PNNL-SA-78160

Hydrogen Safety Knowledge Tools

Linda Fassbender
Pacific Northwest National Laboratory

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

Overview

Timeline
- Project start: 2003
- Continuing

Budget
- FY10 Funding: $200K for both **Best Practices** and **Incident Reporting**
- FY11 Funding: $250K for both **Best Practices** and **Incident Reporting**

Barriers
- Limited Historical Database
- Proprietary Data

Partners
- **Best Practices** – Hydrogen Safety Panel, NASA, Nuvera Fuel Cells, and NREL
- **Incident Reporting** – Hydrogen Safety Panel and NASA

Relevance --- Objectives

H2 Safety Best Practices (H2BestPractices.org)

Capture vast and growing knowledge base of hydrogen experience and make it publicly available. The Hydrogen and Fuel Cells Program Multi-Year Program Plan says, “This living document provides guidance for ensuring safety in DOE hydrogen projects, while serving as a model for all hydrogen projects and applications.”

H2 Incident Reporting and Lessons Learned (H2Incidents.org)

Collect information and share lessons learned from hydrogen incidents and near-misses, with a goal of preventing similar incidents from occurring in the future.

Relevance --- Goals

- H2 Safety Best Practices
  - **Update Hydrogen Safety Best Practices Online Manual (9/30/11)**
    - Update existing content based on recommendations from the Hydrogen Safety Panel
    - Add new content after Hydrogen Safety Panel review/approval
- H2 Incident Reporting and Lessons Learned
  - **Achieve Target of 220 Records in Database (9/30/11)**
    - Currently 194 records
    - 26 more in progress
  - **Analyze Lessons Learned from Incidents (9/30/11)**
    - Publish thematic "Lessons Learned Corner" quarterly

Approach
H2 Safety Best Practices

Best practice = a technique or methodology that utilizes available knowledge and technology to achieve success

- Best practices are compiled from learnings and observations from Hydrogen Safety Panel site visits, safety plan reviews and other work, and available reference materials tailored specifically to working with hydrogen.
- Proposed new content is discussed at Panel meetings.
- PNNL staff create draft strawman materials.
- Panel members and PNNL subject matter experts review the drafts and provide comments.
- PNNL staff revise drafts based on reviewers' comments and then publish materials on website.
- Respond quickly to user questions submitted from the website.

H_2 Safety Best Practices

Welcome!

H_2BestPractices Home

Introduction to Hydrogen

So you want to know something about hydrogen...

Hydrogen Properties

Hydrogen Compared with Other Fuels

Safety Practices

Safety Culture

Safety Planning

Incident Procedures

Communications

Design and Operations

Facility Design Considerations

Storage & Piping

Operating Procedures

Equipment Maintenance

Laboratory Safety

Indoor Refueling of H2 Forklifts

What is a best practice?

A best practice is a technique or methodology that has reliably led to a desired result. Using best practices is a commitment to utilizing available knowledge and technology to achieve success.

What is H_2BestPractices.org?

A wealth of knowledge and experience related to safe use and handling of hydrogen exists as a result of an extensive history in a wide variety of industrial and aerospace settings. Hydrogen is gaining increasing attention worldwide as a possible energy storage medium, for later conversion to electricity through fuel cells or for use as a combustion fuel. This focus has introduced many new participants to research, development, demonstration, and deployment of hydrogen technologies (e.g., fuel cell vehicles and stationary fuel cells).

The purpose of the Hydrogen Safety Best Practices online manual is to share the benefits of extensive experience by providing suggestions and recommendations pertaining to the safe handling and use of hydrogen. Best Practices have been compiled from a variety of resources, many of which are in the public domain and can be downloaded directly from the References section. Many others can be obtained via reference links found at various places within the manual.

Best Practices are organized under a number of hierarchical categories in this online manual, beginning with those displayed down the left-hand column. Because of the interdependence of the topical areas, however, individual pages are often accessible via multiple internal links. A web-based electronic document format lends itself well to this type of overlapping content.

Website features

Please notice the mouse-over feature on this website. When a word in the text appears in blue font, you can see its definition by placing your cursor over the word. All the definitions are compiled into a Glossary that can be accessed from the References section of every page. There is also an Acronyms list and a Bibliography that can be accessed from every page. When you click on the link to the Bibliography, it will take you to the alphabetized list of references for the particular section from which you accessed it. Please contact us if you notice any definitions, acronyms, or references that should be in these lists but aren't.

