

INCREASE YOUR

H₂IQ

The #H2IQ Hour

Today's Topic:

What's New with the Center for Hydrogen Safety?

This presentation is part of the monthly H2IQ hour to highlight research and development activities funded by U.S. Department of Energy's Hydrogen and Fuel Cell Technologies Office (HFTO) within the Office of Energy Efficiency and Renewable Energy (EERE).

CENTER FOR
Hydrogen
SAFETY
Connecting a Global Community

Nick Barilo
Director, Center for Hydrogen Safety
June 23, 2020



Enabling Widespread Success: Addressing Safety

- ▶ Safety issues must be addressed for successful hydrogen technology acceptance and deployment
- ▶ Safety issues can be a 'deal breaker'
- ▶ Hydrogen technology stakeholders may not be able to identify and effectively address all safety issues
- ▶ Stakeholders benefit from an independent and experienced hydrogen safety review resource involved in early design and safety planning activities



Safely Fueling Our Future...

by building on a strong foundation of resources built through collaboration

Safety Knowledge Resources

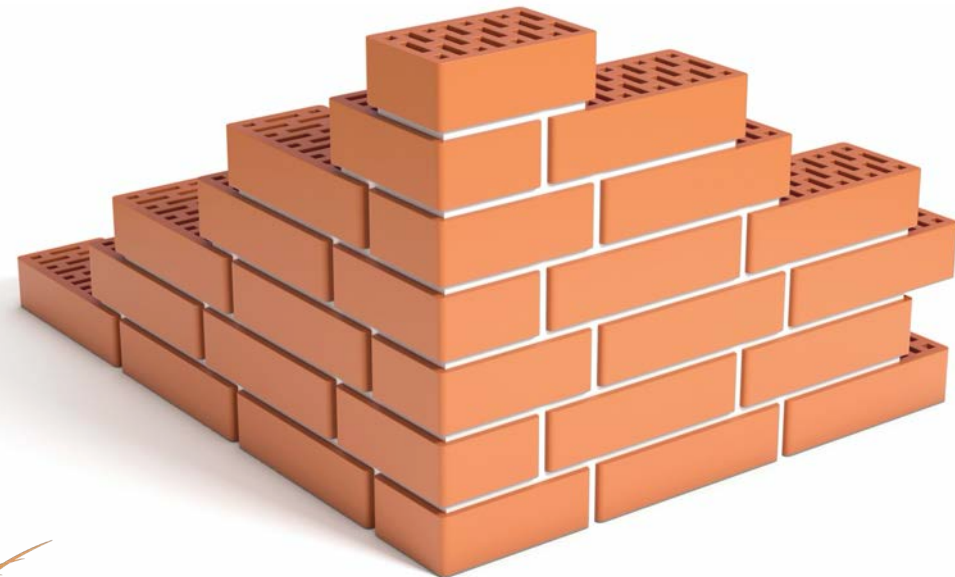
- ▶ Hydrogen Tools Web Portal
- ▶ Hydrogen Lessons Learned
- ▶ Best Safety Practices

First Responder Training Resources

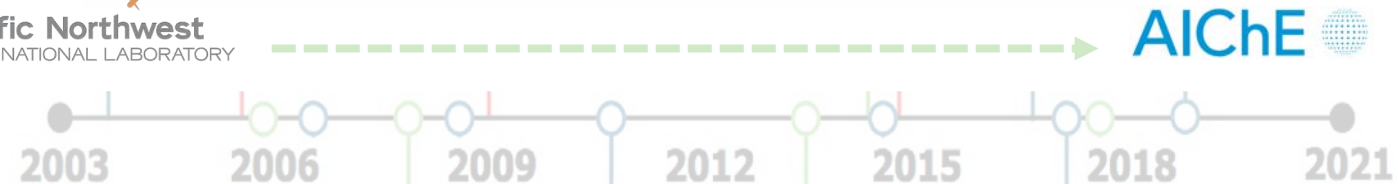
- ▶ Online Awareness Training
- ▶ Operations-Level Classroom Training
- ▶ National Training Resource

