IX.6 Hydrogen Safety Knowledge Tools

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

Objectives

- Hydrogen Safety Best Practices - Capture the vast knowledge base of hydrogen experience and make it publicly available. The best practices online manual is a "living" document that provides guidance for ensuring safety in DOE hydrogen projects, while serving as a model for all hydrogen projects and applications.
- Hydrogen Incident Reporting and Lessons Learned - Collect information and share lessons learned from hydrogen incidents and near-misses, with the goal of preventing similar safety events from occurring in the future.

Technical Barriers

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

(A) Limited Historical Database

(B) Proprietary Data

Contribution to Achievement of DOE Safety, Codes & Standards Milestones

This project has already met the following DOE milestones from the Hydrogen Safety section of the FCT Program Multi-Year Research, Development and Demonstration Plan:

- Milestone 18: Publish safety bibliography and incident databases (3Q, 2006).
- Milestone 19: Publish a Best Practices Handbook (1Q, 2008).
- Milestone 20: Update peer-reviewed Best Practices Handbook (4Q, 2008).

Accomplishments

Hydrogen Safety Best Practices

- We enhanced the best practices content for outdoor storage of hydrogen cylinders in the Laboratory Safety/Laboratory Design section.
- We made Management of Change (MOC) more visible by adding a new page on the Web site and adding links to that page from three other Web pages.
- We drafted a new section called Hydrogen Properties that is focused on hydrogen combustion and liquid hydrogen expansion.
- We updated the Hydride Storage and Handling Section of Laboratory Safety/Laboratory Operations to cover the risks related to large-scale experiments with metal hydrides.
- We added approximately 50 links to safety event records in the Incident Reporting and Lessons Learned database to illustrate the kinds of incidents and near-misses that can occur if hydrogen safety best practices are not followed.

Hydrogen Incident Reporting and Lessons Learned

- We added 37 new safety event records, for a total of 177 records currently in the database. The new records came from DOE projects, private companies, and member countries of the International Energy Agency (IEA) Hydrogen Implementing Agreement (HIA) Task 19 (Hydrogen Safety).
- We created a new feature on the Web site called the Lessons Learned Corner to analyze and present hydrogen safety themes illustrated with database content.

Introduction

PNNL has developed and continues to improve two software tools to support the Hydrogen Safety, Codes and Standards Sub-Program. This report covers the Hydrogen Safety Best Practices online manual (http://

www.H2BestPractices.org) and the Hydrogen Incident Reporting and Lessons Learned database (http://www.H2Incidents.org). The National Research Council's second report on the FreedomCAR and Fuel Partnership states that "The creation of a database on incidents involving hydrogen will be useful in promoting safety." The report also states that "The committee encourages DOE to continue to develop, publish, and update the best practices document" [1].

Approach

Hydrogen Safety Best Practices - There are many references and resources that deal with the safe use of hydrogen, and our intent is to organize and compile relevant information in an easy-to-use Web-based manual without duplicating existing resources. PNNL teams with hydrogen safety experts at Los Alamos National Laboratory (LANL), Sandia National Laboratories (SNL), the Hydrogen Safety Panel, and other subject matter experts to compile hydrogen-specific best practices from a variety of references. Links to Web-based resources and actual PDF files are provided on the Web site.

Hydrogen Incident Reporting and Lessons Learned - The purpose of "H2Incidents.org" is to facilitate open sharing of lessons learned from hydrogen safety events to help avoid similar incidents in the future. Our approach to this task includes encouraging DOE-funded project teams and others to voluntarily submit incidents and near-misses and to provide specific lessons learned. We continue to pursue the addition of new records by actively seeking news reports on hydrogen incidents and searching existing databases and other sources for hydrogen-related safety event records. We contact private-sector companies who experience hydrogen-related safety events to solicit their permission to publish such records. We continue to maintain a mechanism for online submission of records. Specific safety event records are linked to Best Practices online manual content to emphasize safe practices for working with hydrogen and avoiding future incidents. Expert review of all safety events and lessons learned is provided by PNNL subject matter experts and the Hydrogen Safety Panel.

Results

Hydrogen Safety Best Practices – We enhanced the best practices content for outdoor storage of hydrogen cylinders in the Laboratory Safety/Laboratory Design section. The Hydrogen Safety Panel identified the need for more detailed content and recommendations as the result of conducting a number of safety review site visits to facilities and discussing safe practices for outdoor cylinder storage.

MOC content is now more visible because we added a new page on the Web site and provided links to that page from three other pages (Safety Culture/Formalized Procedures; Equipment Maintenance and Integrity; and Development of Operating Procedures). Multiple references are provided on the new MOC page, including publications by the American Institute of Chemical Engineers Center for Chemical Process Safety and the U.S. Chemical Safety and Hazard Identification Board. Links to incidents in our Incident Reporting and Lessons Learned database are provided to illustrate what can happen if MOC procedures aren't rigorously followed.

