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PNNL-SA-102062

Hydrogen Safety Panel and Hydrogen Safety Knowledge Tools

NICK BARILO

Hydrogen Program Annual Merit Review and Peer Evaluation Meeting
Washington, DC
June 18, 2014

This presentation does not contain any proprietary, confidential or otherwise restricted information.

SCS019

Overview

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Hydrogen Safety Panel

- Project Start Date: 2003
- Project End Date: 2014*
- FY13 DOE Funding: $625K
- Planned FY14 DOE Funding: $625K
- Total Project Value: $8,979K

Safety Knowledge Tools

- Project Start Date: 2003
- Project End Date: 2014*
- FY13 DOE Funding: $100K
- Planned FY14 DOE Funding: $100K
- Total Project Value: $1,750K

Barriers addressed[1]

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
G. Insufficient technical data to revise standards

Partners

- Panel member organizations

*Project continuation and direction determined annually by DOE
[1]Technical Plan – Hydrogen Safety, Codes and Standards, Section 3.7, Multi-Year Research, Development and Demonstration Plan, July 2012.

PNNL Hydrogen Safety Program

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Hydrogen Safety Panel

- Identify Safety-Related Technical Data Gaps
- Review Safety Plans and Project Designs
- Perform Safety Evaluation Site Visits
- Provide Technical Oversight for Other Program Areas

Safety Knowledge Tools

- H_2incidents.org
- H_2bestpractices.org
- Hydrogen Tools (iPad/iPhone mobile application)

Hydrogen Safety Training

- Hydrogen Emergency Response Training for First Responders
- Maintain Live-Fire Burn Prop

Objectives

Hydrogen Safety Panel

- 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.

Safety Knowledge Tools

- 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 vast and growing knowledge base of hydrogen experience and make it publicly available to the “hydrogen community” and stakeholders.

Approach

Priority attention to safety and enhanced visibility

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Hydrogen Safety Panel

- Conduct ongoing safety assessments of DOE projects through design reviews, safety plan reviews and site visits
- Utilize Panel expertise to develop and maintain safety guidance tools; address technical safety gaps and make recommendations to DOE

Safety Knowledge Tools

- Enhance safety knowledge tools through interactions with code officials, stakeholders and project proponents
- Use multiple approaches to identify new safety event records
  - Encourage all DOE projects to submit records of incidents and near-misses with clear descriptions of lessons learned.
  - Pursue addition of new records by actively reviewing media reports of hydrogen incidents.
  - Contact private-sector companies who experience hydrogen incidents and near-misses to solicit permission to publish records.
- Bring greater visibility to hydrogen safety and the project's safety knowledge tools through presentations to audiences not familiar with fuel cell technologies

Accomplishments: Hydrogen Safety Panel

Vision: Hydrogen Safety Panel

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Safety practices, incorporating a wealth of historical experience with new knowledge and insights gained, are in place. Continuous and priority attention is being given to safety in all aspects of hydrogen and fuel cell technologies: research, development and demonstration; design and manufacturing; deployment and operations.

Name	Affiliation
Nick Barilo, Program Manager	Pacific Northwest National Laboratory
Bill Fort, Chair	Consultant
David Farese	Air Products and Chemicals
Larry Fluer	Fluer, Inc.
Donald Frikken	Becht Engineering
Aaron Harris	Air Liquide
Richard Kallman	City of Santa Fe Springs, CA
Miguel Maes	NASA-JSC White Sands Test Facility
Glenn Scheffler	GWS Solutions of Tolland
Andrew J. Sherman	Mescoat Inc.
Ian Sutherland	General Motors R&D
Steven Weiner	Pacific Northwest National Laboratory
Robert Zalosh	Firexplo

Note: Addison Bain retired from the Panel in December 2013

Accomplishments

Positive Impacts in Early Project Reviews

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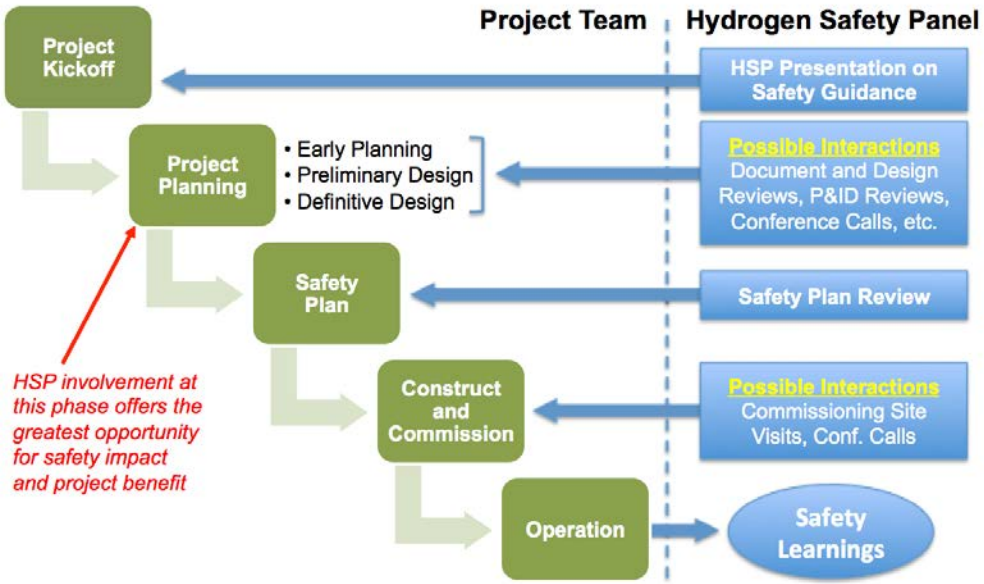
Our presentation at the 2013 AMR discussed the best methods for utilizing the HSP for project reviews. The following projects participated in this approach since the last review:



- Review of a preliminary hazard analysis for the "Demonstration of Fuel Cell-Based Auxiliary Power Unit (APU) for Refrigerated Trucks" project in July 2013
  - new safety vulnerabilities were identified by the HSP
- Preliminary design review of the LLNL Cryogenic Refueling and Testing Facility
  - need for additional tank analysis was revealed during the review
- Early design review for the MARAD-DOE Maritime Fuel Cell Deployment Project, May 2014 at Hydrogenics in Toronto, Canada

Accomplishments

Identifying Safety Gaps/Supporting Codes and Standards Development

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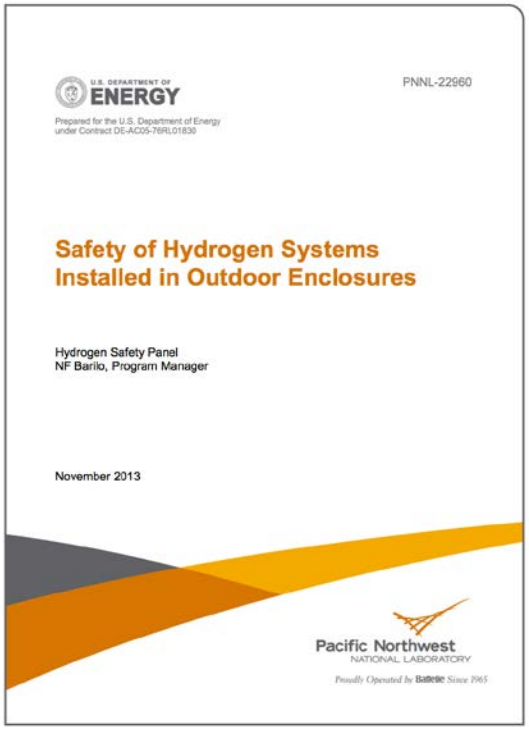
- White paper, "Safety of Hydrogen Systems Installed in Outdoor Enclosures," provided to DOE and the NFPA 2/55 Technical Committees in December 2013
- An enclosures risk assessment task group is performing qualitative and quantitative risk analyses for enclosures.
- A second task group is evaluating the current NREL Secure Data Center composite data products and templates with the goal of utilizing the actual safety-related data and information reported by project teams in support of safety learnings. Efforts include:
  1. An analysis of safety-related composite data products (CDPs) for discussion/Q&A with NREL, and
  2. Providing modified templates for potential use by NREL for future data collection

The Panel's work on this topic has raised awareness of the need for changes to NFPA 2 and NFPA 55.


U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy under Contract DE-AC05-76RL01830

PNNL-22960

Safety of Hydrogen Systems Installed in Outdoor Enclosures

Hydrogen Safety Panel
NF Barilo, Program Manager

November 2013

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Accomplishments
Learning from Commercial Projects

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- Two Panel members travelled to Flint, Michigan on March 19, 2014, to meet participants in a hydrogen fueling station and repair garage project. The purpose of the meeting was to introduce participants to the Hydrogen Safety Panel and discuss their safety learnings from recent hydrogen projects.
- The meeting included representatives from:
  - Flint Mass Transportation Authority
  - Grand Blanc Fire Department
  - City of Flint (inspectors)
  - Ino-Tek (installers of the gas detection and alarm system).
- The clear message from project participants was the need for more education and networking among those involved in plans review and inspection.

This type of interaction offers an opportunity for the program to learn from actual commercial projects (understanding safety issues and barriers) and better prioritize future activities.

Accomplishments

Highlighting the HSP as a Safety Resource

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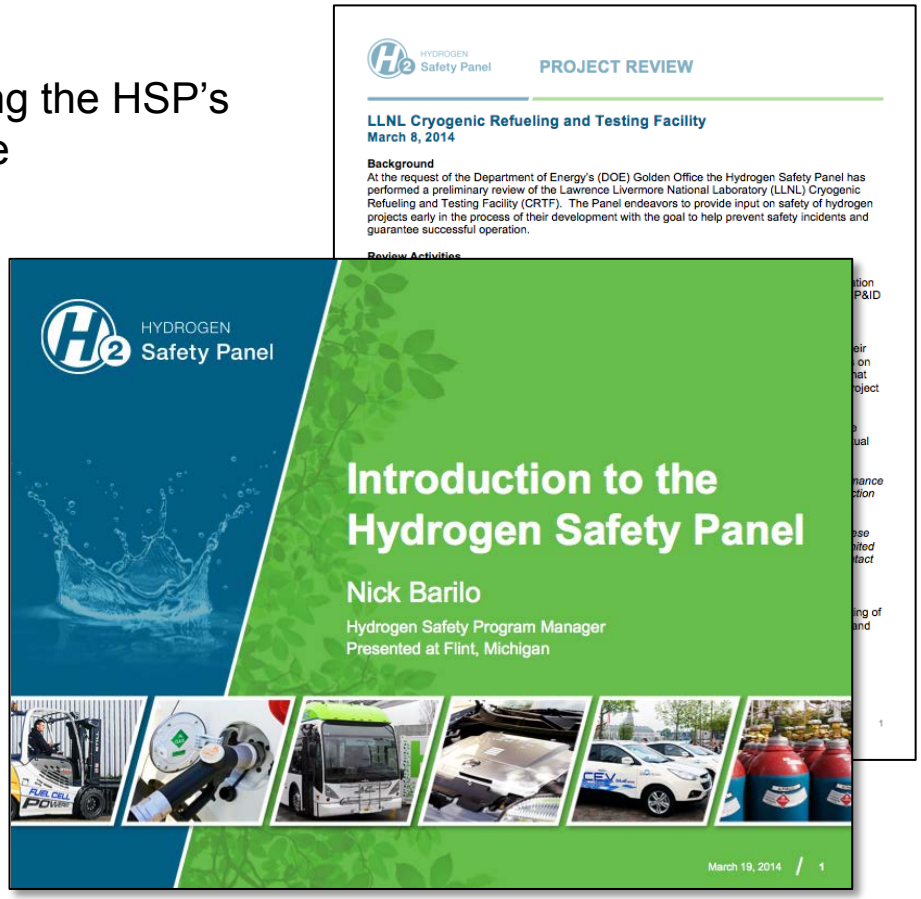
HYDROGEN Safety Panel