A word about safety

Following the best practices contained in this online manual represents a commitment to the safe use and handling of hydrogen, but it should be recognized that no information resource can provide 100% assurance of safety. Personnel with applicable expertise should always be consulted in designing and implementing any system carrying a potential safety risk. Additionally, since following these best practices does not guarantee compliance with local codes, standards, and regulations, users should check with their local Authority Having Jurisdiction to ensure that those requirements are adequately addressed.

This online manual is linked to a companion website, H2Incidents.org, to provide unambiguous illustration of the importance of following safe practices and procedures when working with and around hydrogen. Like virtually all energy forms, hydrogen can be used safely when proper procedures and engineering techniques are followed, but its use still involves a degree of risk that must be respected. The importance of avoiding complacency and/or haste in the safe conduct and performance of projects involving hydrogen cannot be overstated.

Search H_2BestPractices

Enter a search term below.

References

Glossary

Acronyms

Bibliography

Codes & Standards

NFPA 2, *Hydrogen Technologies Code*, 2011 Edition

Related Sites

- H_2Incidents Database
- NHA Hydrogen and Fuel Cell Safety
- DOE Hydrogen Program
  - Hydrogen Safety Bibliographic Database

Contact Us

h2bestpractices@pnl.gov

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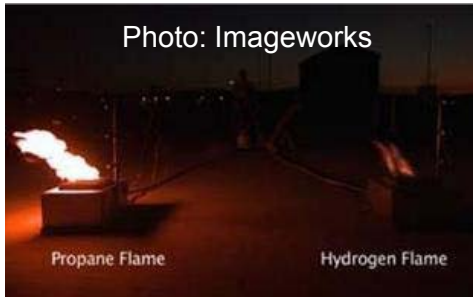
A collaboration of the Pacific Northwest National Laboratory and Los Alamos National Laboratory with funding from the U.S. Department of Energy.

Technical Accomplishments
H2 Safety Best Practices

- Added new section on Hydrogen Properties, focused on combustion and liquid hydrogen expansion
- Added new section for students, technicians, and young engineers not familiar with hydrogen called "So You Want To Know Something about Hydrogen"
- Added new section on Indoor Refueling of Hydrogen-Powered Forklifts with team of industry experts
- Added new section on Chemical Hydrogen Storage
- Added more photos to enhance website appearance



Hydrogen Overview
- Properties and Behavior
- Applications
- Systems and Controls

Hydrogen Hazards
- Leaks
- Flames
- Explosions

Proposed Future Work
H2 Safety Best Practices

- Add new content
  - Brainstorm with Hydrogen Safety Panel to identify gaps in content that should be addressed
- Enhance website utility
  - Continue to link content to safety event records in H2Incidents.org
  - Add more photos, graphics, and videos
- Encourage use of website and respond quickly to user questions with assistance from Hydrogen Safety Panel, NASA, and PNNL staff

Alarm System in a PNNL Laboratory

Fume Hood in a PNNL Laboratory

Collaborations
H2 Safety Best Practices
Since 2010 AMR

- Hydrogen Safety Panel
  - Addison Bain
  - Dave Farese
  - Don Frikken
  - Richard Kallman
  - Andy Sherman
- NASA White Sands Test Facility
  - Steve Woods
- Nuvera Fuel Cells
  - Aaron Harris
- NREL
  - Carl Rivkin

Hydrogen Safety Panel visits Bridgestone Firestone in Graniteville, SC

Thanks to my PNNL colleagues:
- Nick Barilo
- Andy Minister
- Kathleen Quick
- Steve Weiner

Approach
H2 Incident Reporting and Lessons Learned

Purpose: Facilitate sharing of lessons learned from hydrogen incidents to help avoid similar future incidents, without attribution to organization, location, or date of occurrence

- Success requires that people use the database and not fear negative consequences from reporting incidents. We encourage all DOE projects to submit incidents and near-misses with lessons learned.
- Pursue addition of new records by actively seeking news reports for hydrogen incidents and searching existing databases for hydrogen events.
- Contact private-sector companies who experience hydrogen incidents and near-misses to solicit permission to publish records.
- Establish and maintain a mechanism for online submissions of records.
- Add links to H2BestPractices.org to emphasize safe practices for working with hydrogen.
- Provide expert review of all incidents and lessons learned by Hydrogen Safety Panel and PNNL subject matter experts.