Hydrogen Safety Panel

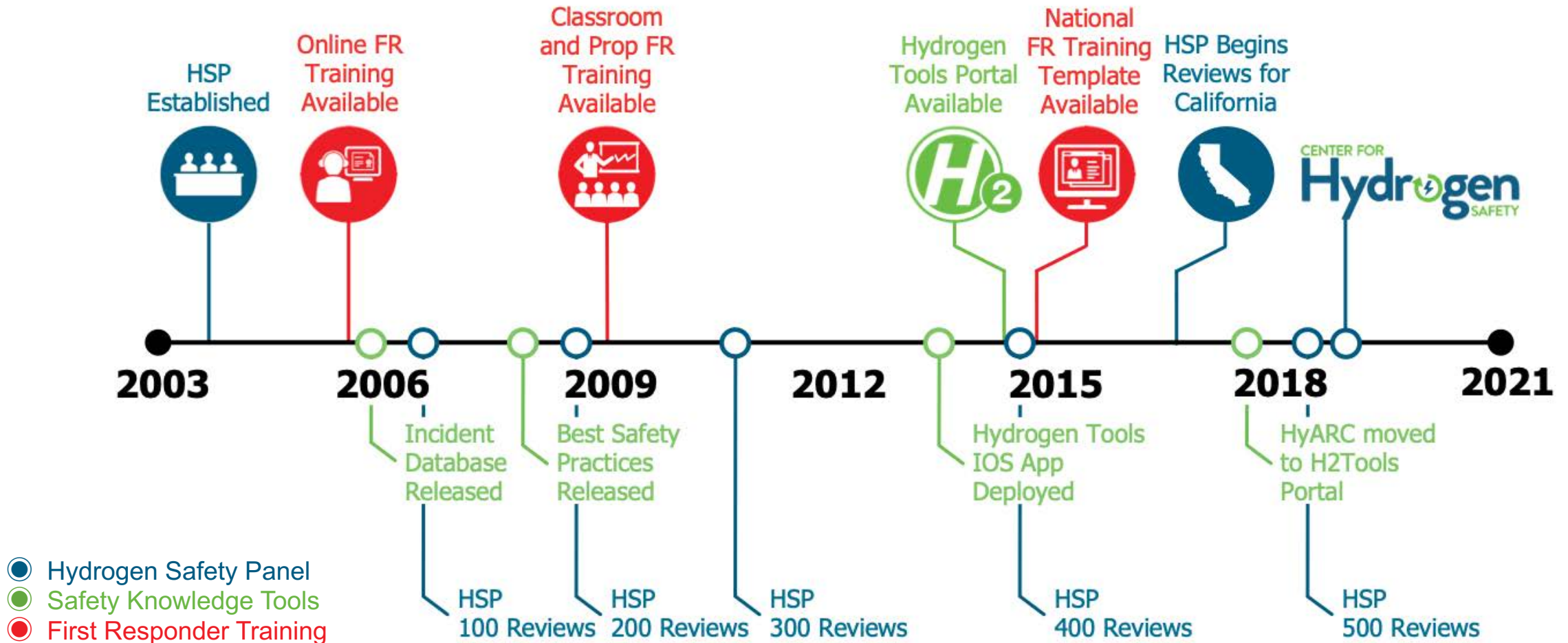
- ▶ Reviews Projects and Facilities
- ▶ Identifies Gaps and Shares Learnings




Pacific Northwest
NATIONAL LABORATORY



Timeline of Our Hydrogen Safety Resources



*Bringing together a global membership
to expand the body of safety knowledge*

Vision

- ▶ The **Center for Hydrogen Safety** is a global non-profit dedicated to promoting applied hydrogen safety and best practices worldwide

Mission

- ▶ Support and promote the safe handling and use of hydrogen across applications in the energy transition
- ▶ Provide a common communication platform with a global scope to ensure safety information, guidance and expertise is available to all stakeholders



CHS...Overview of the Past Year

April 2019

New Orleans, U.S.
The Center for Hydrogen Safety launches with 13 founding members



October 2019

- First Responder H₂-safety course deployed online
- First CHS Conference



January 2020

CHS signed MOU with Gangwon Technopark from South Korea



April 2020

- First members meeting
- Members-only website debuted
- Member meeting on U.S. incident

June 2020

- FR Micro Courses completed
- 40 Members



June 2019

CHS holds member meeting to discuss H₂ incidents



December 2019

- First Member Newsletter deployed
- Technical bulletins developed



February 2020

Initiated planning for virtual conferences in U.S. and Europe

May 2020

- Revised FR course
- First working group
- Bylaws approved
- First international government member

Membership Benefits – Focusing on Applied Safety



Project/Facility support

- ▶ Design Reviews
- ▶ Hazard Analysis Support
- ▶ Facility/Site Reviews



Outreach

- ▶ Stakeholders
- ▶ Code Officials
- ▶ Communities



Networking

- ▶ H₂ Safety Conferences
- ▶ Collaborative Teaming



Training & Education

- ▶ First Responders
- ▶ Researchers
- ▶ Technicians



Incident Management Resource

- ▶ Timely Information on Incidents
- ▶ Facts Sheets
- ▶ Resource Guide

Training and Education Resources



Online Courses

- First Responders
- Researchers and Academia (coming soon)
- Workforce Development



Focused Webinars and Custom Training

- Project Safety and Safety Planning
- Researchers and Academia
- Code Officials
- Others (based on customer needs)



Information Materials

- First Responders
- Public



Future Language Support

- English
- French
- Dutch (current First Responder)
- Japanese (legacy First Responder)