Current and future activities for enhancing the HSP's role as a safety resource for enabling the widespread acceptance of hydrogen:

- **Branding (in use now)**
  - The consistent and appropriate use of branding will strengthen recognition of the Panel and its reputation as a safety resource
  - Branding will also validate that information is coming from a reliable and credible source
- **Website/Social Media**
  - HSP web page (2015)
  - HSP on LinkedIn (2015)



Accomplishments

International Conference on Hydrogen Safety Highlighting our Hydrogen Safety Work

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- European/U.S. bilateral webinar, *What Can We Learn from Hydrogen Safety Event Databases?*, brought lessons learned and related knowledge to the forefront of the hydrogen community.
- Presentations offered highlights of accomplishments of the Hydrogen Safety Panel and other international collaborations.
  - *Deploying Fuel Cell Systems: What Have We Learned?* – examining safety considerations in early market applications for hydrogen and fuel cell systems
  - *Advancing the Hydrogen Safety Knowledge Base* – a white paper of the IEA Hydrogen Implementing Agreement Task 31

Brussels, September 9-11, 2013

Accomplishments
Hydrogen Safety Panel Scorecard

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Activity	Since the 2013 AMR	Total for the Project Duration
Project Reviews (including safety plans, site visits reviewed, follow-up interviews and design review activities)	12 (includes 3 early project reviews)	395
Panel Meetings	2 (Washington, DC and Golden, CO)	20
White Papers & Recommendations (e.g., *Safety of Hydrogen Systems Installed in Outdoor Enclosures*)	1	7
Accident Investigations	0	3
Publications and Presentations (both projects combined total)	5	39

Accomplishments
Responses to 2013 Reviewers' Comments

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- "The project team should increase the safety reviews and start outreach to the AHJs."
  - *The number of safety reviews conducted is dependent on FCTO project activities. A limited number of projects required such a review between the 2012 and 2013 AMRs. However, since the 2013 AMR, 12 project reviews have taken place.*
  - *As shown in earlier slides, the project team has been working to identify ways to bring safety knowledge to a broader audience outside of the "hydrogen community." Activities include a presentation at the 2013 NFPA Conference & Expo, a NFPA Journal article on hydrogen safety and a scheduled educational session for the 2014 NFPA Conference & Expo. Additionally, the project team is exploring methods to reach additional AHJs through interactions on ICC-related activities. The project team is also seeking opportunities to meet with AHJs from completed hydrogen projects (Flint, Michigan) to better understand their learnings and what information or tools would have helped them through the design and commission process.*

Accomplishments: Safety Knowledge Tools

Accomplishments

Strategizing future safety resource needs…

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The widespread availability and communication of safety-related information are crucial to ensure 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. [Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration (MYRD&D) Plan]

There are currently a variety of electronic safety resource tools currently available.

Do we have the right tools to support the next phase of hydrogen and fuel cell commercialization?

To answer that question a planning session was held in Los Angeles, CA In April 2014.

HYDROGEN AND FUEL CELL SAFETY ELECTRONIC RESOURCES

Resource by Category	URL	DOE-funded (Y/N)	Last Update/Posting	Target Audiences
DATABASES/WEBSITES (including REGULATIONS, C&S)				
Hydrogen Incident Reporting and Lessons Learned Database	http://www.h2incidents.org/	Y	October 31, 2013	OM, PP, RD
Hydrogen Safety Bibliographic Database	http://www.hydrogen.energy.gov/biblio_database.html	Y	August 2008	RD
Hydrogen/Fuel Cell Codes and Standards	http://www.fuelcellstandards.com/	N		AHJ, PP
29 CFR 1910.103 Occupational Safety and Health Standards (Hydrogen)	https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9749	N		AHJ, OM, PB, PP, STK
Storage and Handling of Gaseous and Liquefied Hydrogen	http://www.michigan.gov/lara/0,4601,7-154-35299_42271_4115_4237-193832--,00.html	N		AHJ, PB, PP, STK
NFPA 2: Hydrogen Technologies Code	http://www.nfpa.org/2	N	2011	AHJ, PB, PP, STK
NFPA 853: Standard for the Installation of Stationary Fuel Cell Power Systems	http://www.nfpa.org/853	N	2010	AHJ, PB, PP, STK
MANUALS				
Hydrogen Safety Best Practices	http://h2bestpractices.org/	Y	April 18, 2013	OM, PP, RD
Technical Reference for Hydrogen Compatibility of Materials	http://www.sandia.gov/matlsTechRef/	Y	May 13, 2013	OM, PP, RD
ANSI/AIAA G-095 - Guide to Safety of Hydrogen and Hydrogen Systems	http://www.aiaa.org/StandardsDetail.aspx?id=3864 [US$100.95]	N	2004	AHJ, OM, PB, PP, STK
ISO/TR 15916 - Basic considerations for the safety of hydrogen systems	http://www.iso.org/iso/catalogue_detail?csnumber=29145 [CHF 172,00]	N	2004	AHJ, OM, PB, PP, STK
FM Global Property Loss prevention Data Sheets	http://www.fmglobal.com/FMGlobalRegistration/Vshared/FMDS0791.pdf	N	January 2012	AHJ, OM, PB, PP, STK