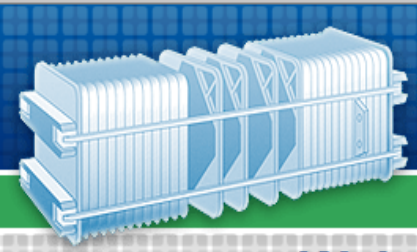
Approach
H2 Incident Reporting and Lessons Learned

Each safety event record contains:

- Description
- Severity (Was hydrogen released? Was there ignition?)
- Setting
- Equipment
- Characteristics (High pressure? Low temperature?)
- Damage and Injuries
- Probable Cause
- Contributing Factors
- Lessons Learned and Mitigation Steps
- Some records include photos


Tube Trailer Rollover


Gas Chromatograph Piping Leak and Explosion



H_2 Incident Reporting and Lessons Learned

Welcome!

Navigation

Clear Find Records >>

Settings

- Laboratory (67)
- Fueling Station (20)
- Commercial Facility (17)
- Power Plant (16)

Show All Options

Equipment

- Piping/Fittings/Valves (93)
- Hydrogen Storage Equipment (47)
- Vehicle & Fueling Systems (35)
- Safety Systems (24)

Show All Options

Damage and Injuries

- Property Damage (101)
- None (79)
- Minor Injury (26)
- Lost Time Injury (14)

Show All Options

Probable Causes

- Equipment Failure (81)
- Human Error (30)
- Design Flaw (24)
- Failure to Follow Standard Operating Procedures (20)

Show All Options

What is H_2Incidents?

H_2Incidents is a database-driven website intended to facilitate the sharing of lessons learned and other relevant information gained from actual experiences using and working with hydrogen. The database also serves as a voluntary reporting tool for capturing records of events involving either hydrogen or hydrogen-related technologies.

The focus of the database is on characterization of hydrogen-related incidents and near-misses, and ensuing lessons learned from those events. All identifying information, including names of companies or organizations, locations, and the like, is removed to ensure confidentiality and to encourage the unconstrained future reporting of events as they occur.

More About H_2Incidents...

How does H_2Incidents work?

You can access incident reports on H_2Incidents in a number of different ways. Here on the home page, you can go directly to the latest posted incidents using the navigation in the box to the right labeled "Latest Reports." The bottom of this box also contains a total for the number of incident reports in the system. By clicking the "show all" text next to this number, you can view a complete, alphabetical list of incidents.

To look for incidents related to specific details, you can use the left navigation. The five main headings—Settings, Equipment, Damage and Injuries, Probable Causes, Contributing Factors—will help you drill through the collection of incidents to find those that interest you. To see a graphical representation of the number of incidents associated with each of these main headings, simply click on the heading and then mouse over the chart to view a larger image. At any time, you can also use the Advanced Search form, found at the top of the page, for some more options to search the database.

If you have an incident you would like to include in the H_2Incidents database, please visit the Submit an Incident page. This page will ask for a wide range of information on your incident. Please enter as much of the information as possible. In order to protect your and your employer's identities, information that may distinguish an incident (your contact information, your company's name, the location of the incident, etc.) will not be displayed in the incident reports on H_2Incidents.

Submit an Incident

Latest Reports

Release of Stored Hydrogen as Water Temperature Increases

Hydrogen Explosion in Battery Compartment of Dinner Cruise Boat

TOTAL EVENTS REPORTED: 195 (SHOW ALL)