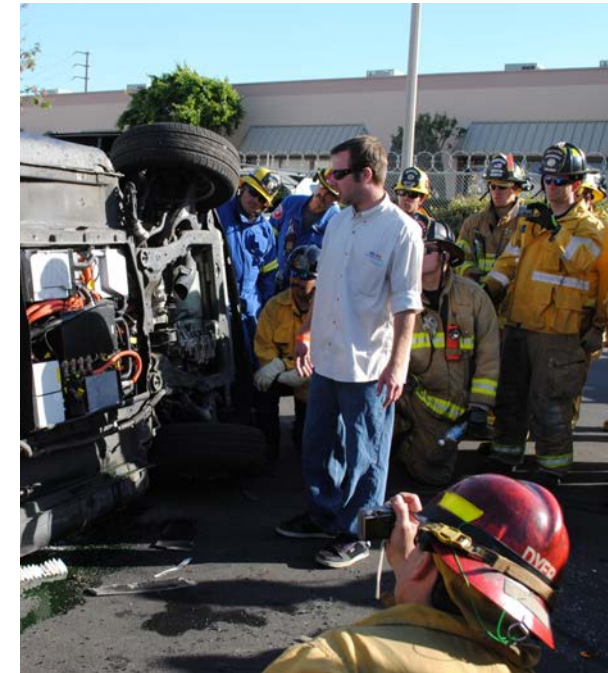
First Responder Hydrogen Safety Training

► Goal

- Support the successful implementation of hydrogen and fuel cell technologies by providing technically accurate hydrogen safety and emergency response information to first responders

► Integrated Activities

- Online, awareness-level training
- Classroom and hands-on operations-level training
- Trainer material (PowerPoint slides with speaker notes)



A properly trained first responder community is critical to the successful introduction of hydrogen fuel cell applications and their transformation in how we use energy.

Online First Responder Hydrogen Safety Training

► Awareness-level Training

- Redeployed on the AIChE Academy on 10/08/2019 offering CEU/PDH credits
- Updated in May 2020 to include video clips and information on transportation safety in response to the 2018 Diamond Bar incident

► First Responders Micro Training Learning Plan (video based)

- Introduction to Hydrogen Fuel Cell Vehicles For Incident Response
- Fire Response & Extrication of a Hydrogen Fuel Cell Vehicle
- Transport of Hydrogen Fuel
- Hydrogen Fueling Station Incident Response



Awareness-level Training

<https://www.aiche.org/academy/courses/ela253/introduction-hydrogen-safety-first-responders>

Micro Learning Plan

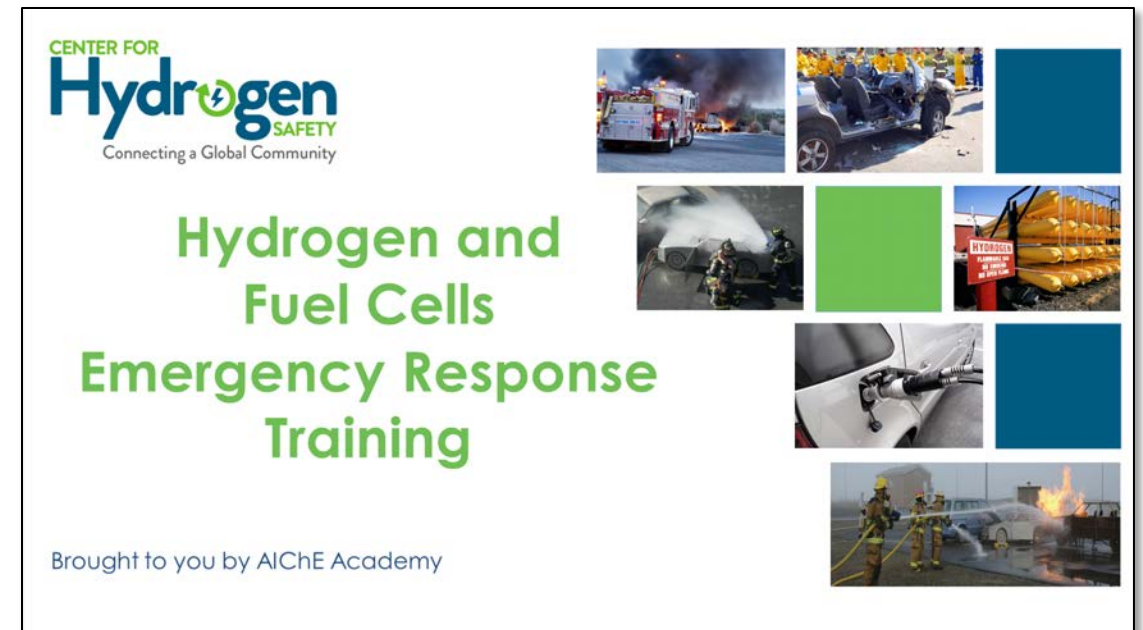
<https://www.aiche.org/academy/courses/elp001/first-responders-micro-training-learning-plan>

