

Hydrogen Safety Knowledge Tools

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Overview

Timeline

- ▶ Project start: March 2003
- ▶ Continuing

Budget

- ▶ FY08 Funding: \$325K
for both **Best Practices**
and **Incident Reporting**
- ▶ FY09 Funding: \$300K
for both **Best Practices**
and **Incident Reporting**

Barriers

- ▶ Limited Historical Database
- ▶ Proprietary Data

Partners

- ▶ **Best Practices** – LANL, SNL, NREL, NASA, Hydrogen Safety Panel, and IEA HIA Tasks 19 and 22
- ▶ **Incident Reporting** – NASA and Hydrogen Safety Panel



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Objectives

H2 Safety Best Practices (H2BestPractices.org)

Capture the vast knowledge base of hydrogen experience and make it publicly available. As stated in the DOE Hydrogen Program's MYPP, "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 the goal of preventing similar incidents from occurring in the future.



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Milestones

▶ H2 Safety Best Practices

- **Update Peer-Reviewed Hydrogen Safety Best Practices Online Manual (9/30/08)**
 - Added section on Laboratory Safety
 - Added page on Vacuum Pumps
 - Added page on Codes and Standards, with links to three useful codes and standards websites

▶ H2 Incident Reporting and Lessons Learned

- **Achieve target of 150 records in database (9/30/08)**
 - 11 new records added since last year, including several incidents from within the DOE Hydrogen Program
 - About 9 more records drafted and pending approvals
- **Complete planned website enhancements (9/30/08)**
 - Improved lessons learned text for completeness and clarity
 - Made incident submission form more user-friendly by streamlining layout
 - Improved search function

Approach

H2 Safety Best Practices

“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.”

- ▶ Challenge: How to apply this broad definition to hydrogen-specific practices?
- ▶ Compile draft best practices using Hydrogen Safety Panel observations as well as available reference materials (e.g., NFPA 45, “Standard on Fire Protection for Laboratories Using Chemicals”, for the Laboratory Safety section), but tailoring them specifically to working with hydrogen.
- ▶ Use Hydrogen Safety Panel experts as reviewers, and make changes based on their comments.
- ▶ Launch **<http://www.H2BestPractices.org>**



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H₂ Safety Best Practices

Welcome!

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 H₂BestPractices.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

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.

This online manual is directly 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.

[H₂BestPractices Home](#)

Safety Practices

[Safety Culture](#)

[Safety Planning](#)

[Incident Procedures](#)

[Communications](#)

Design and Operations

[Facility Design Considerations](#)

[Storage & Piping](#)

[Operating Procedures](#)

[Equipment Maintenance](#)

[Laboratory Safety](#)

Search H₂BestPractices

Enter a search term below.

References

[Glossary](#)

[Acronyms](#)

[Bibliography](#)

[Codes & Standards](#)

Related Sites

- [H₂Incidents 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](#)
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[Site Map](#) | [Security & Privacy](#)

Technical Accomplishments

H2 Safety Best Practices

Safety Practices

- ▶ Safety Culture
- ▶ Safety Planning
- ▶ Incident Procedures
- ▶ Communications

Design and Operations

- ▶ Facility Design Considerations
- ▶ Storage and Piping
 - Vacuum Pumps
- ▶ Operating Procedures
- ▶ Equipment Maintenance
- ▶ Laboratory Safety

Website Features

- ▶ Codes and Standards
- ▶ Mouse-over Definitions of Terms
- ▶ Comprehensive Glossary
- ▶ Acronyms List
- ▶ Bibliography
- ▶ More Downloadable References
- ▶ More Links to Related Sites
- ▶ More Links to H2Incidents.org
- ▶ New Flame Characteristics Video
- ▶ Google Search Capability
- ▶ Contact Us Feature on Every Page



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Technical Accomplishments

H2 Safety Best Practices – Development, Review, and Comment Resolution

- ▶ Addison Bain (NASA, retired)
- ▶ Nick Barilo (PNNL)
- ▶ Chad Blake (NREL)
- ▶ Linda Fassbender (PNNL)
- ▶ Don Frikken (Becht Engineering)
- ▶ Richard Kallman (City of Santa Fe Springs, CA)
- ▶ Andy Minister (PNNL)
- ▶ Chris Moen (SNL)
- ▶ Michael Pero (Hydrogen Safety LLC)
- ▶ Butch Phillippi (ExxonMobil)
- ▶ Kathleen Quick (PNNL)
- ▶ Andrew Sherman (Powdermet, Inc.)
- ▶ Steve Weiner (PNNL)
- ▶ Steve Woods (NASA)
- ▶ Bob Zalosh (Firexplo)