Resource by Category	URL	DOE-funded (Y/N)	Last Update/Posting	Target Audiences
FLIERS, POSTERS, NEWSLETTERS, REPORTS, APPS, OTHER LITERATURE				
Hydrogen Tools				
H2 Safety Snapshot				
Hydrogen Safety Tips for First Responders				
Fuel Cell and Hydrogen Safety Report (FCHEA)				
Fact Sheet on Hydrogen Safety (FCHEA)				
Hydrogen Safety Fact Sheet (NHA)				
National Template: Hydrogen Vehicle and Infrastructure Codes and Standards				
Hydrogen Vehicle and Infrastructure Codes and Standards Citations				
Regulations, Codes, and Standards Template for California Hydrogen Dispensing Stations	http://www.nrel.gov/docs/fy13osti/56223.pdf	Y	November 2012	AHJ, PP, STK
Reaching the U.S. Fire Service with Hydrogen Safety Information: A Roadmap	http://www.nfpa.org/~/media/Files/Research/Research%20Foundation/Research%20Foundation%20reports/For%20emergency%20responders/report%20final%20h2fs.pdf	Y	September 2009	AHJ, FR, STK
Safetygrams	http://www.airproducts.com/company/Sustainability/environment-health-and-safety/product-safety-safetygrams.aspx	N	April 2007 (LH2) February 2011 (GH2)	AHJ, OM, PP, RD
Materials Safety Data Sheets (GH2)	https://apdirect.airproducts.com/msds/DisplayPDF.aspx?docid=63578	N	April 2006	AHJ, OM, PP, RD
Materials Safety Data Sheets (LH2)	http://www.hydrogenandfuelcellsafety.info/resources/mdss/Praxair-LH2.pdf	N	September 2004	AHJ, OM, PP, RD

Resource by Category
TRAINING
Introduction to Hydrogen Safety for First Responders
Introduction to Hydrogen for Code Officials
Hydrogen Safety Training for Researchers
Permitting Hydrogen Facilities
Regulators' Guide to Permitting Hydrogen Technologies
Identification, Preparation and Dissemination of Hydrogen Safety Facts to Regulators and Public Safety Officials (HyFACTS)
IAFF HazMat/WMD Training
PROPERTIES, CALCULATORS
Hydrogen Analysis Resource Center (HARC): Basic Hydrogen Properties
HARC: Hydrogen Conversions Calculator

TARGET AUDIENCES			
AHJ	Authorities having jurisdiction	PP	Project proponents
FR	First responders (fire, law enforcement, and emergency medical personnel)	RD	Researchers, scientists, engineers
OM	Operations and maintenance personnel	STK	Stakeholders having an interest in the successful completion of a project
PB	The public		

Accomplishments
Electronic Safety Resource Tools Planning Session

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Session Activities

- 20 individuals representing a variety of user groups and owners of the existing resource tools participated in the meeting.
- Session participants agreed on user group designations.
- The brainstorming portion of the meeting focused on soliciting unconstrained ideas (tickets) for each of the user groups (136 total).
- Tickets which had common themes were organized by session participants into stories.
- The stories were rated by a smaller group based on their impact and ease of development.
- Existing DOE-funded resource tools were also evaluated for their impact/ease of development or maintenance.
- The final stories and their ratings were sent to session participants and discussed with the Hydrogen Safety Panel.
- The results and recommendations are being incorporated into a final report.

- User Groups
  - Authorities Having Jurisdiction (AHJ)
  - First Responders (FR)
  - Project Proponents (PP)
  - Operations & Maintenance (O&M)
  - Stakeholders (STK)
  - Research & Development (RD)
  - The Public (PUB)
  - Insurers and Risk Managers (INS)
- Organizations Represented
  - Air Products
  - Air Liquide
  - Orange County Fire Department
  - Daimler
  - Santa Monica Fire Department
  - Santa Fe Springs Fire Department
  - NASA
  - California Fuel Cell Partnership
  - Hydrogen Frontier
  - California Office of the State Fire Marshal
  - Toyota
  - DOE
  - NREL
  - Sandia
  - PNNL

Accomplishments
Preliminary Results of the Planning Session

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- The results of the session revealed areas where the various user groups could benefit from a different approach to providing safety knowledge resources, including:
  - **Hydrogen safety web portal** – a "one-stop shop" for credible and reliable safety information
  - **Codes and standards wizard** – utilizing questions to direct users to the applicable requirements and resource documents
  - **Videos, Wiki's and networking tools** to help educate and connect users

ID #	Functionality	Impact	Ease	Affected User Groups								Weighted Score
				AHJ	FR/SR	OM	PP	R&D	INV	PUB	INS	
GI-4	General safety information on properties of hydrogen and its behavior, including a Wiki and videos and diagrams showing important safety features, pressure safety, flame arrestors, vent systems and relief devices	5	4	✓	✓	✓	✓	✓	✓	✓	✓	49.83
GI-1	Hydrogen safety portal as a credible and reliable and one stop shop for safety information	5	3	✓	✓	✓	✓	✓	✓	✓	✓	44.83
CS-1	A clear overview of applicable codes and standards using	5	4	✓		✓	✓	✓		✓	✓	40.83
DR-3	Modeling tools to predict consequences of cryogenic releases, pv failure, cryogenic to gas releases, gaseous releases, BLEVEs, etc., to support station layout and risk informed changes to regulation, codes and standards	5	3	✓			✓	✓			✓	30.01
DR-5	Enable the performance of risk assessments and provide options for risk mitigation, support performance-based analysis, include checklist functionality for basic risk, component databases, calculators and cost-benefit features	5	3	✓			✓		✓		✓	29.64
GI-3	Vehicle and equipment information covering general information, safety features, safe usage parameters, recall notices, etc.	4	3	✓	✓	✓					✓	29.19

Accomplishments
Disseminating Safety Knowledge

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- Reaching out to spread hydrogen safety knowledge and learnings to new audiences
  - "Design to Operation: Integrating Safety into Hydrogen and Fuel Cell Projects," will be presented at the 2014 NFPA Conference & Expo, Las Vegas, NV. The session will focus on activities necessary for integrating safety into a hydrogen project and the resources available to designers, AHJs and first responders.
  - "Deployment of Hydrogen Fuel Cells – Safety Considerations and Resources," presented at the 2013 NFPA Conference & Expo, in Chicago, IL. The conference was attended by approximately 4,000 persons. The presentation was included on the USB drive provided to attendees.

