VIII.9 Hydrogen Safety Panel and Hydrogen Safety Knowledge Tools

Nick Barilo
Pacific Northwest National Laboratory (PNNL)
P.O. Box 999
Richland, WA 99354
Phone: (509) 371-7894
Email: nick.barilo@pnnl.gov

DOE Manager
Rick Farmer
Phone: (202) 586-1623
Email: Richard.Farmer@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
- Larry Fluer, Fluer, Inc., Paso Robles, CA
- 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
- Robert G. Zalosh, Firexplo, Wellesley, MA

Project Start Date: 2004
Project End Date: Project continuation and direction determined annually by DOE

Overall 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.
- Collect information and share lessons learned from hydrogen incidents and near-misses, with a goal of preventing similar safety events from occurring in the future.
- Capture the vast and growing knowledge base of hydrogen experience and make it publicly available to the "hydrogen community" and stakeholders.

Fiscal Year (FY) 2013 Objectives

- Conduct ongoing safety assessments of DOE projects through safety plan reviews and site visits.
- Engage other hydrogen and fuel cell technology stakeholders through Hydrogen Safety Panel (HSP) meetings and targeted outreach.
- Increase number of records in database by encouraging "incident owners" to share lessons learned with the hydrogen community.
- Enhance utility of the safety knowledge tools.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Safety section of the Fuel Cell Technologies Office 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

(D) Lack of Hydrogen Knowledge by Authorities Having Jurisdiction

(G) Insufficient Technical Data to Revise Standards

Contribution to Achievement of DOE Safety, Codes and Standards Milestones

This project contributes to achievement of the following DOE tasks and milestones from the Hydrogen Safety, Codes and Standards section (3.7) of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

- Task 1: Address Safety of DOE R&D Projects (ongoing)
- Task 5: Dissemination of Data, Safety Knowledge, and Information (ongoing)
- Milestone 5.1: Update safety bibliography and incidents databases. (4Q, 2011-2020)

FY 2013 Accomplishments

- Conducted the 18th HSP meeting in Honolulu, HI, February 4–7, 2013, in conjunction with "Hydrogen Emergency Response Training for First Responders."
- Issued a final report, "Hydrogen Safety Panel Review of DOE Fuel Cell Projects," for the HSP's American Recovery and Reinvestment Act (ARRA) project.
- Contributed to early safety review activities for the University of Hawaii's Hawaii Natural Energy Institute (HNEI) two projects (Power Park Project; Geothermal Hydrogen Grid Management Project) on Oahu and the Big Island.

- Collaborated with DOE to present the educational session, "Deployment of Hydrogen Fuel Cells – Safety Considerations and Resources," at the 2013 National Fire Protection Association (NFPA) Conference & Expo, in Chicago, IL, on June 11, 2013.
- Reviewed seven safety plans since July 1, 2013, for projects in fuel cell and hydrogen storage research and development (R&D).
- Completed a safety checklist for an outdoor supply system providing hydrogen for an indoor application to be utilized as a resource for hazard analysis.
- Added four new safety event records to H2Incidents.org since the 2012 Annual Merit Review and Peer Evaluation Meeting, for a total of 210 records currently in the database.
- Developed a first-of-its-kind iPad/iPhone app to enhance the utility and integration of the safety knowledge tools (H2Incidents.org and H2bestpractices.org) with other safety planning resources.

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) Office. This annual report summarizes activities associated with two projects, the Hydrogen Safety Panel and Hydrogen Safety Knowledge Tools.

Recognizing the nature of the DOE FCT Program and the importance of safety planning, the HSP 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 HSP 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 HSP 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.

PNNL continues to improve the safety knowledge software tools as well as develop new techniques for dissemination of this information. This report covers the Hydrogen Incident Reporting and Lessons Learned database (H2Incidents.org) and the Hydrogen Safety Best Practices online manual (H2bestpractices.org). These web-based resources play a key role in reaching, educating, and informing stakeholders whose contributions will help enable the deployment of new hydrogen and fuel cell technologies.

APPROACH

The HSP 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 HSP are trying to achieve safe operation, handling, and use of hydrogen and hydrogen systems for all DOE projects.

The Hydrogen Incident Reporting and Lessons Learned (H2Incidents.org) facilitates open sharing of lessons learned from hydrogen safety events to help avoid similar events from occurring in the future. DOE-funded project teams and others are encouraged to voluntarily submit records of incidents and near-misses, along with specific lessons learned. The addition of new records is also pursued by actively seeking news reports on hydrogen events, searching existing databases, and encouraging self-submittals by "incident owners."

