

VIII.6 Hydrogen Safety Panel, Safety Knowledge Tools and First Responder Training Resources

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Project Start Date: 2004

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

Overall Objectives

- Enable the safe and timely transition to hydrogen and fuel cell technologies.
- Provide expertise and recommendations to help identify safety-related technical data gaps, best practices, and lessons learned.
- Help integrate safety planning into funded projects to ensure that projects address and incorporate hydrogen safety practices.
- Collect information and share lessons learned from hydrogen incidents and near misses to help prevent similar safety events in the future.
- Capture vast and growing knowledge base of hydrogen experience and make it publicly available to the hydrogen community and stakeholders.

- Support implementation of hydrogen and fuel cell technologies by providing technically accurate hydrogen safety and emergency response information to first responders.

Fiscal Year (FY) 2017 Objectives

- Complete a third party hydrogen certification guide to facilitate timely project permitting and approval by code officials.
- Meet with code officials, project proponents, and stakeholders from recently completed fuel station projects to discuss and document safety learnings and needs.
- Provide classroom training for first responders at a minimum of three locations in the Northeast U.S. to support the deployment of fueling stations and rollout of fuel cell electric vehicles.
- Participate in outreach events on hydrogen safety aimed at a variety of stakeholder groups to emphasize available tools and resources.

Technical Barriers

This project addresses the following technical barriers from the DOE Fuel Cell Technologies Office (FCTO) Multi-Year Research, Development and Demonstration Plan [1].

Safety, Codes and Standards

- (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 AHJs
- (E) Lack of Hydrogen Training Materials and Facilities for Emergency Responders
- (F) Insufficient Technical Data to Revise Standards

Education and Outreach

- (A) Lack of Readily Available, Objective, and Technically Accurate Information
- (D) Lack of Educated Trainers and Training Opportunities

Contribution to Achievement of DOE Milestones

This project contributes to achievement of the following DOE tasks and milestones from the FCTO Multi-Year Research, Development, and Demonstration Plan:

Safety, Codes, and Standards

- 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)

Education and Outreach

- Task 1: Educate Safety and Code Officials (ongoing)
- Milestone 1.1: Update “Introduction to Hydrogen Safety for First Responders” Course for First Responders. (Biannually)

FY 2017 Accomplishments

- Conducted 33 project reviews (including safety plans and project designs) from July 15, 2016 to July 1, 2017.
- Evaluated 12 applicant safety plans in support of the California Energy Commission (CEC) general funding opportunity for new light-duty vehicle hydrogen fueling stations.
- Provided four first responder training classes at three locations in the Northeast United States, November 6–10, 2016, with approximately 250 attendees.
- Held the 23rd Hydrogen Safety Panel (HSP) meeting in Washington, D.C., November 15–17, 2016, enabling consideration of timely and relevant safety issues and the engagement of key hydrogen infrastructure stakeholders.
- Published the completed Hydrogen Equipment Certification Guide for public download in January 2017.
- Expanded available resources on the Hydrogen Tools Portal (<http://h2tools.org>), adding the Hydrogen Analysis Resource Center and presentations and papers from the International Conference on Hydrogen Safety (ICHS).
- Provided outreach and educational sessions for a variety of audiences including the National Fire Protection Association, Boston Tunnel Authorities, and Hydrogen South Africa.



INTRODUCTION

Safety is essential 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 FCTO. This annual report summarizes activities associated with three project tasks: the HSP, Safety Knowledge Tools, and First Responder Training Resources.

Recognizing the nature of the DOE FCTO program and the importance of safety planning, the HSP was formed in December 2003 to assemble 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 panel’s experience resides in industrial hydrogen production and supply, hydrogen research and development 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 hydrogen projects and their safety plans, and explores ways to develop and disseminate best practices and lessons learned, all broadly benefiting industry and the FCTO program. The panel currently has 15 members with a total of over 400 years of industry and related experience (see Table 1 for FY 2017 panel membership).