Short Clip from First Responder Training Courses



Hydrogen Safety Resource for Trainers

- ▶ The template is a PowerPoint slide deck intended to serve as a resource and guide for the delivery of a variety of training regimens to various audiences
- ▶ The material is adaptable for different presentation styles, ranging from higher level overview formats to more comprehensive classroom training
- ▶ Recent updates
 - Updated with links to video clips from micro learning courses and to address transportation issues
 - Additional information provided on transportation considerations
 - Moved to universal 16x9 format



Custom Training

- ▶ Can be done by **virtually or onsite**
- ▶ Available for a wide variety of audiences
 - Code officials, fire prevention officers and inspectors
 - Academia and laboratories
 - OEMs and equipment producers
 - Military organizations
- ▶ Topics can be tailored to specific needs
- ▶ Materials include slides, videos and animations
- ▶ Led by members of the Hydrogen Safety Panel

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Additional Properties of Hydrogen

- ▶ **Description**
 - Colorless, odorless
- ▶ **General Properties**
 - Flammable
 - Non-irritating, non-toxic
 - Non-corrosive
 - Lightest gas, buoyant
- ▶ **Physical Properties**
 - GH_2 density @ NTP: 0.08988 g/L
 - GH_2 specific gravity: 0.07
 - Viscosity: 8.96 $\times 10^{-5}$ poise
 - Diffusivity: 6.11 $\times 10^{-5}$ m²/s
 - Thermal Conductivity: 0.181 W/mK

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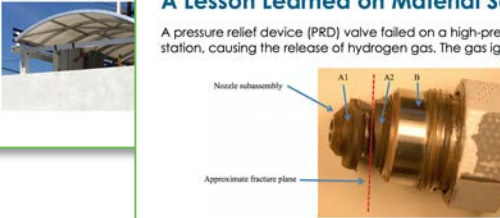
Passive Ventilation, Indoors and Outdoors

- ▶ **Passive ventilation with roof or eave vents can prevent H_2 buildup if a leak or discharge occurs**
 - Evaluate passive ventilation thoroughly to ensure that a hydrogen leak will dissipate safely both normal conditions and emergency situations.
 - Locate inlet openings at floor level in room exterior walls.
 - Locate outlet openings at ceiling level in room exterior walls.
- ▶ **Passive/natural ventilation**
 - Avoid pockets under eaves
 - Ensure at least 75% of floor area is ventilated

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A Lesson Learned on Material Selection

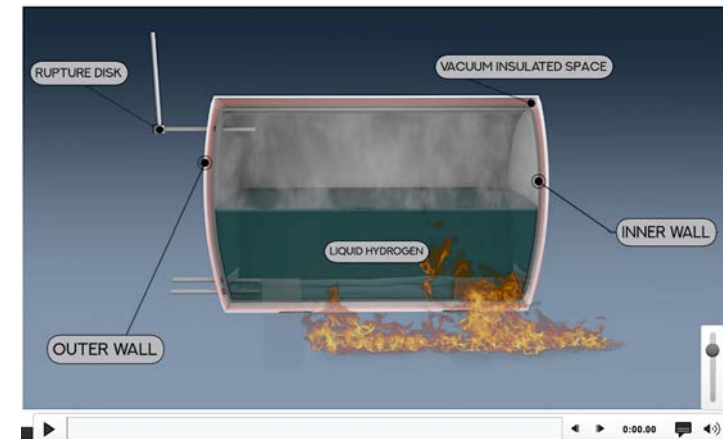
A pressure relief device (PRD) valve failed on a high-pressure storage tube at a hydrogen fueling station, causing the release of hydrogen gas. The gas ignited at the exit of the vent pipe.



- The root cause of the incident was a failed pressure relief valve...
- An extensive metallurgical analysis of the failed valve concluded that **improper material selection and deviations from valve production processes led to the valve failure.**

The good news... There were no injuries and very little property damage. The corrugated roof on an adjacent canopy over a fueling dispenser was slightly singed by the escaping hydrogen flame, causing minimal damage.