Hydrogen Safety Best Practices (H2bestpractices.org) is an easy-to-use web-based manual focusing on the safe use of hydrogen. It has been compiled from learnings and observations from HSP site visits, safety plan reviews and other work, and available reference materials tailored specifically to working with hydrogen. Links are provided to other web-based resources and supporting information to enhance the usefulness of this resource. Experts from the HSP, national laboratories, and other subject matter experts contribute and review new material added to the site. PNNL staff members, with assistance from the HSP, respond to user questions and comments.

RESULTS

The HSP was formed in FY 2004 and the first meeting was held in Washington, D.C., December 11–12, 2003. The HSP is comprised of 14 members having over 400 years of industry and related experience (see Table 1 for FY 2013 Panel membership).

The 18th HSP meeting was held in Honolulu, HI, during the week of February 4, 2013. The meeting provided a unique opportunity to hold a first-of-its-kind meeting with local stakeholders and authorities having jurisdiction to discuss

the barriers to the safe commercial deployment of hydrogen technologies in Hawaii. One outcome of this meeting was an initiative to create a local hydrogen stakeholder network. Two HSP task groups were formed to address technical safety gaps related to certifications and outdoor enclosures. Also, the concurrent timing of the meeting and first responder training was beneficial for bringing focused attention to hydrogen and fuel cell technologies to Hawaii. Many of the guests expressed thanks and shared that the meetings, interactions, and related activities were a great benefit.

TABLE 1. HSP Members

Nick Barilo, Project Manager*	PNNL
Bill Fort, Chair*	Shell Global Solutions (ret)
Addison Bain	NASA (ret)
David Farese	Air Products and Chemicals
Larry Fluer*	Fluer, Inc.
Don Frikken	Becht Engineering
Aaron Harris	Sandia National Laboratories
Richard Kallman*	City of Santa Fe Springs, CA
Miguel Maes	NASA White Sands Test Facility
Glenn Scheffler	GWS Solutions of Tolland, LLC
Andrew Sherman	Powdermet Inc.
Ian Sutherland	General Motors
Steven Weiner*	PNNL
Robert Zalosh	Firexplo

* Changes in HSP membership/responsibility

A final report, "Hydrogen Safety Panel Review of DOE Fuel Cell Projects," was issued for the HSP's ARRA project [1]. The report includes recommendations in the areas of project integration/safety planning, hazard analysis, codes and standards requirements, and third-party certification. Dissemination of this report will help bring the safety learnings to a broader set of stakeholders who also play an essential role in helping accelerate fuel cell commercialization.

During the past year the HSP has provided various safety review and support to projects as noted in Table 2. Since 2004, the HSP has reviewed 325 safety plans, conducted 48 safety reviews, and performed 16 follow-up interviews.

The HSP's most recent safety review work has focused on project investments intended to accelerate the commercialization and deployment of fuel cells and fuel cell manufacturing, installation, maintenance, and support services. The timing of the HSP's safety plan reviews and subsequent site visits has often occurred after equipment was deployed or operational. This resulted in safety recommendations on safety planning, equipment design, and configuration that were often difficult to implement. A new approach for earlier project involvement was utilized in support of safety review activities for the HNEI hydrogen production and fuel station projects. The activities included piping and instrumentation diagram reviews, design reviews, and a certification study review. The concept proved successful and the project teams were able to realize the benefits of:

- Understanding and evaluating the safety issues and code requirements.
- Implementing significant design changes based on input from the HSP.
- Enhancing the confidence of project managers and stakeholders in approving the final design configuration.

This new model for HSP interaction with project teams is shown in Figure 1. Implementation of this approach will help ensure that HSP recommendations and safety considerations are integrated into the project to influence the final equipment configuration. To promote this model, PNNL worked with the DOE Golden Office to expand contract language to encourage projects to integrate the HSP into additional project activities. Additionally, the HSP is now participating in project kickoff meetings in order to help the projects understand the safety planning requirements and how the HSP may be a resource for ensuring that safety is integrated into all aspects of their project scope (Table 2 identifies where those activities have occurred).

Engagement in the project planning phase enables the HSP to identify technical safety gaps. As a result of the HSP's ARRA and HNEI project work, an HSP task group was established to consider the "Safety of Hydrogen Systems Installed in Outdoor Enclosures." The HSP's learnings regarding incomplete code requirements for equipment enclosures has already been impactful on the NFPA 2, "Hydrogen Technologies Code," committee which has formed its own task group to evaluate possible changes for the 2015 edition of that document.

Sharing and disseminating safety information and knowledge continues to be an important aspect of HSP work. For example, HSP members collaborated with DOE to present the educational session, "Deployment of Hydrogen Fuel Cells – Safety Considerations and Resources," at the 2013 NFPA Conference & Expo, in Chicago, IL, on June 11, 2013 [10]. This session addressed the current status of hydrogen fuel cells and the applicable codes and standards that enable their deployment. The resources which play a key role in reaching, educating and informing stakeholders whose contributions will help enable a broad set of fuel cell applications were also presented.