TABLE 1. Current Hydrogen Safety Panel Membership



Nick Barilo, Program Manager	PNNL
Richard Kallman, Chair	City of Santa Fe Springs, CA
Eric Binder*	Santa Monica Fire Department
Ken Boyce*	UL
David Farese	Air Products and Chemicals
Don Frikken	Becht Engineering
Livio Gambone	CSA Group
Aaron Harris	Air Liquide
Chris LaFleur	Sandia National Laboratories
Miguel Maes	NASA White Sands Test Facility
Steve Mathison	Honda Motor Company
Larry Moulthrop	Proton OnSite
Glenn Scheffler	GWS Solutions of Tolland, LLC
Tom Witte	Witte Engineered Gases
Robert Zalosh	Firexplo

* New panel members

Widespread availability and communication of safety-related information are crucial to ensuring the safe operation of future hydrogen and fuel cell technology systems. The entire hydrogen community benefits if hydrogen-safety-related knowledge is openly and broadly shared. To that end, PNNL continues to improve the safety knowledge software tools and develop new techniques for disseminating this information. This report covers the Hydrogen Tools Portal (<http://h2tools.org>), the Hydrogen Lessons Learned database (<http://h2tools.org/lessons/>), and the Hydrogen Safety Best Practices online manual (<https://h2tools.org/bestpractices>). These resources are key to reaching, informing, and educating users and stakeholders whose contributions will help enable the deployment of new hydrogen and fuel cell technologies.

Suitably trained emergency response personnel are essential to a viable infrastructure. The FCTO has placed a priority on training emergency response personnel, not only because these personnel need to understand how to respond to a hydrogen incident, but also because firefighters and other emergency responders are influential in their communities and can be a positive force in the introduction of hydrogen and fuel cells into local markets. This report covers hazardous materials emergency response training to provide a tiered hydrogen safety education program for emergency responders. The effort started with development and distribution of the awareness-level online course in FY 2006–2007. An operations-level classroom curriculum was developed in FY 2008–2009, including design, construction, and operation of a fuel cell vehicle prop for hands-on training. PNNL and the California Fuel Cell Partnership (CaFCP) collaborated to develop a national hydrogen safety training resource for emergency responders, which was made publicly available in September 2014.

APPROACH

The HSP strives to raise safety consciousness most directly at the project level through organizational policies and procedures, safety culture, and priorities. Project safety plans and design documents are reviewed to encourage thorough and continuous attention to safety aspects of the specific work being conducted. Panel safety reviews focus on engagement, learning, knowledge sharing, and active discussion of safety practices and lessons learned, rather than performing audits or regulatory exercises. Through this approach, the HSP is trying to achieve safe operation, handling, and use of hydrogen and hydrogen systems for all projects.

The approach for disseminating safety knowledge in FY 2017 focused on adding resources to the existing Hydrogen Tools Portal and participating in impactful outreach activities. The portal brings together and enhances the utility of a variety of tools and web-based content on the safety aspects of hydrogen and fuel cell technologies.

It is intended to help inform those tasked with designing, approving, or using systems and facilities, as well as those responding to incidents. Additional discussion is provided in the Results section of this report.

PNNL collaborates with subject matter experts in hydrogen safety and first responder training to develop, review, and revise training materials as needed. The PNNL project team works with DOE to inform stakeholder groups of training opportunities and to provide live training when appropriate. The online awareness-level course provides the student with a basic understanding of hydrogen properties, uses, and appropriate emergency response actions. The operations-level classroom and hands-on prop-based course has been presented at the Volpentest Hazardous Material Management and Materials Response Federal Training Center in Richland, Washington, and at several fire training centers in California, Hawaii, and the Northeastern United States to reach larger audiences in areas where hydrogen and fuel cell technologies are being deployed. The National Hydrogen and Fuel Cell Emergency Response Training Resource provides a consistent source of accurate information and current knowledge to ensure that training organizations have the information needed to develop or supplement their own courses. As part of this resource, a training template has been developed to guide the delivery of a variety of training regimens to various audiences.

RESULTS

The 23rd HSP meeting was held in Washington, D.C., November 15–17, 2016. The meeting provided opportunities to consider timely and relevant safety issues and provide direct input to the FCTO. The topics discussed and outcomes achieved at the meeting are detailed in the meeting minutes [2]. Significant activities during the panel meeting included interaction with representatives from the Department of Transportation on hydrogen safety issues associated with vehicles and tank testing, and a panel review of a Department of Defense project.