Source: <http://www.h2tools.org/lessons> March 24, 2020 / 11



New Hydrogen Safety Training Courses Being Developed

New courses based on H2Tools.org Best Safety Practices

- ▶ *Fundamentals of Hydrogen and Fuel Cell Technology Safety*
- ▶ *Hydrogen Facility Design*
- ▶ *Compressed Hydrogen Systems Design*
- ▶ *Liquid Hydrogen Systems Design*
- ▶ *Maintaining Hydrogen Equipment*
- ▶ *Operating Hydrogen Equipment*
- ▶ *Hydrogen in the Laboratory – Safe Design*
- ▶ *Hydrogen in the Laboratory – Safe Operations*
- ▶ *Hydrogen Safety Best Practices and Considerations for Management*
- ▶ *Hydrogen Materials Compatibility*
- ▶ *Fuel Cell Forklifts and Indoor Refueling*



Concept was submitted
by a CHS member during
an onboarding meeting

Translating Resources (multi-language support)

- ▶ Will focus on addressing education materials and safety information bulletins
- ▶ Utilize CHS membership to help establish priorities and support the translation process
- ▶ First product was a safety bulletin issued in Japanese in December 2019
- ▶ Next products will be the First Responder training template
 - Dutch
 - French
 - Japanese



Credentialing/Certification for Hydrogen Safety

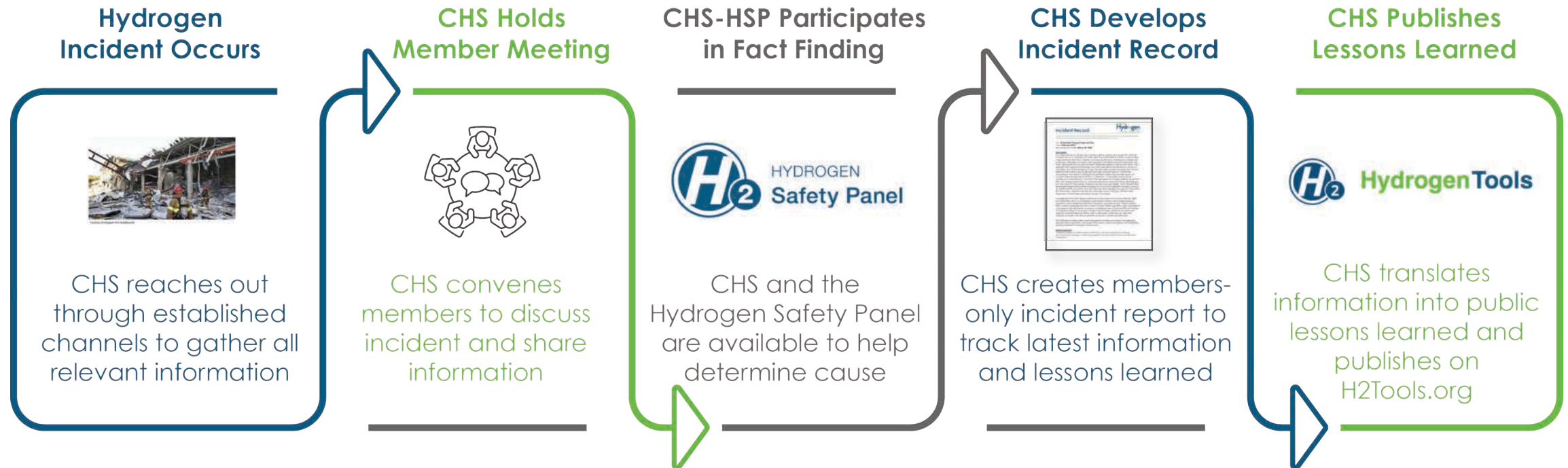
AICHE CREDENTIAL

As the hydrogen industry grows there is an increased need for workforce development and validation

- ▶ AIChE has a credentials activity as part of its Institute for Learning & Innovation
- ▶ CHS is in the early stages of working with industry members for developing credential program for hydrogen safety
- ▶ It is anticipated that CHS members and the Hydrogen Safety Panel will help direct the process and review content



