [1,8]	University of California, Los Angeles
Storage	* # Development of Improved Composite Pressure Vessels for Hydrogen Storage [2,9]	Lincoln Composites, Lincoln, NE
Storage	Design of Novel Multi-Component Metal Hydride-Based Mixtures for Hydrogen Storage [3]	Northwestern University, Evanston, IL
Storage	New Carbon-Based Materials with Increased Heats of Adsorption for Hydrogen Storage [4]	Northwestern University, Evanston, IL
ARRA	H-E-B Grocery Total Power Solution for Fuel Cell-Powered Material Handling Equipment [5]	Nuvera Fuel Cells/H-E-B, San Antonio, TX
ARRA	Fuel Cell-Powered Lift Truck Fleet Deployment [6]	Sysco Food Services, Houston, TX
Production and Delivery	# Water-Gas Shift Reaction via a Single-Stage Low-Temperature Membrane Reactor [7]	MPTI, Pittsburgh, PA

\* Safety evaluation report for previously conducted site visit

# Follow-up interview and report

Best Practices website ([www.h2bestpractices.org](http://www.h2bestpractices.org)) and the Hydrogen Incident Reporting and Lessons Learned database ([www.h2incidents.org](http://www.h2incidents.org)). For example, the Panel supported work on best practices to add new content on hydrogen properties, chemical hydrogen storage and indoor refueling of hydrogen-powered fuel cell forklifts. Panel members also assisted in reviewing technical content for the following postings in the Lessons Learned Corner of the above mentioned safety event database:

- The Importance of Purging Hydrogen Piping and Equipment
- Hydrogen Use in Anaerobic Chambers
- Adequate Ventilation of Battery Charging Facilities
- Learning from Burst Disk Failures

With Panel members serving as technical contributors and reviewers, two issues of the topical newsletter, *H2 Safety Snapshot*, were published:

- Handling Compressed Hydrogen Gas Cylinders [11]
- Identifying Safety Vulnerabilities [12]

Leadership has been provided to the International Energy Agency Hydrogen Implementing Agreement Task 31 (Hydrogen Safety) for the work under Subtask D, Knowledge Analysis, Dissemination and Use. The recently completed work under Task 19 (Hydrogen Safety) helped facilitate collaboration between member countries on the incident lessons learned and best practices databases [13].

## Conclusions and Future Directions

Being conscious of the need to use safe practices is a necessary first step for the conduct of all work. The work and approaches taken by the Panel will continue to focus on how safety knowledge, best practices and lessons learned can be brought to bear on the safe conduct of project work.

The Panel will undertake a number of initiatives in FY 2012 including:

- Safety plan reviews, safety review site visits and a final report for ARRA fuel cell deployment projects in specialty vehicle, auxiliary and back-up power, portable and combined heat and power applications.
- Follow-up teleconferences with all project teams for which safety review site visit reports have been issued in order to identify actions taken, findings, conclusions and other learnings.

**TABLE 3.** Categorizing Actions Taken on Report Recommendations - 11 Interviews

Category	Recommendations Implemented	Partial or In Progress	No Action	Total Recommendations
Safety Vulnerability/ Mitigation Analysis	15	4	5	24
System/Facility Design Modifications	7	5	1	13
Equipment/Hardware Installation and Operations and Maintenance	10	6	0	16
Safety Documentation	7	7	0	14
Training	1	3	0	4
Housekeeping	9	6	0	15
Emergency Response	7	3	2	12
<b>Total</b>	<b>56</b>	<b>34</b>	<b>8</b>	<b>98</b>

- Technical support for work on future issues of *H2 Safety Snapshot* and PNNL's hydrogen safety knowledge databases.
- Additional topics for study consistent with the Hydrogen Safety Panel's charter to identify safety-related data and knowledge gaps.

The 17<sup>th</sup> and 18<sup>th</sup> meetings of the Hydrogen Safety Panel are planned for April 2012 and September 2012, respectively.