During the past year, the HSP has provided safety reviews and support to the 31 projects identified in Table 2. Since 2004, the panel has participated in 474 project reviews (including safety plans, site visit reviews, follow-up phone interviews, and design review work). In addition to reviewing safety plans for DOE, the HSP provided crucial support to the CEC in support of the California general funding opportunity for fueling stations through formal evaluation of applicant safety plans. The feedback provided by the HSP assisted the CEC in evaluating applicants and determining awardees. Future support will be provided in the form of a site visit and teleconferences with awardees to ensure that the final station configurations have addressed the necessary safety considerations. The HSP is also contracted to provide expertise to the CEC should a hydrogen incident occur.

TABLE 2. HSP Project Safety Work July 15, 2016 to July 1, 2017

Work	Project Title	Contractor
Safety Plan Review	High Performance PEFC Electrode Structures	UTRC
Safety Plan Review	Advancing Hydrogen Dispenser Technology by Using Innovative Intelligent Networks	Ivys, Inc.
Safety Plan Review	Modular SOEC System for Efficient H ₂ Production at High Current Density	FuelCell Energy
Safety Plan Review	High Temperature Alkaline Water Electrolysis	Giner, Inc.
Safety Plan Review	Solid Oxide Based Electrolysis and Stack Technology with Ultra-High Electrolysis Current Density (>3 A/cm ²) and Efficiency	FuelCell Energy
Safety Plan Review	Hybrid Electrochemical Hydrogen/Metal Hydride Compressor	Greenway Energy, LLC
Safety Plan Review	Novel Ionomers and Electrode Structures for Improved PEMFC Electrode Performance at Low PGM Loadings	3M
Safety Plan Review	Integrated Insulation System for Cryogenic Automotive Tanks (iCAT)	Vencore Services and Solutions, Inc.
Safety Plan Review	Metal Hydride Compressor for High Pressure Hydrogen Delivery	HHC
Safety Plan Review	Advanced Electrochemical Hydrogen Compressor	Giner, Inc.
Safety Plan Review	Development of Magnesium Boride Etherates as Hydrogen Storage Materials	University of Hawaii
Safety Plan Review	Multi-Scale Ordered Cell Structure for Cost Effective Production of Hydrogen by HTWS	Ceramatec
Design Review	Advanced Hydrogen Mobile Fueler	Electricore, Inc.
Design Review	Fuel Cell Hybrid Electric Delivery Van	Center for Transportation and the Environment
Safety Plan Review	CHEF HAZOP/Safety Plan	Washington State University
Safety Plan Review	Light Duty Hydrogen Vehicle Fueling Station	CEC/Everfuel
Safety Plan Review	Light Duty Hydrogen Vehicle Fueling Station	CEC/Shell
Safety Plan Review	Light Duty Hydrogen Vehicle Fueling Station	CEC/ITM Power (#4)
Safety Plan Review	Light Duty Hydrogen Vehicle Fueling Station	CEC/ITM Power (#5)
Safety Plan Review	Light Duty Hydrogen Vehicle Fueling Station	CEC/Jensen-Linde
Safety Plan Review	Light Duty Hydrogen Vehicle Fueling Station	CEC/Hydrogen-XT
Safety Plan Review	Light Duty Hydrogen Vehicle Fueling Station	CEC/Air Liquide
Safety Plan Review	Light Duty Hydrogen Vehicle Fueling Station	CEC/FirstElement
Safety Plan Review	Light Duty Hydrogen Vehicle Fueling Station	CEC/HTEC
Safety Plan Review	Light Duty Hydrogen Vehicle Fueling Station	CEC/Air Products
Safety Plan Review	Light Duty Hydrogen Vehicle Fueling Station	CEC/A3L-Next Hydrogen
Safety Plan Review	Light Duty Hydrogen Vehicle Fueling Station	CEC/StratosFuel
Safety Plan Review	Highly Active, Durable, and Ultra-Low PGM NSTF Thin Film ORR Catalysts and Supports	3M
Site Visit	H-Prize	Ivys, McPhy and PDC
Site Visit	Hydrogen Incident Fact Finding - Simple.Fuel	Washington State University
Safety Plan Review	Linear Motor Reciprocating Compressor (LMRC) for Forecourt Hydrogen Compression (Updated Safety Plan)	Southwest Research Institute