CHS Hydrogen Incident Response Activities

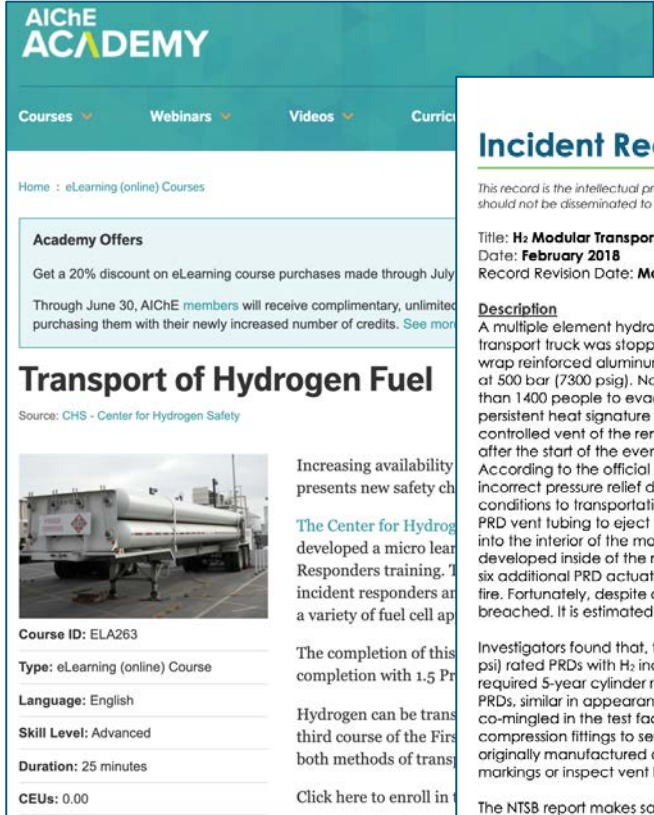


Other resources CHS may use for responding to an incident:

- Education Materials – new courses, revised course content, etc.
- Technical Bulletins – members only and public safety bulletins developed and disseminated
- Working Groups – to address important safety issues and develop learnings for community and industry
- Conferences & Workshops – share incident information and learnings
- Incident Management Guide

CHS Response to The Diamond Bar Incident

- ▶ CHS members have been provided access to short lesson learned bulletin (Incident Record)
- ▶ First responder training materials have been revised to address the transportation issues and a recommendation provided by the US National Transportation Safety Board in 2019
- ▶ Incident record will be input into the H2Tools Lessons Learned database



AICHE ACADEMY

Courses ▾ Webinars ▾ Videos ▾ Curric

Home : eLearning (online) Courses


Academy Offers

Get a 20% discount on eLearning course purchases made through July

Through June 30, AICHE members will receive complimentary, unlimited purchasing them with their newly increased number of credits. [See more](#)

Transport of Hydrogen Fuel

Source: CHS - Center for Hydrogen Safety



Course ID: ELA263

Type: eLearning (online) Course

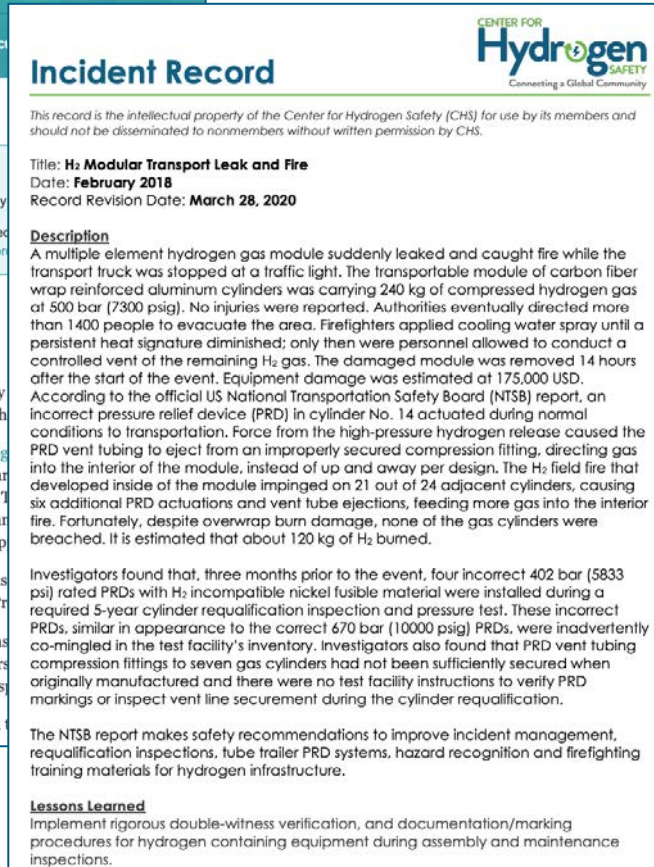
Language: English

Skill Level: Advanced

Duration: 25 minutes

CEUs: 0.00

Click here to enroll in t



Incident Record

This record is the intellectual property of the Center for Hydrogen Safety (CHS) for use by its members and should not be disseminated to nonmembers without written permission by CHS.

Title: **H₂ Modular Transport Leak and Fire**
Date: **February 2018**
Record Revision Date: **March 28, 2020**

Description

A multiple element hydrogen gas module suddenly leaked and caught fire while the transport truck was stopped at a traffic light. The transportable module of carbon fiber wrap reinforced aluminum cylinders was carrying 240 kg of compressed hydrogen gas at 500 bar (7300 psig). No injuries were reported. Authorities eventually directed more than 1400 people to evacuate the area. Firefighters applied cooling water spray until a persistent heat signature diminished; only then were personnel allowed to conduct a controlled vent of the remaining H₂ gas. The damaged module was removed 14 hours after the start of the event. Equipment damage was estimated at 175,000 USD. According to the official US National Transportation Safety Board (NTSB) report, an incorrect pressure relief device (PRD) in cylinder No. 14 actuated during normal conditions to transportation. Force from the high-pressure hydrogen release caused the PRD vent tubing to eject from an improperly secured compression fitting, directing gas into the interior of the module, instead of up and away per design. The H₂ field fire that developed inside of the module impinged on 21 out of 24 adjacent cylinders, causing six additional PRD actuations and vent tube ejections, feeding more gas into the interior fire. Fortunately, despite overwrap burn damage, none of the gas cylinders were breached. It is estimated that about 120 kg of H₂ burned.