### FY 2011 Publications/Presentations

1. Weiner, S.C., Fassbender, L.L. and K.A. Quick, "Using Hydrogen Safety Best Practices and Learning from Safety Events," PNNL-SA-70148, *International Journal of Hydrogen Energy*, Volume 36, Issue 3, February 2011, pp. 2729-2735.
2. Weiner, S.C. and Fassbender L.L., "Lessons Learned from Safety Events," PNNL-SA-78868, *International Conference on Hydrogen Safety*, San Francisco, CA, September 12–14, 2011 (manuscript accepted June 1, 2011).
3. Weiner, S.C., Fassbender, L.L., Blake, C., Aceves, S., Somerday, B.P. and Ruiz, A., "Web-based Resources Enhance Hydrogen Safety Knowledge," PNNL-SA-79693, *HYPOTHESIS IX*, San José, Costa Rica, December 12–15, 2011 (abstract accepted June 24, 2011).

### References

1. Barilo, N.F., R.A. Kallman, E.G. Skolnik and S.C. Weiner, "Safety Evaluation Report: A Joint Theory and Experimental Project in the High-Throughput Synthesis and Testing of Porous COF and ZIF Materials for On-Board Vehicular Hydrogen Storage, University of California, Los Angeles," PNNL-19900, October 19, 2010.
2. Fort, W.C., R.A. Kallman, M.J. Maes, E.G. Skolnik and S.C. Weiner, "Safety Evaluation Report: Development of Improved Composite Pressure Vessels for Hydrogen Storage, Lincoln Composites, Lincoln, NE," PNNL-20082, December 28, 2010.
3. Bain, A., N.F. Barilo, A.J. Sherman, E.G. Skolnik and S.C. Weiner, "Safety Evaluation Report: Design of Novel Multi-Component Metal Hydride-Based Mixtures for Hydrogen Storage, Northwestern University, Evanston, IL," PNNL-20280, March 28, 2011.
4. Bain, A., A.J. Sherman, E.G. Skolnik and S.C. Weiner, "Safety Evaluation Report: New Carbon-Based Materials with Increased Heats of Adsorption for Hydrogen Storage, Northwestern University, Evanston, IL," PNNL-20406, May 17, 2011.
5. Fort, W.C., G.W. Scheffler, E.G. Skolnik and S.C. Weiner, "Safety Evaluation Report: H-E-B Grocery Total Power Solution for Fuel Cell-Powered Material Handling Equipment, H-E-B, San Antonio, TX," PNNL-20480, June 14, 2011.
6. Fort, W.C., G.W. Scheffler, E.G. Skolnik and S.C. Weiner, "Safety Evaluation Report: Fuel Cell-Powered Lift Truck Fleet Deployment, Sysco Food Services of Houston, Inc., Houston, TX," PNNL-20504, June 27, 2011.
7. Skolnik, E.G., Safety Evaluation Follow-up Report for "Water-Gas Shift Reaction via a Single-Stage Low-Temperature Membrane Reactor, Media and Process Technology, Inc., Pittsburgh and Schenley, PA," August 6, 2010.
8. Skolnik, E.G., Safety Evaluation Follow-up Report for "Safety Evaluation Report: A Joint Theory and Experimental Project in the High-Throughput Synthesis and Testing of Porous COF and ZIF Materials for On-Board Vehicular Hydrogen Storage, University of California, Los Angeles," May 16, 2011.
9. Skolnik, E.G., Safety Evaluation Follow-up Report for "Safety Evaluation Report: Development of Improved Composite Pressure Vessels for Hydrogen Storage, Lincoln Composites, Lincoln, NE," May 16, 2011.
10. Weiner, S.C., R.A. Kallman and E.G. Skolnik, "Speaking of Safety: Learning from Safety Reviews," PNNL-SA-71062, 18<sup>th</sup> World Hydrogen Energy Conference, Essen, Germany, May 18, 2010.
11. Barilo, N.F. and Fassbender, L.L., "Handling Compressed Hydrogen Gas Cylinders," *H2 Safety Snapshot*, Volume 2, Issue 1, PNNL-SA-75299, November 2010.
12. Barilo, N.F. and Fassbender, L.L., "Identifying Safety Vulnerabilities," *H2 Safety Snapshot*, Volume 2, Issue 2, PNNL-SA-77099, July 2011.
13. Weiner, S.C. and Blake, C.W., "Safety Knowledge Tools Enhanced by International Collaboration," A White Paper of the International Energy Agency Hydrogen Implementing Agreement Task 19 – Hydrogen Safety, PNNL-19901, October 18, 2010.