New! Lessons Learned Corner

Adequate Ventilation of Battery Charging Facilities

Hydrogen Use in Anaerobic Chambers

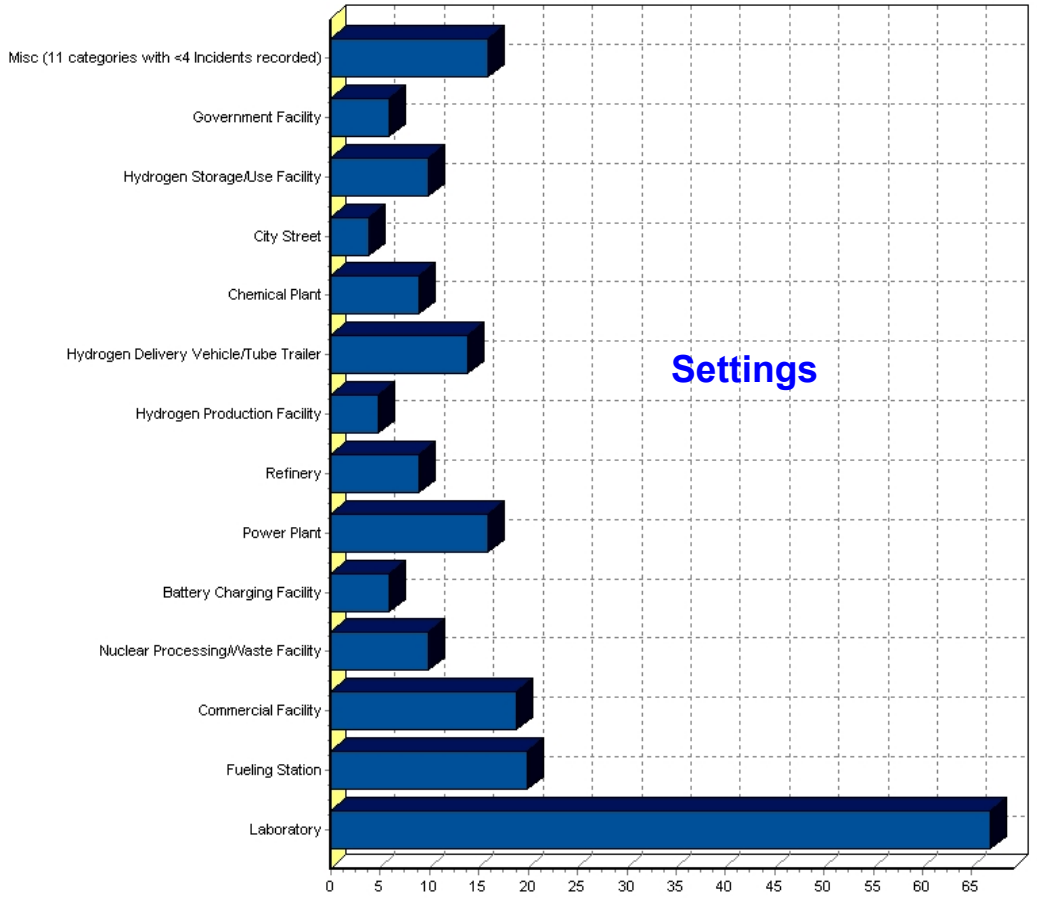
LESSONS LEARNED ARCHIVES

Technical Accomplishments
H2 Incident Reporting and Lessons Learned

- Added 55 incident records since 2010 AMR
- Currently 194 records in database, and 26 more in progress
- Collaborated with national labs, universities, and private-sector firms in the U.S. and other countries to prepare/submit records of incidents and near-misses
- Significant time spent interacting with incident "owners" to extract maximum value in lessons learned from their perspectives
- Obtained hydrogen incident alerts from DOE and Google Alerts
- Created quarterly issues of "Lessons Learned Corner" to analyze hydrogen safety themes illustrated by database content

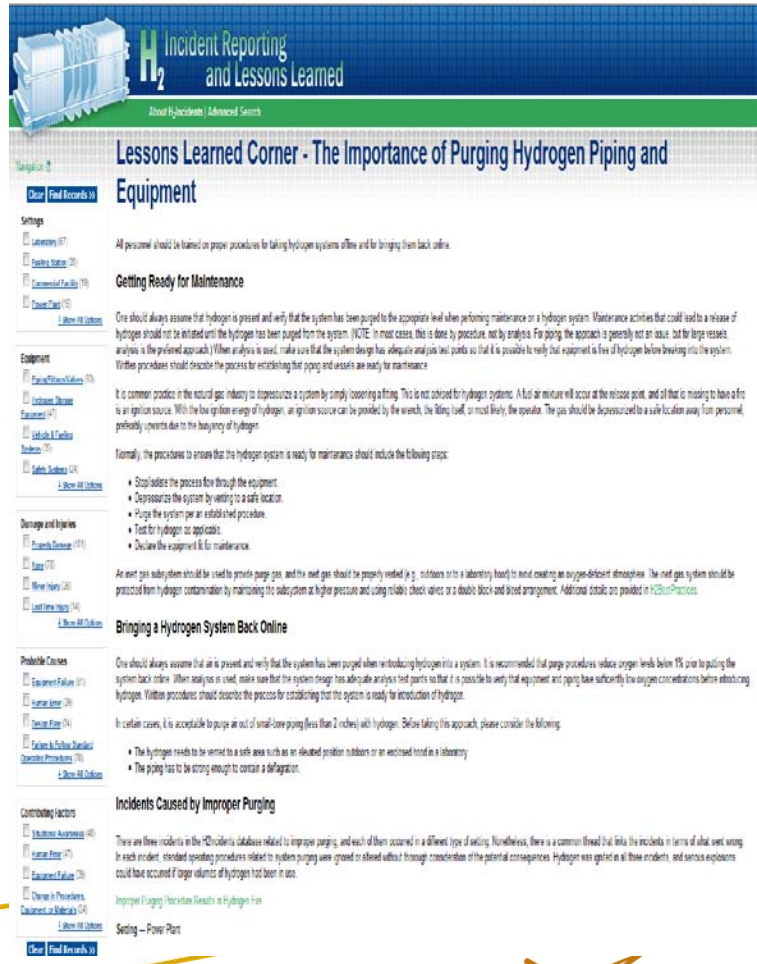
Technical Accomplishments
H2 Incident Reporting and Lessons Learned