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CONFERENCE & EXPO®
JUNE 9-12, 2014 • LAS VEGAS, NV

Accomplishments
Disseminating Safety Knowledge

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- Authored a May/June 2014 *NFPA Journal*® article focusing on hydrogen safety which highlights the Hydrogen Safety Panel and DOE's Hydrogen Emergency Response Training for First Responders
- *NFPA Journal*® is the official magazine of the National Fire Protection Association and reaches all Association members (70,000 individuals in 100 countries)
- Article is also available online at http://www.nxtbook.com/nxtbooks/nfpa/journal_20140506/index.php#/80

Accomplishments/Future Plans

Identifying New Opportunities for Sharing Safety Knowledge

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U.S. Fire Administration
Working for a Fire-Safe America
FEMA

ICC INTERNATIONAL CODE COUNCIL®
People Helping People Build a Safer World™

- PNNL and DOE met with personnel from the US Fire Administration in November 2013. This meeting identified potential collaborations in three hydrogen safety-related areas to be explored:
  - first responder training
  - incident records (NFIRS and h2incidents.org)
  - educating stakeholders/AHJs in support of commercialization activities
- Similar to the NFPA Journal article and presentation at the NFPA Conference & Expo, PNNL is also exploring methods to bring safety knowledge to code and fire officials through interactions with the International Code Council (ICC). We are currently evaluating messages and methods (e.g. magazine article, webinar, presentation at annual meeting/show) to best share that knowledge.

Accomplishments

Safety Knowledge Tools Stats…

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H_2incidents.org

Year	Visitors*	Max Visitors in 1 month
2006	3,357	751
2007	15,797	1,928
2008	25,539	4,568
2009	17,081	2,084
2010	17,502	1,954
2011	20,936	2,339
2012	19,635	2,347
2013	15,273	1,613

New safety knowledge content: 6 lessons learned events added to H_2incidents.org since the 2013 AMR (213 total)

H_2bestpractices.org

Year	Visitors*	Max Visitors in 1 month
2008	703	93
2009	1,029	113
2010	1,373	166
2011	1,373	167
2012	1,658	188
2013	1,684	194

Total Visits for 2013
- H_2incidents.org - 26,665
- H_2bestpractices.org - 5,062

*Visitors = unique visits as tracked by PNNL on a monthly basis. Regardless of how many times a particular individual may access a website during a particular month, they are counted as one unique visitor.

Accomplishments
New Ways to Share Safety Knowledge

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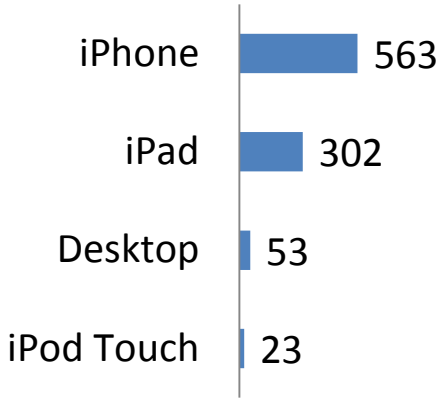
First mobile app being developed for the Fuel Cell Technologies Office

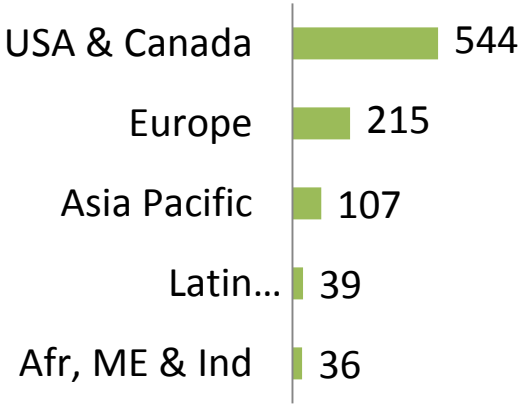
- Released in September 2013
- Integrates H_2incidents.org and H_2bestpractices.org into a single, searchable, iPad and iPhone application
- Features include safety planning guidance and checklists
- All tools (except H_2incidents.org) are available without a data connection

941
Downloads since September 2013

By Platform



By Territory



Accomplishments

Responses to 2013 Reviewers' Comments

- "The proposed work is appropriate. A caution on the app is in order. The project team should define the audience and then address the app to the audience. If the intended user is an AHJ, the project team should write the information in the app for a fire marshal, not a PhD or a researcher. This is easier said than done."
- "Weaknesses include the limited safety reviews and the need to determine the audience for the app."
  - *The Hydrogen Tools app was developed and released to address comments from previous AMRs and requests by the FCTO to bring increased visibility to the Safety Knowledge Tools, and to make the content of h2bestpractices.org available offline. While similar statements (to the ones above) were raised during the app's development process, the resources were not available to fully address the issue. The electronic safety resource tools planning session that was conducted in April 2014 (and discussed in previous slides) was undertaken to address this topic. Rather than just considering the Hydrogen Tools app, the session took a more global look at what resource tools are needed (whether apps, websites or other formats) for the next phase of commercialization.*
  - *The number of safety reviews conducted is dependent on FCTO project activities. A limited number of projects required such a review between the 2012 and 2013 AMRs. However, since the 2013 AMR, 12 project reviews have taken place.*