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Technical Accomplishments

H2 Safety Best Practices

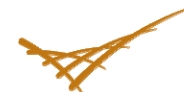
The newest section on Laboratory Safety covers hydrogen-related design and operations elements, including:

- ▶ Ventilation
- ▶ Fume Hoods
- ▶ Fire Protection
- ▶ Explosion Prevention
- ▶ Cylinder Safety
- ▶ Cryogenic Liquid
- ▶ Metal Hydride Storage & Handling *(by an SNL-led international team)*
- ▶ Pressure Equipment
- ▶ Leak and Flame Detection
- ▶ Emergency Plans

24 references included

Main reference = NFPA 45

>40 links to relevant safety records in [H2Incidents.org](https://www.h2incidents.org)



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Future Work

H2 Safety Best Practices

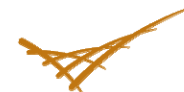
Work planned for the next 12 months includes:

▶ Add new content

- Add new section focused on technicians, supervisors, and young engineers that is more practical and concise, formatted as a series of simple bullets showing “Do’s” and “Don’ts” with lots of photos and graphics.
- Add new section on working with chemical hydrides (analogous to existing section on metal hydrides).
- Add new section on working with nanomaterials.

▶ Improve existing content

- Enhance existing section on outdoor storage of hydrogen cylinders based on recent incidents and incidents “waiting to happen” as observed by the Hydrogen Safety Panel.



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Future Work (continued)

H2 Safety Best Practices

- Include more detail on hydrogen properties, including:
 - Combustion properties
 - Explosive limits
 - Heating and expansion of cryogenic liquid
- Improve “management of change” (using a well-defined approach for planning, implementing, and communicating changes in a systematic and controlled manner) to include personnel changes as well as changes in equipment, processes, and procedures.
- ▶ Enhance website utility.
 - Continue to link content to safety event records in H2Incidents.org.
 - Add more photos (warning placards), graphics, and videos.
- ▶ Encourage use and respond in a timely manner to comments and questions posted on the website.

Approach

H2 Incident Reporting and Lessons Learned

The purpose of H2Incidents.org is to facilitate open sharing of lessons learned from hydrogen incidents to help avoid similar future incidents. All records are anonymous.

- ▶ Success requires that people use the incident database and not fear negative consequences from reporting their incidents. We encourage all DOE-funded projects to submit incidents and near-misses at their facilities, especially clear lessons learned to help others avoid similar incidents in the future.
- ▶ Pursue continued addition of new records by actively seeking news reports for hydrogen incidents and by searching existing databases for hydrogen event records.
- ▶ Contact private-sector companies who experience hydrogen incidents and near-misses to solicit their permission to publish incident records.
- ▶ Establish and maintain a mechanism for online submissions of records.
- ▶ Add links to H2BestPractices.org as appropriate to emphasize safe practices for working with hydrogen and avoiding future incidents.
- ▶ Provide for expert review of all incidents and lessons learned (by PNNL staff and Hydrogen Safety Panel members).



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H₂ Incident Reporting and Lessons Learned

About H₂Incidents |

Search



Navigation ?

Welcome!

[Clear](#) [Find Records >>](#)

Settings

- ☐ [Laboratory](#) (53)
- ☐ [Commercial Facility](#) (17)
- ☐ [Fueling Station](#) (11)
- ☐ [Nuclear Processing/Waste Facility](#) (10)

[Show All Options](#)

Equipment

- ☐ [Piping/Fittings/Valves](#) (61)
- ☐ [Hydrogen Storage Equipment](#) (19)
- ☐ [Safety Systems](#) (18)
- ☐ [Ventilation System](#) (17)

[Show All Options](#)

Damage and Injuries

- ☐ [Property Damage](#) (67)
- ☐ [None](#) (54)
- ☐ [Minor Injury](#) (18)
- ☐ [Lost Time Injury](#) (9)

[Show All Options](#)

Probable Causes

- ☐ [Equipment Failure](#) (64)
- ☐ [Design Flaw](#) (16)
- ☐ [Human Error](#) (16)
- ☐ [Inadequate Maintenance](#) (14)

[Show All Options](#)

Contributing Factors

- ☐ [Equipment Failure](#) (44)
- ☐ [Human Error](#) (41)
- ☐ [Situational Awareness](#) (38)
- ☐ [Change in Procedures, Equipment, or Materials](#) (27)

[Show All Options](#)

[Clear](#) [Find Records >>](#)

What is H₂Incidents?