Investigators found that, three months prior to the event, four incorrect 402 bar (5833 psi) rated PRDs with H₂ incompatible nickel fusible material were installed during a required 5-year cylinder requalification inspection and pressure test. These incorrect PRDs, similar in appearance to the correct 670 bar (10000 psig) PRDs, were inadvertently co-mingled in the test facility's inventory. Investigators also found that PRD vent tubing compression fittings to seven gas cylinders had not been sufficiently secured when originally manufactured and there were no test facility instructions to verify PRD markings or inspect vent line securement during the cylinder requalification.

The NTSB report makes safety recommendations to improve incident management, requalification inspections, tube trailer PRD systems, hazard recognition and firefighting training materials for hydrogen infrastructure.

Lessons Learned

Implement rigorous double-witness verification, and documentation/markings procedures for hydrogen containing equipment during assembly and maintenance inspections.

Tracking Recent Hydrogen Incidents

- ▶ Electrolyzer (2019)
 - Personnel did not fully understand the interrelation of electrolyzer membrane gas permeability, membrane degradation, and dynamic operating range
- ▶ Hydrogen Vehicle Fueling Station (2019)
 - Assembly error of an end plug for the high-pressure hydrogen tank
- ▶ Hydrogen Transport (2018)
 - Incorrect pressure relief devices installed during maintenance
- ▶ Hydrogen Tanker Loading (2019)
 - Unauthorized repair and failure to follow procedures
- ▶ Hydrogen Bus Fueling Station (2012)
 - Incompatible pressure relief device installed



Courtesy of Gangwon Fire HeadQuarter

Damage from Electrolyzer Incident

Hydrogen Safety Panel (HSP)

THE HSP PROMOTES SAFE OPERATION, HANDLING, AND USE OF HYDROGEN

- ▶ Formed in 2003
- ▶ 16 members with 500+ yrs combined experience
- ▶ Hydrogen safety reviews – hydrogen fueling, auxiliary power, backup power, CHP, portable power, and lab R&D
- ▶ White papers, reports, and guides
- ▶ Provides support on the application of hydrogen codes and standards
- ▶ H₂ safety knowledge shared through the H₂ Tools Portal (h2tools.org)