Proposed Future Work

Remainder FY2014

Hydrogen Safety Panel

- Continue early project engagements (e.g., MARAD-DOE Maritime Fuel Cell Deployment Project) and safety plan reviews
- Continue HSP task group work on the enclosures risk assessment and NREL data evaluation

Safety Knowledge Tools

- Develop a Hydrogen Tools portal that combines H_2incidents.org, H_2bestpractices.org and other safety resources into one website
- Present "Deployment of Hydrogen Fuel Cells – Safety Considerations and Resources" at the National Fire Protection Association Conference and Expo

FY2015

Hydrogen Safety Panel

- Utilize Panel resources to address safety knowledge gaps through white papers, recommendations to DOE, manuscripts, presentations and technical oversight of the Safety Knowledge Tools
- Expand the Panel's visibility through a web page and integration into key social media tools
- Work with DOE FCTO to strengthen FOA and contract language to support HSP early involvement in projects and a commitment to NFPA 2 implementation
- Integrate the HSP into H2USA activities

Safety Knowledge Tools

- Implement new safety resource tools identified during the FY14 planning session

Collaborations

Hydrogen Safety Panel and Safety Knowledge Tools

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Hydrogen Safety Panel

- Sandia National Laboratories – workshop on the tools for hydrogen fuel cell quantitative risk assessment (June 11-12, 2013) and enclosures risk assessments (current activities)
- International Energy Agency Hydrogen Implementing Agreement Task 31 (Hydrogen Safety)
  - Weiner lead author for task white paper, "Advancing the Hydrogen Safety Knowledge Base," presented at the 2013 ICHS and to be published in the International Journal of Hydrogen Energy (IJHE)
  - Weiner submits final report for Subtask D, Knowledge Analysis, Dissemination and Use
- Organizations representing various Hydrogen Safety Panel membership

Safety Knowledge Tools

- European Commission Joint Research Centre (JRC) and the International Association for Hydrogen Safety (HySafe)
  - Bilateral webinar, *What Can We Learn from Hydrogen Safety Event Databases?*, ICHS, Brussels, Belgium, September 10, 2013.

Summary

Hydrogen Safety Panel

- Safety planning is a critical step!
- The HSP's early engagement of projects can be beneficial for the safe deployment of these technologies.
- Learnings from the Panel's specific project involvement and interaction with code officials, stakeholders and project proponents can benefit the FCT program more broadly.
- Bringing greater visibility to the Hydrogen Safety Panel through branding and outreach activities is a positive step toward reinforcing it's role as a safety resource.

Safety Knowledge Tools

- New and improved safety knowledge tools warrant increased DOE investment
  - Reaching out to new stakeholders and users is essential for enabling a safe transition to commercialization of hydrogen and fuel cell technologies
  - To remain vital and useful, databases and websites require a concerted effort beyond general maintenance. The content must be current, relevant to the community being served and valuable to the user.

Thank you

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- U.S. Department of Energy
  - Fuel Cell Technologies Office (Sunita Satyapal, Program Manager; Ned Stetson, Will James and Kym Carey, Safety Codes and Standards Team)
- All of my colleagues at Pacific Northwest National Laboratory, the Hydrogen Safety Panel and other collaborators

Technical Back-up Slides for the FY2014 Merit Review and Peer Evaluation

Existing Hydrogen Safety Knowledge Resource Tools (from Slide #10) – 1 of 3

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HYDROGEN AND FUEL CELL SAFETY ELECTRONIC RESOURCES

Resource by Category	URL	DOE-funded (Y/N)	Last Update/Posting	Target Audiences
DATABASES/WEBSITES (including REGULATIONS, C&S)				
Hydrogen Incident Reporting and Lessons Learned Database	http://www.h2incidents.org/	Y	October 31, 2013	OM, PP, RD
Hydrogen Safety Bibliographic Database	http://www.hydrogen.energy.gov/biblio_database.html	Y	August 2008	RD
Hydrogen/Fuel Cell Codes and Standards	http://www.fuelcellstandards.com/	N		AHJ, PP
29 CFR 1910.103 Occupational Safety and Health Standards (Hydrogen)	https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9749	N		AHJ, OM, PB, PP, STK
Storage and Handling of Gaseous and Liquefied Hydrogen	http://www.michigan.gov/lara/0,4601,7-154-35299_42271_4115_4237-193832--,00.html	N		AHJ, PB, PP, STK
NFPA 2: Hydrogen Technologies Code	http://www.nfpa.org/2	N	2011	AHJ, PB, PP, STK
NFPA 853: Standard for the Installation of Stationary Fuel Cell Power Systems	http://www.nfpa.org/853	N	2010	AHJ, PB, PP, STK

MANUALS				
Hydrogen Safety Best Practices	http://h2bestpractices.org/	Y	April 18, 2013	OM, PP, RD
Technical Reference for Hydrogen Compatibility of Materials	http://www.sandia.gov/matlsTechRef/	Y	May 13, 2013	OM, PP, RD
ANSI/AIAA G-095 - Guide to Safety of Hydrogen and Hydrogen Systems	http://www.aiaa.org/StandardsDetail.aspx?id=3864 [US$100.95]	N	2004	AHJ, OM, PB, PP, STK
ISO/TR 15916 - Basic considerations for the safety of hydrogen systems	http://www.iso.org/iso/catalogue_detail?csnumber=29145 [CHF 172,00]	N	2004	AHJ, OM, PB, PP, STK
FM Global Property Loss prevention Data Sheets	http://www.fmglobal.com/FMGlobalRegistration/Vshared/FMDS0791.pdf	N	January 2012	AHJ, OM, PB, PP, STK