International collaboration is also an important theme. Leadership was provided to the International Energy Agency Hydrogen Implementing Agreement Task 31 (Hydrogen Safety) for the work under Subtask D, Knowledge Analysis,

TABLE 2. HSP Project Safety Work since July 1, 2012

Work	Project Title	Contractor
Process diagram, on-location site layout and conceptual design reviews (July 2012)	Renewable Hydrogen Production Research Projects	Hawaii Natural Energy Institute
HNEI Certification Study Review [2]	Renewable Hydrogen Production Research Projects	Hawaii Natural Energy Institute
Safety plan reviews [3,4]	Hydrogen Storage in Metal-Organic Frameworks	NIST, GM, LBNL, UC Berkeley
Safety plan review [5]	Room Temperature Hydrogen Storage in Nano-Confined Liquids	HRL Laboratories
Safety plan reviews [6,7,8]	Roots Air Management System with Integrated Expander	Eaton Corp., Ballard
Safety evaluation follow-up report [9]	Fuel-Cell Powered Lift Truck Fleet Deployment	Coca-Cola, Bottling Co., Plug Power
Safety evaluations final report [1]	HSP Review of DOE Fuel Cell Projects	Various contractors
Safety guidance at project kickoff (March 2013)	Hydrogen Recycling System Demonstration	H2Pump
Safety guidance at project kickoff (March 2013)	Fuel Cell Ground Support Equipment Development and Demonstration	Plug Power
Safety guidance at project kickoff (May 2013)	Fuel Cell Auxiliary Power Unit for Refrigerated Trucks	Nuvera

NIST – National Institute of Standards and Technology; GM – General Motors; LBNL – Lawrence Berkeley National Laboratory; UC Berkeley – University of California, Berkeley

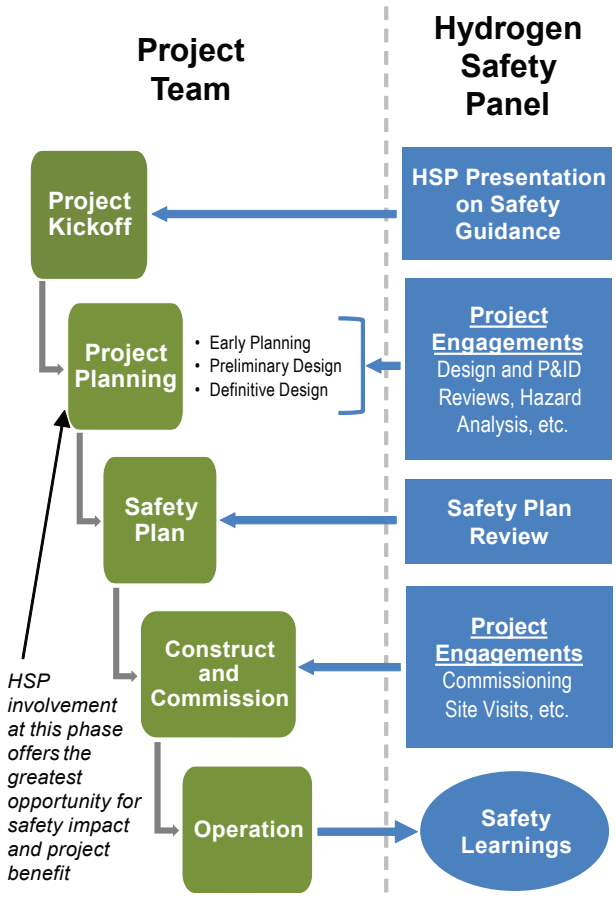

FIGURE 1. Hydrogen Safety Panel Reviews for Deployment Projects

Dissemination and Use. Under this task, a white paper was authored to illustrate how technology information and knowledge dissemination are an integral part of this international collaboration [11]. Two talks were contributed to the Hydrogen Safety Stakeholder Workshop, *Sharing Knowledge, Identifying Needs, Celebrating Progress,* in Bethesda, MD, on October 2-3, 2012 [12,13]. PNNL also contributed two manuscripts for presentation at the International Conference on Hydrogen Safety in Brussels, Belgium, on September 9-11, 2013 [14,15].

The safety knowledge tools H2incidents.org and H2bestpractices.org websites continue to see a steady number of visitors. To increase visibility and get this information in the hands of a greater audience, the project has integrated information from the websites into a mobile application (see Figure 2). The "Hydrogen Tools" application brings added value by combining information from the websites (H2incidents.org and H2bestpractices.org) as well as other project resources (safety planning guidance and a safety checklist), calculators and related tools. The mobile app also allows for search capabilities across the incidents and database resources and the best practices can be viewed offline.

