

# Hydrogen Safety Tools: Software and Hardware

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

# Overview

## Timeline

- ▶ Project start: March 2003
- ▶ Project continuing

## Budget

- ▶ Funding received in FY07:
  - **Best Practices** and **Incident Reporting** - \$300K
  - **FCV Simulator Prop** - \$430K
- ▶ Funding for FY08:
  - **Best Practices** and **Incident Reporting** - \$325K
  - **FCV Simulator Prop** - \$115K

## Barriers

- ▶ Limited Historical Database
- ▶ Proprietary Data
- ▶ Lack of Hydrogen Training Facilities for Emergency Responders

## Partners

- ▶ **Best Practices** – LANL, SNL, NASA, and Hydrogen Safety Panel
- ▶ **Incident Reporting** – Hydrogen Safety Panel
- ▶ **FCV Simulator Prop** – HAMMER, Kidde Fire Trainers, and Hydrogen Safety Panel

# Objectives

## H2 Safety Best Practices

Capture the vast knowledge base of hydrogen experience and make it publicly available to those working with hydrogen and related systems, including those just starting to work with hydrogen.

## H2 Incident Reporting and Lessons Learned

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

## ▶ H2 FCV Simulator Prop

Support the design, construction, commissioning, and training use of a life-size mobile FCV burn prop that is hydrogen-specific.

### National Research Council Phase 2 Report on FreedomCAR and Fuel Partnership:

“The creation of a database on **incidents involving hydrogen** will be useful in promoting safety. The committee encourages DOE to continue to develop, publish, and update the **best practices document**.”

# Milestones

## ▶ H2 Safety Best Practices

- Release Hydrogen Safety Best Practices Online Manual, <http://www.H2BestPractices.org> (12/31/07)
- Update Peer-Reviewed Hydrogen Safety Best Practices Online Manual (9/30/08)

## ▶ H2 Incident Reporting and Lessons Learned

- Achieve target of 150 records in database (9/30/08)
- Complete planned website enhancements (9/30/08)

## ▶ H2 FCV Simulator Prop

- Complete construction of hands-on FCV training prop (6/1/08)
- Incorporate prop operation into train-the-trainer course and initial pilot course for emergency responders to be conducted by the DOE Hydrogen Education Program (9/30/08)

# 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?
- ▶ Team with hydrogen safety experts at LANL and SNL to compile draft best practices using available reference materials (e.g., NFPA 45 for Lab Safety), but tailoring them specifically to working with hydrogen
- ▶ Use Hydrogen Safety Panel experts as initial reviewers
- ▶ Coordinate limited public review of draft and make changes based on public comments
- ▶ Launch **<http://www.H2BestPractices.org>**





# H<sub>2</sub> 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 H<sub>2</sub>BestPractices.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.

[H<sub>2</sub>BestPractices Home](#)

#### Safety Practices

[Safety Culture](#)

[Safety Planning](#)

[Incident Procedures](#)

[Communications](#)

#### Design and Operations

[Facility Design Considerations](#)

[Storage & Piping](#)

[Operating Procedures](#)

[Equipment Maintenance](#)

#### Search H<sub>2</sub>BestPractices

Enter a search term below.

#### References

[Glossary](#)

[Acronyms](#)

[Bibliography](#)

#### Related Sites

- [H<sub>2</sub>Incidents Database](#)
- [NHA Hydrogen and Fuel Cell Safety](#)
- [DOE Hydrogen Program](#)
  - [Hydrogen Safety Bibliographic Database](#)
- [Hydrogen and Fuel Cells Codes and Standards Matrix](#)

#### Contact Us

✉ [h2bestpractices@pnl.gov](mailto:h2bestpractices@pnl.gov)

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# Technical Accomplishments

## H2 Safety Best Practices

### Safety Practices

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

### Design and Operations

- ▶ Facility Design Considerations
- ▶ Storage and Piping
- ▶ Operating Procedures
- ▶ Equipment Maintenance

### Website Features

- ▶ Mouse-over Definitions of Terms
- ▶ Comprehensive Glossary
- ▶ Acronyms List
- ▶ Bibliography
- ▶ Downloadable References
- ▶ Links to Related Sites
- ▶ Links to H2Incidents.org
- ▶ Google Search Capability
- ▶ Contact Us Feature on Every Page

