

VIII.10 Hydrogen Safety Panel

Steven C. Weiner

Pacific Northwest National Laboratory (PNNL)
901 D Street SW, Suite 900
Washington, D.C. 20024-2115
Phone: (202) 646-7870
Email: sc.weiner@pnnl.gov

DOE Manager

HQ: Antonio Ruiz
Phone: (202) 586-0729
Email: Antonio.Ruiz@ee.doe.gov

Subcontractors:

- Addison Bain, NASA (ret), Melbourne, FL
- David J. Farese, Air Products and Chemicals, Inc., Allentown, PA
- William C. Fort, Shell Global Solutions (ret), Houston, TX
- Don Frikken, Becht Engineering, St. Louis, MO
- Richard A. Kallman, City of Santa Fe Springs, CA
- Glenn W. Scheffler, GWS Solutions of Tolland, LLC, Tolland, CT
- Andrew J. Sherman, Powdermet Inc., Euclid, OH
- Ian Sutherland, General Motors, Warren, MI
- Edward G. Skolnik, Energetics, Inc. Columbia, MD
- Robert G. Zalosh, Firexplo, Worcester, MA

Project Start Date: 2004

Project End Date: Project continuation and direction determined annually by DOE

Fiscal Year (FY) 2012 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 of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

- (A) Safety Data and Information: Limited Access and Availability
- (C) Safety is Not Always Treated as a Continuous Process
- (G) Insufficient Technical Data to Revise Standards

Contribution to Achievement of DOE Hydrogen Safety Milestones

This project contributes to achievement of the following DOE milestones from the Hydrogen Safety section (3.8) 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 2012 Accomplishments

- Conducted the 16th Hydrogen Safety Panel meeting in San Francisco, CA, September 11, 2011 in conjunction with the International Conference on Hydrogen Safety; conducted the 17th Hydrogen Safety Panel meeting in Washington, D.C., March 28-29, 2012.
- Reviewed 11 safety plans since July 1, 2011 for projects in fuel cell and hydrogen storage research and development (R&D).
- Conducted safety review site visits; completed and submitted safety evaluation reports; conducted follow-up teleconferences for previously issued safety evaluation reports and submitted interview reports.
- Provided technical guidance, source material and review for the Hydrogen Incident Reporting and Lessons Learned database (www.h2incidents.org) and Hydrogen Safety Best Practices (www.h2bestpractices.org).
- Examined the longer-term role of the Hydrogen Safety Panel through brainstorming, discussion and recommendations to DOE.



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 deployment and commercialization. As such, safety is given paramount importance in all facets of the research, development,

demonstration and deployment work of the DOE Fuel Cell Technologies (FCT) Program Office.

Recognizing the nature of the DOE FCT 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, 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 FCT 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 16th Panel meeting was held in San Francisco, CA, September 11, 2011 in conjunction with the International Conference on Hydrogen Safety and focused principally on brainstorming new ideas to support the Safety, Codes & Standards sub-program vision and goals. The Panel was joined by stakeholders and other subject matter experts. In all 75 ideas were generated, collated and ranked and Table 1 emphasizes the initiatives which got the highest number of votes and were, therefore, worthy of further consideration.

The 17th meeting was held in Washington, D.C., March 28-29, 2012 and included the following topics: (1) an “incident owner” discussing the events and learnings from a hydrogen tube trailer fire; (2) brainstorming of ideas for a safety checklist to be utilized for assessing the installation of hydrogen systems with an outdoor supply system providing for an indoor use; (3) discussion of Panel work and results to be presented at the 2012 Annual Merit Review meeting.