FIGURE 2. Hydrogen Tools iPad App

CONCLUSIONS AND FUTURE DIRECTIONS

The work and approaches taken by the HSP 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 Office. The HSP can also be used more broadly as an asset for safe commercialization by reaching out to new stakeholders and users involved in early deployment activities.

The HSP will undertake a number of initiatives over the next year including:

- Support project activities with the focus on early engagement including kickoff meetings, safety plan reviews, site visits and other relevant interactions with project teams.
- Submit a white paper to DOE on "Safety of Hydrogen Systems Installed in Outdoor Enclosures."
- Achieving an appropriate mix of safety expertise and perspective is important for the Panel to perform safety reviews and address relevant issues. PNNL will continue to evaluate the HSP membership to maintain its leadership role in hydrogen safety.
- Seek opportunities to share safety knowledge with new audiences to facilitate the safe deployment of hydrogen and fuel cell technologies. Some examples include the 2014 NFPA Conference and Expo and potential collaboration with the U.S. Fire Administration.

Our hydrogen safety knowledge tools help remove barriers to the deployment and commercialization of hydrogen and fuel cell technologies. Feedback on both of our websites has been extremely positive. In order to remain vital and useful, databases and websites require a concerted effort beyond just general maintenance. The content must be current, relevant to the community being served, and valuable to the users.

- Continue to encourage DOE projects and private-sector incident owners to submit records of incidents and near-misses to share their lessons learned with the hydrogen community.
- Issue the "Hydrogen Tools" app for the iPhone.
- Evaluate additional resources that could be added to the mobile application to enhance its usefulness for projects and permitting officials.

FY 2013 PUBLICATIONS

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2. Kallman, R.A., Barilo, N.F. and Murphy, W.F., "Permitting of a Project Involving Hydrogen – A Code Official's Perspective," PNNL-SA-87780, Energy Procedia, Volume 29, November 2012, pp. 265-275.

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-82812, International Journal of Hydrogen Energy, Volume 38 (2013), pp 7583-7593.

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1. Weiner, S.C. and N.F. Barilo, "Hydrogen Safety Panel Review of DOE Fuel Cell Projects," PNNL-22075, December 18, 2012.

2. Barilo, N. F. to Ewan, M., "Re: Boyd Report on Hydrogen Safety Design Review held at Powertech," December 5, 2012.

3. Weiner, S.C. to Adams, J., "Safety Plan Review for Hydrogen Storage in Metal-Organic Frameworks," September 5, 2012.

4. Weiner, S.C. to Adams, J., "Revised Safety Plan for UC/LBNL Hydrogen Storage in Metal-Organic Frameworks," December 4, 2012.

5. Weiner, S.C. to Randolph, K., "HRL Safety Plan Reviewed by Hydrogen Safety Panel," September 25, 2012.

6. Weiner, S.C. to Tyler, R., "Eaton Corp. Safety Plan Reviewed by Hydrogen Safety Panel," November 28, 2012.

7. Weiner, S.C. to Tyler, R., "Ballard Safety Plan Reviewed by Hydrogen Safety Panel," December 5, 2012.

8. Barilo, N.F. to Tyler, R., "Revised Eaton Corp. Safety Plan," February 20, 2013.

9. Weiner, S.C., Follow-up Report for "Safety Evaluation Report: Fuel-Cell Powered Lift Truck Fleet Deployment, Coca-Cola Bottling Company Consolidated, Charlotte, NC," October 19, 2012.

10. Barilo, N.F., Weiner, S.C., and James, C., "Deployment of Hydrogen Fuel Cells – Safety Considerations and Resources," PNNL-SA-92552, 2013 NFPA Conference & Expo, June 11, 2013.

11. Weiner, S.C., "Advancing the Hydrogen Safety Knowledge Base," A White Paper of the International Energy Agency Hydrogen Implementing Agreement Task 31 – Hydrogen Safety, PNNL-22159, January 15, 2013.

12. Barilo, N.F., "Hydrogen Safety Program," IEA Hydrogen Implementing Agreement Hydrogen Safety Stakeholders Workshop, Bethesda, MD, October 2–3, 2012.

13. Weiner, S.C., "Safety Knowledge Tools Overview and Examples," PNNL-SA-90919, IEA Hydrogen Implementing Agreement Hydrogen Safety Stakeholders Workshop, Bethesda, MD, October 2–3, 2012.

14. Barilo, N.F. and Weiner, S.C., "Deploying Fuel Cell Systems: What Have We Learned?" PNNL-SA-92591, International Conference on Hydrogen Safety, Brussels, Belgium, September 9–11, 2013.

15. Weiner, S.C., "Advancing the Hydrogen Safety Knowledge Base," PNNL-SA-91531, International Conference on Hydrogen Safety, Brussels, Belgium, September 9–11, 2013.