PEFC – proton exchange fuel cell; SOEC – solid oxide fuel cell; PEMFC – proton exchange membrane fuel cell; PGM – precious group metal

In March 2017, members of the HSP met with code officials, project proponents, and stakeholders from recently completed hydrogen fueling station projects to discuss participant experiences and what has been learned from these activities. This activity, combined with the HSP's review of previously mentioned general funding opportunity safety plan reviews, provided a unique opportunity to consider safety learnings from early light duty hydrogen fueling infrastructure deployments. Feedback from the meetings was captured, analyzed, and categorized, and the resulting items were further evaluated and ranked by HSP members. The results of this activity were presented to industry stakeholders at the CaFCP working group meeting in June 2017. Additional presentations of the HSP learnings are expected to be shared at the ICHS in Hamburg, Germany, in September 2017, and the Fuel Cell Seminar and Energy Exposition in Long Beach, CA, in November 2017. It is hoped that this information will be beneficial to:

- DOE and stakeholders, in planning and funding impactful research activities focused on new innovative approaches to station implementation.
- Code development organizations, in further considering storage system configuration and its safety, including separation distance requirements.
- Station providers, in considering and implementing safe and cost-effective design features.
- First responder training organizations, to ensure that first responders are prepared to respond appropriately to vehicle and station incidents.

A significant HSP accomplishment during FY 2017 was the public release of the completed Hydrogen Equipment Certification Guide. The purpose of the guide is to enable designers, users, and code officials to better apply the requirements in cases where the use of listed, labeled, certified, or approved equipment or methods are required, and to increase awareness and understanding of what the equipment is expected to do. The challenge with equipment certification is that the listing process for rapidly changing products, consistent with developing technologies, tends to be cost-prohibitive for equipment providers (each change to the equipment requires recertification). The circumstance of new technologies under development and low demand for early market applications results in few components and systems being currently listed. The scarcity of listed equipment places an extraordinary burden on code officials to ensure (and approve) that products include the appropriate inherent or automatic safety measures. The guide identified listing requirements in the International Code Council codes and National Fire Protection Association 2 (Hydrogen Technologies Code) for hydrogen equipment, and suggests criteria for approval when listed equipment is not available.

The Hydrogen Tools Portal was made publicly available in June 2015 and continues to grow in popularity. Based

on current Google Analytics, the portal is becoming an international resource, as approximately half of all user sessions are from outside of the United States. Additional resources added to the portal in FY 2017 included the Hydrogen Analysis Resource Center – data, calculators and analytical tools for use in evaluating hydrogen-related technologies; and papers and presentations from all ICHS events, including all six conferences from 2005–2015 and 633 presentations. HSP reports from the aforementioned CEC safety plan reviews have also been added to the portal for public dissemination.

Disseminating safety information continues to be an important aspect of this project. FY 2017 activities focused on two areas: reaching new audiences and supporting efforts to remove barriers to deployment. For the former, PNNL presented at the National Fire Protection Association Conference and Expo in Boston, Massachusetts, in June 2017. The event was attended by a national and international audience of designers, consultants, contractors, service companies, end-users, and public safety authorities. PNNL also participated in outreach to personnel that construct, operate, and maintain energy-efficient and cost-effective federal facilities and fleets in the United States. Working with the Federal Energy Management Program, PNNL participated in an outreach at the 2017 Energy Exchange Training and Trade Show in Tampa, Florida, in August 2017. The 90-minute presentation on fuel cell technologies was professionally recorded and produced into training material that can be deployed on Federal Energy Management Program's website and the Hydrogen Tools Portal.

PNNL assisted in removing barriers to technology deployment by participating in outreach events and discussions with stakeholders in Boston, Massachusetts, and Baltimore, Maryland. Presentations made at these events help address safety concerns and identify future activities to address allowing fuel cell vehicles to travel through tunnels.