# Technical Accomplishments

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

- ▶ Bret Akers
- ▶ Addison Bain
- ▶ Nick Barilo
- ▶ Dag Bjerketvedt
- ▶ Dave Farese
- ▶ Linda Fassbender
- ▶ Don Frikken
- ▶ Monterey Gardiner
- ▶ Olav Roald Hansen
- ▶ Dallas Hill
- ▶ Henrik Iskov
- ▶ Todd Jankowski
- ▶ Richard Kallman
- ▶ Ian MacIntyre
- ▶ Andy Minister
- ▶ George Mitchell
- ▶ Chris Moen
- ▶ Robert Morley
- ▶ Jonathan Munetz
- ▶ Cathy Padro
- ▶ Michael Pero
- ▶ Butch Phillippi
- ▶ Coyne Prenger
- ▶ Kathleen Quick
- ▶ Antonio Ruiz
- ▶ Andrew Sherman
- ▶ Ed Skolnik
- ▶ Steve Weiner
- ▶ Steve Woods
- ▶ Bob Zalosh



# Technical Accomplishments

## H2 Safety Best Practices

**A new Laboratory Safety section has been drafted that covers hydrogen-related design and operations elements, including:**

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

# Future Work

## H2 Safety Best Practices

- ▶ Resolve remaining comments from the limited public review
- ▶ Include more detail on hydrogen properties
  - Combustion properties
  - Explosive limits
  - Heating and expansion of cryogenic liquid
- ▶ Add information on pumps and compressors in hydrogen service
- ▶ Complete major new section on Laboratory Safety
  - Hydride Storage and Handling (by Sandia Livermore)
- ▶ Enhance website utility
  - Continue to link content to safety event records in [H2Incidents.org](http://H2Incidents.org)
  - Add more photos (warning placards), graphics, and videos
- ▶ Encourage use and respond to comments 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, including 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 anonymous 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 Safety Panel members).



Navigation ?

## Welcome!

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

### Settings

- [Laboratory](#) (56)
- [Commercial Facility](#) (15)
- [Nuclear Processing/Waste Facility](#) (10)
- [Power Plant](#) (8)

[↓ Show All Options](#)

### Equipment

- [Valve](#) (23)
- [Piping](#) (21)
- [Electrical Equipment](#) (14)
- [Vessel](#) (13)

[↓ Show All Options](#)

### Damage and Injuries

- [Property Damage](#) (62)
- [None](#) (50)
- [Minor Injury](#) (17)
- [Lost Time Injury](#) (10)

[↓ Show All Options](#)

### Probable Causes

- [Equipment Failure](#) (59)
- [Design Flaw](#) (16)
- [Inadequate Maintenance](#) (14)
- [Failure to Follow Standard Operating Procedures](#) (13)

[↓ 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 H<sub>2</sub>Incidents?

This Hydrogen Incident Reporting Database is intended to facilitate the sharing of lessons learned and other relevant information gained from actual experiences using and working with hydrogen. The database contains 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 are removed to ensure confidentiality and to encourage the unconstrained future reporting of events as they occur.

[More About H<sub>2</sub>Incidents...](#)

## How does H<sub>2</sub>Incidents work?

You can access incident reports on H<sub>2</sub>Incidents 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 H<sub>2</sub>Incidents 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<sub>2</sub>Incidents.

## Latest Reports

[Fueling Hose Fails](#)

[Electrical Incident Near a High-Pressure Hydrogen Reactor Cell](#)

[Over-Pressurization of Laboratory Ball Mill](#)

[Hydrogen Boosting Compressor Fails](#)

TOTAL EVENTS REPORTED: 122 ([SHOW ALL](#))

## Search H<sub>2</sub>Incidents

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.

# Technical Accomplishments

## 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



# Technical Accomplishments

## H2 Incident Reporting and Lessons Learned

- ▶ Continuously added new records since the 2007 Annual Merit Review (more are currently pending approval)
- ▶ Improved lessons learned text for completeness and clarity with help from the Hydrogen Safety Panel
- ▶ Enhanced the incident submission form to make it more user-friendly by streamlining the layout and organization of information
- ▶ Improved the search function
- ▶ Successfully encouraged DOE projects and private-sector firms to submit incidents and near-misses

# Future Work

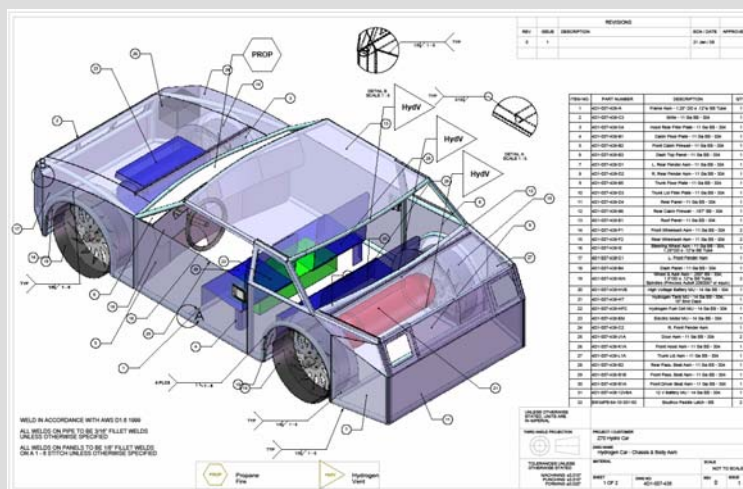
## H2 Incident Reporting and Lessons Learned

- ▶ Increase the number of records and lessons learned in the database.
- ▶ Identify additional sources of hydrogen safety event information (e.g., other databases).
- ▶ Publish “Incident Alerts” section.
- ▶ Add comment submittal feature to every page.
- ▶ 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.
- ▶ Brainstorm new ways to publicize the website availability.