Existing Hydrogen Safety Knowledge Resource Tools (from Slide #10) – 2 of 3

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HYDROGEN AND FUEL CELL SAFETY ELECTRONIC RESOURCES

Resource by Category	URL	DOE-funded (Y/N)	Last Update/Posting	Target Audiences
FLIERS, POSTERS, NEWSLETTERS, REPORTS, APPS, OTHER LITERATURE				
Hydrogen Tools	iPhone/iPad app	Y	September 2013	AHJ, OP, PP, RD, STK
H2 Safety Snapshot	http://www1.eere.energy.gov/hydrogenandfuelcells/codes/snapshot.html	Y	July 2011	OM, PP, RD
Hydrogen Safety Tips for First Responders	http://www.dhses.ny.gov/ofpc/publications/documents/HydrogenPoster_v15.pdf	Y		FR
Fuel Cell and Hydrogen Safety Report (FCHEA)	http://www.hydrogenandfuelcellsafety.info/	Y	September 2013	PP, RD, STK
Fact Sheet on Hydrogen Safety (FCHEA)	http://fchea.org/core/import/PDFs/factsheets/Hydrogen%20Safety_NEW.pdf	N		OM, PB, STK
Hydrogen Safety Fact Sheet (NHA)	http://www.arhab.org/pdfs/h2_safety_fsheet.pdf	Y		OM, PB, STK
National Template: Hydrogen Vehicle and Infrastructure Codes and Standards	http://www.afdc.energy.gov/pdfs/48609.pdf	Y	July 2010	STK
Hydrogen Vehicle and Infrastructure Codes and Standards Citations	http://www.afdc.energy.gov/pdfs/48608.pdf	Y	October 2013	AHJ, PP, STK
Regulations, Codes, and Standards Template for California Hydrogen Dispensing Stations	http://www.nrel.gov/docs/fy13osti/56223.pdf	Y	November 2012	AHJ, PP, STK
Reaching the U.S. Fire Service with Hydrogen Safety Information: A Roadmap	http://www.nfpa.org/~/media/Files/Research/Research%20Foundation/Research%20Foundation%20reports/For%20emergency%20responders/report%20final%20h2fs.pdf	Y	September 2009	AHJ, FR, STK
Safetygrams	http://www.airproducts.com/company/Sustainability/environment-health-and-safety/product-safety-safetygrams.aspx	N	April 2007 (LH2) February 2011 (GH2)	AHJ, OM, PP, RD
Materials Safety Data Sheets (GH2)	https://apdirect.airproducts.com/msds/DisplayPDF.aspx?docid=63578	N	April 2006	AHJ, OM, PP, RD
Materials Safety Data Sheets (LH2)	http://www.hydrogenandfuelcellsafety.info/resources/mdss/Praxair-LH2.pdf	N	September 2004	AHJ, OM, PP, RD

Existing Hydrogen Safety Knowledge Resource Tools (from Slide #10) – 3 of 3

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HYDROGEN AND FUEL CELL SAFETY ELECTRONIC RESOURCES

Resource by Category	URL	DOE-funded (Y/N)	Last Update/Posting	Target Audiences
TRAINING				
Introduction to Hydrogen Safety for First Responders	http://www.hydrogen.energy.gov/firstresponders.html	Y	February 2009	FR
Introduction to Hydrogen for Code Officials	http://www.hydrogen.energy.gov/training/code_official_training/	Y	August 2009	AHJ
Hydrogen Safety Training for Researchers	http://www.h2labsafety.org/	Y	September 2010	RD
Permitting Hydrogen Facilities	http://www.hydrogen.energy.gov/permitting/	Y	October 2013	AHJ, PP
Regulators' Guide to Permitting Hydrogen Technologies	http://www1.eere.energy.gov/hydrogenandfuelcells/codes/permitting_guides.html	Y	October 2011	AHJ, PP
Identification, Preparation and Dissemination of Hydrogen Safety Facts to Regulators and Public Safety Officials (HyFACTS)	http://www.hyfacts.eu/	N		AHJ, FR, STK
IAFF HazMat/WMD Training	http://www.iaff.org/et/HW/index.htm	N		FR
PROPERTIES, CALCULATORS				
Hydrogen Analysis Resource Center (HARC): Basic Hydrogen Properties	http://hydrogen.pnl.gov/cocoon/morf/hydrogen/article/701	Y	July 2008	AHJ, OM, PP, RD
HARC: Hydrogen Conversions Calculator	http://hydrogen.pnl.gov/cocoon/morf/hydrogen/site_specific/hydrogen_calculator?canprint=false.	Y	January 2012	AHJ, PP, RD

TARGET AUDIENCES			
AHJ	Authorities having jurisdiction	PP	Project proponents
FR	First responders (fire, law enforcement, and emergency medical personnel)	RD	Researchers, scientists, engineers
OM	Operations and maintenance personnel	STK	Stakeholders having an interest in the successful completion of a project
PB	The public		

HSP Project Review Reports and White Papers (Since the 2013 AMR)