TABLE 1. Strategically Examining the Hydrogen Safety Panel's Work

Current Initiatives	New Initiative Ideas
Safety Planning and Evaluation	
Continue safety planning work, safety plan reviews, site visits	Evaluate long-term implementation of site visit recommendations
	Conduct non-DOE project site visits upon request including Department of Defense, National Aeronautic and Space Administration facilities
Safety Events, Best Practices and New Tools	
Publish safety event learnings and best practices in technical journals	Establish a mechanism for the Panel to access all reported incidents and near-misses
Panel as technical contributors for international workshops and initiatives	Expand role of investigating H ₂ incidents beyond DOE
	New web-based tools: leak/detection sensors, quantitative risk assessment, maintenance practices, hydrogen properties
Other	
	Tie to codes and standards work; evaluate and propose code changes
	Support authorities having jurisdiction with reviewing hydrogen applications and additional training

Current Panel membership is noted in Table 2.

TABLE 2. Hydrogen Safety Panel

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

The Panel conducted safety reviews for projects as noted in Table 3 since the last reporting (safety reviews have been conducted for 47 projects since March 2004). Final reports issued to DOE with recommendations are also noted [1,2].

In FY 2010, the Panel first established a follow-up protocol to interview project teams in order to identify

TABLE 3. Project Safety Reviews and Reports since July 1, 2011

Program Area	Project Title	Contractor
ARRA	# Accelerating Acceptance of Fuel Cell Backup Power Systems [1,3]	Plug Power/Robins Air Force Base, Warner Robins, GA
ARRA	Fuel Cell-Powered Lift Truck Fleet Deployment [2]	Coca-Cola Bottling Co. Consolidated, Charlotte, NC
Storage	# New Carbon-Based Materials with Increased Heats of Adsorption for Hydrogen Storage [4]	Northwestern University, Evanston, IL
Storage	# Design of Novel Multi-Component Metal Hydride-Based Mixtures for Hydrogen Storage [5]	Northwestern University, Evanston, IL
ARRA	# Fuel Cell-Powered Lift Truck Fleet Deployment [6]	Sysco Food Services, Houston, TX

Follow-up interview and report for previously conducted site visit
ARRA – American Recovery and Reinvestment Act

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 3 identifies the follow-up interviews that were conducted since the last reporting [4-6] and Table 4 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 – 119 in number – have been implemented in some manner or are in progress for the 14 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 [7,8].

The Hydrogen Safety Panel has been engaged in discussing how hydrogen and fuel cell safety event and

equipment failure information and data can serve as a rich and valuable resource if it is systematically collected, analyzed and used to enhance our knowledge. The Panel issued a unanimously endorsed statement to DOE to identify appropriate mechanisms for such information sharing and to facilitate the necessary interactions for such discussion with project teams that would fully recognize and respect confidentiality and contractual obligations [9].

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. Under this task, collaborations in safety event databases continued between member countries. Online tools were demonstrated at the International Conference on Hydrogen Safety [10].

Collaborations to share and disseminate safety information and knowledge continue to be an important aspect of Hydrogen Safety Panel work. For example, the Panel contributed to the University of California Center for Laboratory Safety Workshop, Irvine, CA, March 15-16, 2012. The workshop examined new, more effective ways to make certain that research is performed safely. Work on incidents, lessons learned and best practices was shared with attendees [11].

Conclusions and Future Directions

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 and the deployment of hydrogen technologies and systems in applications of interest and priority in the DOE FCT Program.

The Panel will undertake a number of initiatives over the next year 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.

TABLE 4. Categorizing Actions Taken on Report Recommendations - 14 Interviews

Category	Recommendations Implemented	In Progress	No Action	Total Recommendations
Safety Vulnerability/ Mitigation Analysis	23	4	6	33
System/Facility Design Modifications	8	5	1	14
Equipment/Hardware Installation and O&M	15	6	1	22
Safety Documentation	14	7	0	21
Training	3	3	0	6
Housekeeping	14	6	1	21
Emergency Response	8	3	2	13
Total	85	34	11	130

- 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.
- Completion of a safety checklist for an outdoor supply system providing hydrogen for an indoor application to be utilized as a resource for hazard analysis.
- Additional topics for study and knowledge dissemination that utilize the new initiative ideas discussed previously and consistent with the Hydrogen Safety Panel's charter to identify safety-related data and knowledge gaps.