PNNL's leadership in hydrogen safety is reinforced through its international collaborations. PNNL worked with Hydrogen South Africa, the International Association for Hydrogen Safety, and the United Kingdom's Health and Safety Laboratory to provide an online hydrogen safety awareness webinar/panel discussion for code officials and stakeholders in South Africa in October 2016. PNNL also presented on hydrogen safety to Korean and Japanese Delegations in January 2017.

First responder outreach activities for FY 2017 focused on classroom training conducted in Hempstead, New York, Stow, Massachusetts, and Hartford, Connecticut, November 6–10, 2016. More than 250 people attended the training sessions. The events provided an opportunity to reevaluate material contained in the National Hydrogen and Fuel Cell Emergency Response Training Resource (<https://h2tools.org/fr/nt>) (referred to as "national template") in support of future updates. Additionally, PNNL purchased virtual

reality software to enhance the national template focusing on more impactful information through new video, slides, and scenario development (see Figure 1 for an example). It is anticipated that new material will be incorporated in late FY 2017 or early FY 2018.

CONCLUSIONS AND UPCOMING ACTIVITIES

The HSP will continue to focus on how safety knowledge, best practices, and lessons learned can promote the safe conduct of project work and the deployment of hydrogen technologies and systems in applications of interest and priority in the DOE FCTO. 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, as shown by the success of activities in California.

HSP initiatives over the next year will include the following:

- Continue to support the CEC’s rollout of California’s hydrogen fueling station infrastructure.
- Engage non-DOE entities to identify opportunities to use the panel to review hydrogen and fuel cell initiatives and promote safety.
- Continue to evaluate the panel membership to maintain its leadership role in hydrogen safety through an appropriate mix of safety expertise and perspective to perform safety reviews and address relevant issues.

Hydrogen safety knowledge tools help remove barriers to the deployment and commercialization of hydrogen and fuel cell technologies. The introduction of the Hydrogen Tools Portal opens opportunities for sharing new information and reaching broader audiences. Based on the president’s budget request and direction toward early stage research and development, the primary focus in FY 2018 will be to maintain the portal in an operating state with minimal change.

The project’s First Responder Training Resources can help ensure a safe transition to fuel cell vehicles and a hydrogen infrastructure, and pave the way for broader public acceptance. Based on the president’s budget request and direction toward early stage research and development, only minor changes to the available training resources and support of industry led first responder training are anticipated in FY 2018.

REFERENCES

1. U.S. Department of Energy, “Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan,” <http://energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22>.
2. Barilo, N.F. to Farese, D. et al., “Minutes from the 23rd Hydrogen Safety Panel Meeting,” January 23, 2017.

FY 2017 PUBLICATIONS/PRESENTATIONS

1. Barilo N.F. 2017. “Learnings from Hydrogen Fueling Station Projects.” Presented by Nick F. Barilo at California Fuel Cell Partnership (CaFCP) In-Person Working Group Meeting, Sacramento, CA, on June 21, 2017. PNNL-SA-127046.
2. Barilo N.F. 2017. “Hydrogen Safety Panel, Safety Knowledge Tools and First Responder Training Resources.” Presented by Nick F. Barilo at 2017 DOE Hydrogen Program Annual Merit Review and Peer Evaluation Meeting, Washington, D.C., on June 6, 2017. PNNL-SA-125384.
3. Barilo, N.F., “Hydrogen and Fuel Cells -- Emerging Technology and Safety-Related Issues,” NFPA Conference & Expo, Boston, MA, June 5, 2017.

Barilo N.F. 2017. “Hydrogen Safety Panel Strategic Plan?” Presented at Hydrogen Technical Advisory Committee meeting, Washington, D.C., on May 5, 2017. PNNL-SA-125602.

Barilo N.F., “Hydrogen Equipment Certification Guide Listing, Labeling and Approval Considerations.” Pacific Northwest National Laboratory, Richland, WA. PNNL-25053, January 2017.



FIGURE 1. Examples of virtual reality software use for first responder training resources