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1. Safety Plan Review – LLNL Cryogenic Pressure Vessel Refueling, July 31, 2013.
2. Safety Plan Review – FC-Based APU for Refrigerated Trucks (Nuvera), October 15, 2013.
3. Barilo, N.F., "Safety of Hydrogen Systems Installed in Outdoor Enclosures," a Hydrogen Safety Panel white paper, PNNL-22960, November 2013.
4. Safety Plan Review – Demonstration of a Fuel Cell-powered Transport Refrigeration Unit (Plug Power), February 24, 2014.
5. Design Review – ESIF Fueling Facility (NREL), March 10, 2014.
6. Design Review – LLNL Cryogenic Refueling and Testing Facility, March 12, 2014.
7. Safety Plan Review – Fuel Cell Powered Airport Ground Support Equipment Deployment - GSE Gendrive Safety Plan (Plug Power), March 23, 2014.
8. Safety Plan Review – FC-Based APU for Refrigerated Trucks (Nuvera Revised Safety Plan), March 24, 2014.
9. Safety Plan Review – High Performance, Durable, Low Cost Membrane Electrode Assemblies for Transportation Applications (3M), March 25, 2014.
10. Safety Plan Review – Marine Corps Base Hawaii Hydrogen Fueling Station Project Safety Management Plan (HNEI), April 7, 2014.
11. Safety Plan Review – FC-Based APU for Refrigerated Trucks (Nuvera, 2nd Revision), April 22, 2014.
12. Design Review – MARAD-DOE Maritime Fuel Cell Deployment Project (Sandia), May 9, 2014.

Publications and Presentations

Pacific Northwest NATIONAL LABORATORY
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1. Weiner, S.C., Hartsock, P.A. and Johnson, N., "H2 Safety Snapshot," PNNL-SA-63909, Vol. 1, Issue 1, April 2009.
2. Weiner, S.C., Fassbender, L.L. and Quick, K.A., "Using Hydrogen Safety Best Practices and Learning from Safety Events," PNNL-SA-65427, International Conference on Hydrogen Safety, Ajaccio, Corsica, France, September 16-18, 2009.
3. Zalosh, R.G. and Barilo, N.F., "Wide-Area and Distributed Hydrogen Sensors," PNNL-SA-65498, Paper 186, International Conference on Hydrogen Safety, Ajaccio, Corsica, France, September 16-18, 2009.
4. Weiner, S.C., "Hydrogen Safety: Supporting DOE's Fuel Cell Technologies Program," PNNL-SA-71796, Energy Facility Contractors Group (EFCOG) Hydrogen Safety Interest Group, Knoxville, TN, April 26, 2010.
5. Weiner, S.C., R.A. Kallman and Skolnik, E.G., "Speaking of Safety: Learning from Safety Reviews," PNNL-SA-71062, 18th World Hydrogen Energy Conference, Essen, Germany, May 18, 2010.
6. Weiner, S.C., "Hydrogen Safety Training for First Responders," Istituto Superiore Antincendi (Fire Prevention Institute), Rome, Italy, October 5, 2010.
7. Barilo, N.F. and Fassbender, L.L., "Handling Compressed Hydrogen Gas Cylinders," *H2 Safety Snapshot*, Volume 2, Issue 1, PNNL-SA-75299, November 2010.
8. Fassbender, L.L., "Hydrogen Safety Knowledge Tools," PNNL-SA-77093, Hydrogen and Fuel Cell Safety Report, Fuel Cell and Hydrogen Energy Association, January 2011.
9. Weiner, S.C., Fassbender, L.L. and Quick, K.A., "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.
10. Barilo, N.F. and Fassbender, L.L., "Identifying Safety Vulnerabilities," *H2 Safety Snapshot*, Volume 2, Issue 2, PNNL-SA-77099, March 2011.
11. Barilo, N.F., "Wide-Area Sensor Needs," PNNL-SA-80400, DOE/NREL Hydrogen Sensor Workshop, Rosemont, IL, June 8, 2011.
12. 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.
13. Elmore, M.R., Fassbender, L.L., Hamilton, J.J. and Weiner, S.C., "Hydrogen Emergency Response Training for First Responders," PNNL-SA-79009/82560, International Conference on Hydrogen Safety, San Francisco, CA, September 12-14, 2011.

Publications and Presentations (continued)

Pacific Northwest NATIONAL LABORATORY
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14. 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.
15. Weiner, S.C., "Safety, Codes and Standards – An Overview," U.S. Department of Energy, HYPOTHESIS IX, San José, Costa Rica, December 12-15, 2011.
16. 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.
17. 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).
18. 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.
19. Weiner, S.C., "Advancing the Hydrogen Safety Knowledge Base," PNNL-SA-91531, International Conference on Hydrogen Safety, Brussels, Belgium, September 9-11, 2013 (abstract submitted October 23, 2012).
20. Weiner, S.C. and Fassbender L.L., "Lessons Learned from Safety Events," PNNL-SA-86551, International Journal of Hydrogen Energy, Volume 37, Issue 22, November 2012, pp. 17358-17363 (published onlinehttp://dx.doi.org/10.1016/j.ijhydene.2012.03.152).
21. 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 (published online http://dx.doi.org/10.1016/j.egypro.2012.09.032).
22. **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.**
23. **Barilo, N.F. and Weiner, S.C., "Deploying Fuel Cell Systems: What Have We Learned?" PNNL-SA-94975, International Conference on Hydrogen Safety, Brussels, Belgium, September 9-11, 2013.**

Note: Bold font identifies publications and presentations subsequent to the 2013 Annual Merit Review and Peer Evaluation Meeting

Publications and Presentations (continued)

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24. **Weiner, S.C., "Advancing the Hydrogen Safety Knowledge Base," PNNL-SA-91531, International Conference on Hydrogen Safety, Brussels, Belgium, September 9-11, 2013 (selected for IJHE publication, December 22, 2013).**
25. **Weiner, S.C., "What Can We Learn from Hydrogen Safety Event Databases? – H2Incidents.org," Webinar presented at the International Conference on Hydrogen Safety, Brussels, Belgium, September 10, 2013.**
26. **Barilo, N.F., "Design to Operation: Integrating Safety into Hydrogen and Fuel Cell Projects," 2014 NFPA Conference & Expo, June 9-12, 2014 (educational session abstract accepted November 2013).**

Note: Bold font identifies publications and presentations subsequent to the 2013 Annual Merit Review and Peer Evaluation Meeting