FY 2012 Publications/Presentations

1. Elmore, M.R., Fassbender, L.L., Hamilton, J.J. and Weiner, S.C., "Hydrogen Emergency Response Training for First Responders," PNNL-SA-79009, International Journal of Hydrogen Energy (manuscript HE-D-11-03656 submitted December 2011).
2. 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-82812/83988, HYPOTHESIS IX, San José, Costa Rica, December 12-15, 2011.
3. Weiner, S.C., "Safety, Codes and Standards – An Overview," U.S. Department of Energy, HYPOTHESIS IX, San José, Costa Rica, December 12-15, 2011.
4. Weiner, S.C. and Fassbender L.L., "Lessons Learned from Safety Events," PNNL-SA-86551, International Journal of Hydrogen Energy (manuscript HE9746, <http://dx.doi.org/10.1016/j.ijhydene.2012.03.152>, published online April 28, 2012).
5. Kallman, R.A., Barilo, N.F. and Murphy, W.F., "Permitting of a Project Involving Hydrogen – A Code Official's Perspective," PNNL-SA-87780, World Hydrogen Energy Conference, Toronto, Ontario, Canada, June 3-7, 2012.
6. 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-82812, International Journal of Hydrogen Energy (manuscript HE10236, <http://dx.doi.org/10.1016/j.ijhydene.2012.07.028>, published online August 2, 2012).

References

1. Barilo, N.F., D. Frikken, S.C. Weiner and R.G. Zalosh, "Safety Evaluation Report: Accelerating Acceptance of Fuel Cell Backup Power Systems, Robins Air Force Base, Warner Robins, GA," PNNL-21078, January 17, 2012.
2. Barilo, N.F., D. Frikken, S.C. Weiner and R.G. Zalosh, "Safety Evaluation Report: Fuel Cell Powered Lift Truck Fleet Deployment, Coca-Cola Bottling Co. Consolidated, Charlotte, NC," PNNL-21079, January 18, 2012.
3. Weiner, S.C., Safety Evaluation Follow-up Report for "Safety Evaluation Report: Accelerating Acceptance of Fuel Cell Backup Power Systems, Robins Air Force Base, Warner Robins, GA," June 28, 2012.
4. Skolnik, E.G., Safety Evaluation Follow-up Report for "Safety Evaluation Report: New Carbon-Based Materials with Increased Heats of Adsorption for Hydrogen Storage, Northwestern University, Evanston, IL," January 27, 2012.
5. Skolnik, E.G., Safety Evaluation Follow-up Report for "Safety Evaluation Report: Design of Novel Multi-Component Metal Hydride-Based Mixtures for Hydrogen Storage, Northwestern University, Evanston, IL," February 6, 2012.
6. Skolnik, E.G., Safety Evaluation Follow-up Report for "Safety Evaluation Report: Fuel Cell-Powered Lift Truck Fleet Deployment, Sysco Food Services of Houston, Inc., Houston, TX," March 20, 2012.
7. Weiner, S.C., R.A. Kallman and E.G. Skolnik, "Speaking of Safety: Learning from Safety Reviews," PNNL-SA-71062, 18th World Hydrogen Energy Conference, Essen, Germany, May 18, 2010.
8. Weiner, S.C., "Hydrogen Safety Panel," PNNL-SA-86512, DOE Hydrogen and Fuel Cells Program Annual Merit Review and Peer Evaluation Meeting, Arlington, VA, May 15, 2012.
9. Weiner, S.C., "Learning from Safety Events – A Statement from the Hydrogen Safety Panel," PNNL-SA-85153, January 17, 2012.
10. On-line demonstrations of *Hydrogen Incident Reporting and Lessons Learned* (<http://H2incidents.org>) and *Hydrogen Incident and Accident Database* (HIAD – http://www.hysafe.org/HIAD_DAM/HIAD.php) at the International Conference on Hydrogen Safety, San Francisco, CA, September 12–15, 2011.
11. Gibson, J.H. and N.L. Wayne, "Proceedings of the 2012 University of California Center for Laboratory Safety Workshop," University of California Center for Laboratory Safety, UCLA, Los Angeles, CA, May 5, 2012 (draft).