- Incorporated bar graphs to characterize database contents in terms of:
  - Settings
    - Laboratory (67)
    - H_2 Fueling Station (20)
    - Commercial Facility (19)
    - Power Plant (16)
    - H_2 Delivery Vehicle (14)
    - Others…
  - Equipment
  - Damage/Injuries
  - Probable Causes
  - Contributing Factors



Technical Accomplishments
H2 Incident Reporting and Lessons Learned

- Lessons Learned Corner (LLC)
  - Publish quarterly
  - Summarize lessons learned for specific hydrogen safety themes
  - Illustrate with safety event records
  - Themes covered to date:
    - Management of Change
    - Working with Reactive Metal Hydrides
    - The Importance of Purging Hydrogen Piping and Equipment
    - Hydrogen Use in Anaerobic Chambers
    - Adequate Ventilation of Battery Charging Facilities



Technical Accomplishments
H2 Incident Reporting and Lessons Learned

Sample LLC --- The Importance of Purging H_2 Piping and Equipment

All personnel should be trained on proper procedures for taking hydrogen systems offline and for bringing them back online.

- Getting Ready for Maintenance
  - Always assume that hydrogen is present.
  - Use a properly vented inert gas subsystem for purging.
- Bringing a Hydrogen System Back Online
  - Always assume that air is present.
  - Reduce oxygen levels below 1% before putting system back online.
- Incidents Caused by Improper Purging
  - Improper purging procedure in a power plant results in hydrogen fire
  - Ignition of leaking hydrogen from tubing in a hydrogen production facility
  - Small-scale chemical reaction flash in a laboratory

Proposed Future Work
H2 Incident Reporting and Lessons Learned

- Continue to add incident records and lessons learned to the database
- Continue to publish quarterly thematic installments of Lessons Learned Corner
- Notify interested parties when new incident records and Lessons Learned Corner installments are posted
- Identify additional sources of hydrogen safety event information (e.g., other databases)
- Add links from incident records to best practices that should have been used to avoid incidents
- Encourage national labs, universities, and private-sector organizations to voluntarily submit records of incidents and near-misses to the website to share their lessons learned

Collaborations
H2 Incident Reporting and Lessons Learned
Since 2010 AMR

- Key collaborators are organizational "owners" of the incidents and near-misses added to the database
- Hydrogen Safety Panel
  - Addison Bain
  - Dave Farese
  - Don Frikken
  - Richard Kallman
  - Andy Sherman
  - Ed Skolnik
  - Bob Zalosh
- NASA White Sands Test Facility
  - Steve Woods


Hydrogen Safety Panel visits Bridgestone Firestone in Graniteville, SC

Thanks to my PNNL colleagues:
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- Eric Berglin
- Andy Minister
- Roger Pollari
- Kathleen Quick
- Steve Weiner

Summary

- **H2 Safety Best Practices**
  - New content has been added
    - Hydrogen Properties
    - So You Want to Know Something about Hydrogen
    - Indoor Refueling of Hydrogen-Powered Forklifts
    - Chemical Hydrogen Storage
  - Best practices linked to hydrogen incidents that illustrate the hazards of not working safely with hydrogen.
- **H2 Incident Reporting and Lessons Learned**
  - Database currently contains 194 records
  - Lessons Learned Corner (LLC) published quarterly
  - New graphical representation of database contents
  - Notices sent out when new incident records and LLCs are posted
  - Lessons learned linked to best practices that would have helped avoid the incidents