# Approach

## H2 FCV Simulator Prop

- ▶ Leverage Kidde Fire Trainers' experience with building propane-fueled training props (HAMMER has 8 of them)
- ▶ Design a mobile FCV simulator prop to integrate with emergency responder training curriculum developed by the DOE Hydrogen Education Program
- ▶ Have Kidde construct and test a mobile FCV simulator prop and provide O&M training to HAMMER, PNNL, and firefighter trainers
- ▶ Test the prop functionality with hands-on training exercises for trainers and pilot course participants (jointly with DOE Hydrogen Education Program)
- ▶ Determine costs and benefits of providing prop-based training at HAMMER versus offsite locations



# Technical Accomplishments

## H2 FCV Simulator Prop

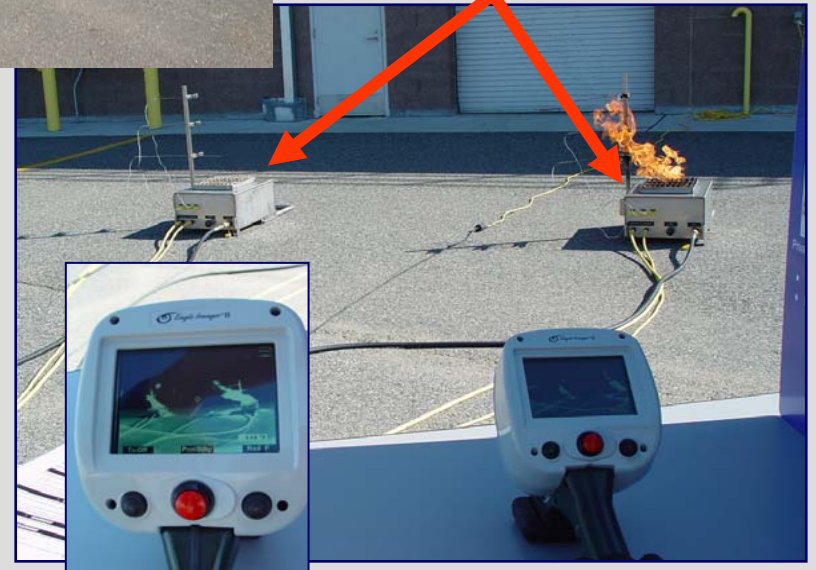


The hydrogen FCV simulator prop at about 90% complete.

HAMMER's existing propane-fueled burn prop recreates conditions encountered during control and suppression of vehicle fires.



Our existing hydrogen demo prop illustrates the differences between hydrogen and propane flame characteristics.



# Technical Accomplishments

## H2 FCV Simulator Prop

- ▶ Prop will provide a life-size, hands-on demonstration of an emergency response to a FCV incident, including:
  - Safe approach to a FCV
  - Use of gas and flame detectors
  - Hydrogen venting and ignition
  - Extinguishment of a compartment fire
  - Extrication techniques
- ▶ 60% and 90% designs were reviewed by:
  - OEMs
  - Energy companies
  - DOE program managers
  - Firefighters
  - Hydrogen Safety Panel



# Future Work

## H2 FCV Simulator Prop

- ▶ Finalize safety plan for FCV prop operations.
- ▶ Continue testing prop operation at HAMMER.
- ▶ Integrate hands-on prop training into train-the-trainer and pilot courses this FY.
- ▶ Develop prop deployment schedule for emergency responder training (jointly with DOE Hydrogen Education Program):
  - at HAMMER
  - at regional fire training facilities
  - other opportunities
- ▶ Explore the opportunity for using the prop to train emergency responders in Washington, Oregon, and California for hydrogen-related activities planned for the February 2010 Winter Olympics in Vancouver, British Columbia.

# Summary

## ▶ **H2 Safety Best Practices**

- Website is publicly available.
- Laboratory Safety section will be available this FY.
- Best practices are being linked to H2 Incidents.
- Website enhancements are currently underway.

## ▶ **H2 Incident Reporting and Lessons Learned**

- Database contains 122 records and counting.
- Lessons learned are being linked to H2 Best Practices.

## ▶ **H2 FCV Simulator Prop**

- Mobile FCV prop is being tested at HAMMER.
- Train-the-trainer and pilot courses will be held this FY.