H₂Incidents 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 H₂Incidents...](#)

How does H₂Incidents work?

You can access incident reports on H₂Incidents 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—[Contributing Factors](#), [Damage and Injuries](#), [Equipment](#), [Probable Causes](#), [Settings](#)—will help you drill through the collection of incidents to find those that interest you. At any time, you can also use the Search box along the top of the page, or use the [Advanced Search](#) form for some more options as you search the database.

If you have an incident you would like to include in the H₂Incidents 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 H₂Incidents.

Latest Reports

[Hydrogen Fire at an Aircraft Parts Manufacturing Facility](#)

[Improper Fill Speed at Fuel Dispenser](#)

[Fire at Hydrogen Fueling Station](#)

[First Responders Control Liquid Hydrogen Leak at Lamp Manufacturing Plant](#)

TOTAL EVENTS REPORTED: 133 ([SHOW ALL](#))

Search H₂Incidents

Enter a search term below or use the [Advanced Search](#) form. Separate words or phrases with commas or spaces, then select whether to include **ALL** or **ANY** of the words when searching for matching incidents.

☒ Find **ALL** of the terms entered.

☐ Find **ANY** of the terms entered.

Tools

[Advanced Search](#)

[Submit an Incident](#)

Approach

H2 Incident Reporting and Lessons Learned

Each safety event record in the database contains:

- ▶ Description
- ▶ Severity (Was H2 released? Was there ignition?)
- ▶ Setting
- ▶ Equipment
- ▶ Characteristics (High pressure? Low temperature?)
- ▶ Damage and Injuries
- ▶ Probable Cause
- ▶ Contributing Factors
- ▶ Lessons Learned and Mitigation Steps



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Technical Accomplishments

H2 Incident Reporting and Lessons Learned

- ▶ Continuously added new records since the 2008 Annual Merit Review (about 9 more are currently pending approval)
- ▶ Created and used a new Incident Alerts module to help us track potential database submissions
- ▶ Incident alerts obtained from DOE, NHA, and Google Alerts for hydrogen and fuel cell vehicles
- ▶ Improved lessons learned text for completeness and clarity with help from the Hydrogen Safety Panel
- ▶ Successfully encouraged DOE projects and private-sector firms to submit incidents and near-misses



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Technical Accomplishments

H2 Incident Reporting and Lessons Learned

► Early Incident Records

- Mainly from databases and journal articles, and some are quite old (1970s or earlier)
- Some have no dates, points of contact (for clarification), primary causes, or lessons learned
- Most entered by PNNL staff extracting information directly from databases or documents
- Hydrogen safety best practices were different 30-40 years ago, so early incidents may be less relevant to current hydrogen-related work

► Recent Incident Records

- > 90% of the incidents added during the past year occurred between 2002 and 2009
- All came from incident information forwarded to us by DOE or NHA, or from Google alerts about recent news media stories
- Almost all entered by PNNL in collaboration with other national labs or private industry
- Each record reviewed and approved by national lab or company that experienced it to ensure completeness and accuracy



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Future Work

H2 Incident Reporting and Lessons Learned

- ▶ Increase the number of records and lessons learned in the database.
- ▶ Identify additional sources of hydrogen safety event information (e.g., other databases).
- ▶ Utilize “Incident Alerts” module to pursue incident submissions.
- ▶ Add links from incident records to relevant best practices that should have been used to avoid the incidents in the first place.
- ▶ Incorporate software to enable display of database contents in graphical format.
- ▶ Encourage all DOE-funded projects, non-DOE projects, and private-sector organizations to voluntarily submit records of their incidents and near-misses to the website.



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Summary

▶ H2 Safety Best Practices

- Website is publicly available, including Laboratory Safety section.
- Best practices are being linked to H2 Incidents.

▶ H2 Incident Reporting and Lessons Learned

- Database contains 133 records and counting.
- Lessons learned are being linked to H2 Best Practices.



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