In response to reviewer requests, we drafted a new section called Hydrogen Properties that is focused on hydrogen combustion and liquid hydrogen expansion. The section was reviewed and approved by the Hydrogen Safety Panel and the National Aeronautics and Space Administration and then added to the Web site.

The Hydride Storage and Handling Section of Laboratory Safety/Laboratory Operations was updated by Sandia Livermore to cover the risks related to large-scale experiments with metal hydrides. The section now includes several photos in addition to new text.

We added approximately 50 links to safety event records in the Incident Reporting and Lessons Learned database to illustrate the kinds of incidents and near-misses that can occur if hydrogen safety best practices are not followed.

Hydrogen Incident Reporting and Lessons Learned - We added 37 new records to the database during the past year from DOE projects, private companies, and member countries of IEA HIA Task 19 (Canada, France, Germany, Italy, Japan, The Netherlands, Norway, Switzerland, the U.K., and the U.S.). We now have 177 records in the database, and about 15 more are pending approval by the organizations involved. PNNL staff, the Hydrogen Safety Panel, and others provided technical review of all records, with emphasis on fully capturing lessons learned.

Based on recommendations received at the 2009 Annual Merit Review, we created a new Lessons Learned Corner (LLC) on the Web site to analyze and present hydrogen safety themes illustrated with database content. LLC content will be published quarterly; the first theme was MOC (March 2010), and the second was Working with Reactive Metal-Hydride Materials in the Laboratory (May 2010).

Conclusions and Future Directions

Hydrogen Safety Best Practices - Our future work includes improving existing Web site content as well as drafting new content. Ideas for new content come from the Hydrogen Safety Panel, other national laboratories, technical reviewers at the DOE Annual Merit Review, and actual Web site users. For example, a new section on indoor refueling of forklifts is planned.

It has been suggested that we should consider the needs of end-user communities with less engineering and technological expertise. In response to this suggestion, we are drafting a new section that is focused on technicians and young engineers with limited or no knowledge of hydrogen properties and behavior. This new section will be practical and concise, formatted as a series of bullets showing what to do and what not to do, and include lots of photos and graphics to enhance the material. It will be highlighted on the Web site with a link that says "Starting Point for Those Not Familiar with Hydrogen" and will cover Hydrogen Basics, Hydrogen Hazards, and Design and Operation of Hydrogen Systems. It will also include links to existing Web site sections for further information.

We are also adding new content on working safely with chemical hydrides (analogous to the metal hydride section discussed earlier). The section has been drafted and reviewed by PNNL research staff working with chemical hydrides, and a revised version will be reviewed by Hydrogen Safety Panel members.

PNNL continues to monitor website usage and respond to user feedback. Users have submitted many requests for additional information and guidance through the Web site's comment submittal feature. We routinely seek guidance from one or more Hydrogen Safety Panel members in crafting our responses to these requests. Web site utility is enhanced by continuing to link the content to safety event records in the Hydrogen Incident Reporting and Lessons Learned database and by adding photos, graphics, and videos to complement the text.

Hydrogen Incident Reporting and Lessons Learned - Our future work will focus on increasing the number of records in the database, in part through identifying additional sources of hydrogen safety event data and lessons learned. A significant part of our effort involves working with the national laboratories, universities, and private-sector firms that experience hydrogen incidents and/or near-misses to help them communicate what happened, what the primary causes and contributing factors were, and most importantly, what lessons were learned by their organizations that could benefit others if they were freely shared. We are planning to incorporate graphical software to enable the display of the database contents in graphical format. We will continue to monitor Web site usage and respond to user feedback.

We will also continue to encourage all DOE-funded projects, universities, private-sector organizations, and others to voluntarily submit records of their hydrogen incidents and near-misses. Success requires that people use the database and submit information without fear of negative consequences from reporting and publicizing safety events. We will continue to maintain confidentiality for the organizations that voluntarily submit safety event records.

FY 2010 Publications/Presentations

1. 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 (Special Edition), 2010.

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, Corsica, France, September 2009.

3. Fassbender, LL. "H2 Incident Reporting and Lessons Learned," PNNL-SA-68306, NextEnergy 2009 Hydrogen Codes and Standards Conference, Detroit, MI, September 30, 2009.

4. Fassbender, LL. "H2 Safety Best Practices Website," PNNL-SA-68307, NextEnergy 2009 Hydrogen Codes and Standards Conference, Detroit, MI, September 30, 2009.

References

1. National Research Council, 2008, Review of the Research Program of the FreedomCAR and Fuel Partnership, Second Report, The National Academies Press, Washington, D.C.