17 Years

535 Reviews

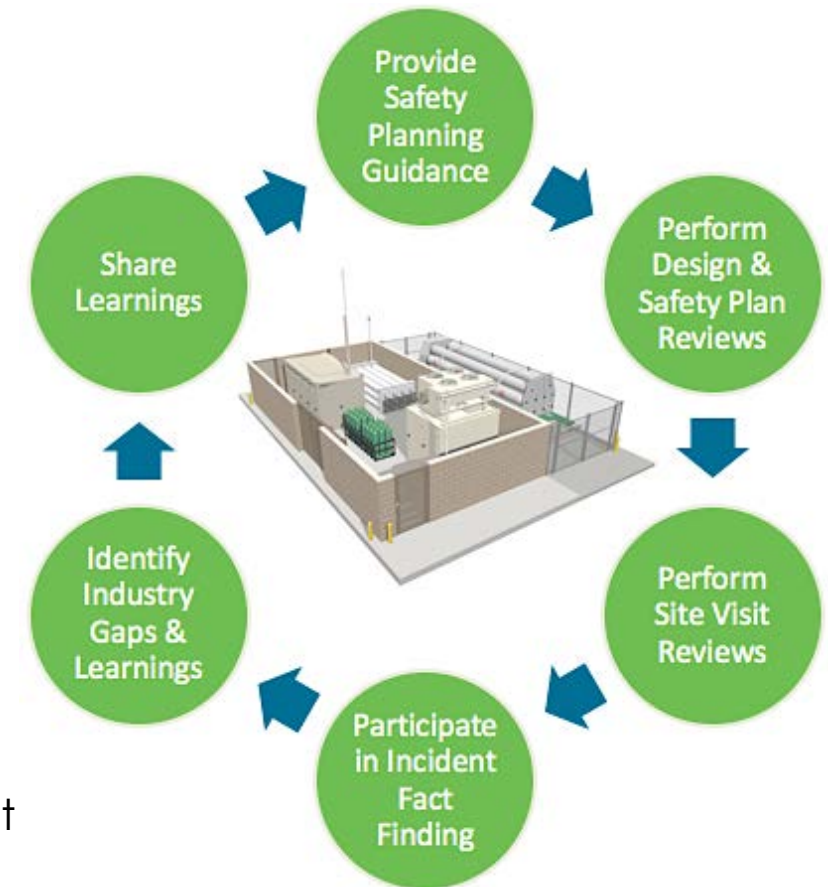
369 Projects

100+ Presentations

12 Guides

Impact of the HSP

- ▶ Serves as a non-regulatory, objective, and neutral resource
- ▶ Sees the “big picture”
 - Shares learnings
 - Identifies gaps
- ▶ Can help reduce costs
 - Over-engineering resulting in unnecessary features
 - Delayed approvals
 - Missed safety considerations/features
- ▶ A group with diverse experience can:
 - Respond with a balanced solution to questions, problems, and issues
 - Aid in avoiding repeating costly mistakes among disparate project proponents
 - Help project proponents avoid industry-impacting incidents
 - Help establish stakeholder and public confidence



Hydrogen Safety Panel Activities



AIChE* has partnered with PNNL to establish a Center for Hydrogen Safety (CHS). CHS will expand the HSP's access to new customers by:

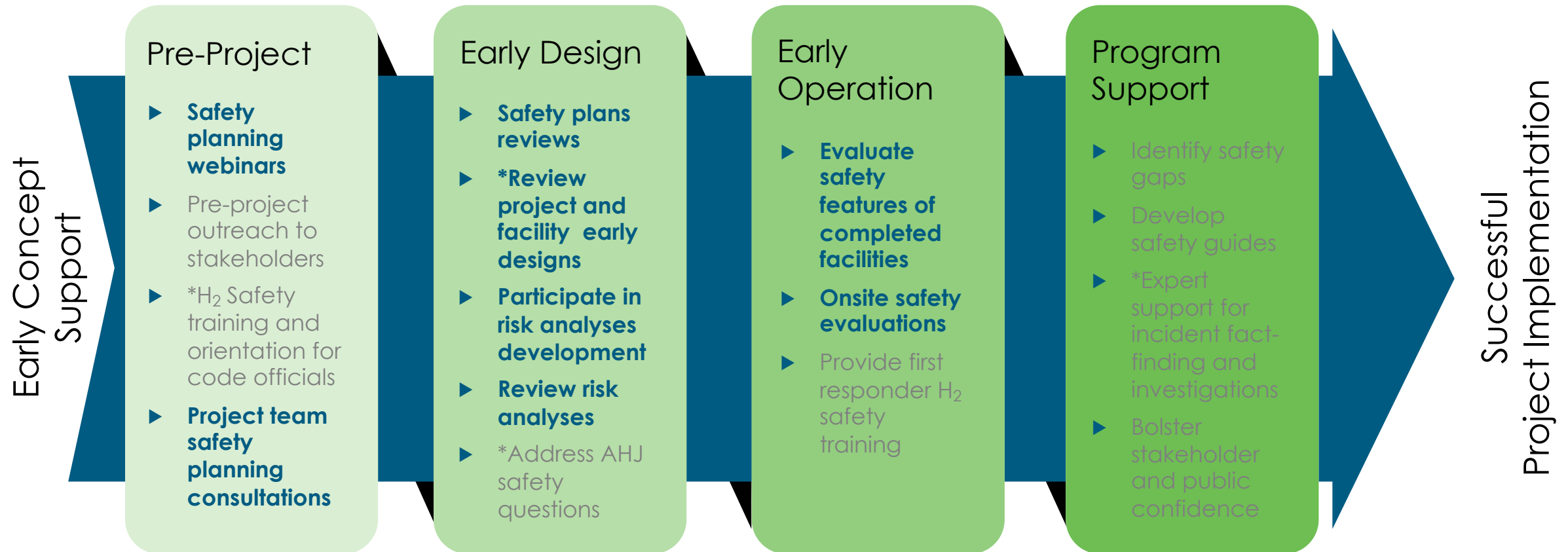
- ▶ Making the HSP more readily available to industry, state, and federal government agencies (national and international)
- ▶ **Enabling less cumbersome/time-consuming contracting efforts (from 3-6 months to 1-2 weeks)**

PNNL is transferring its first responder hydrogen safety training resources to AIChE to enable broader access to online and in-person training resources

* AIChE is the world's leading organization for chemical engineering professionals, with more than 60,000 members from more than 110 countries. AIChE has the breadth of resources and expertise to support industries or emerging areas, such as hydrogen and fuel cell technologies.

Support for the Safe Implementation of H₂ Technologies

Activities that can significantly benefit from CHS Project/Facility Support



* Support for AHJ and code officials can bridge the gap for inexperienced staff, facilitate faster approvals, support a greater confidence in project safety and provide more technically justified safety features

Networking

Incident Response Meetings

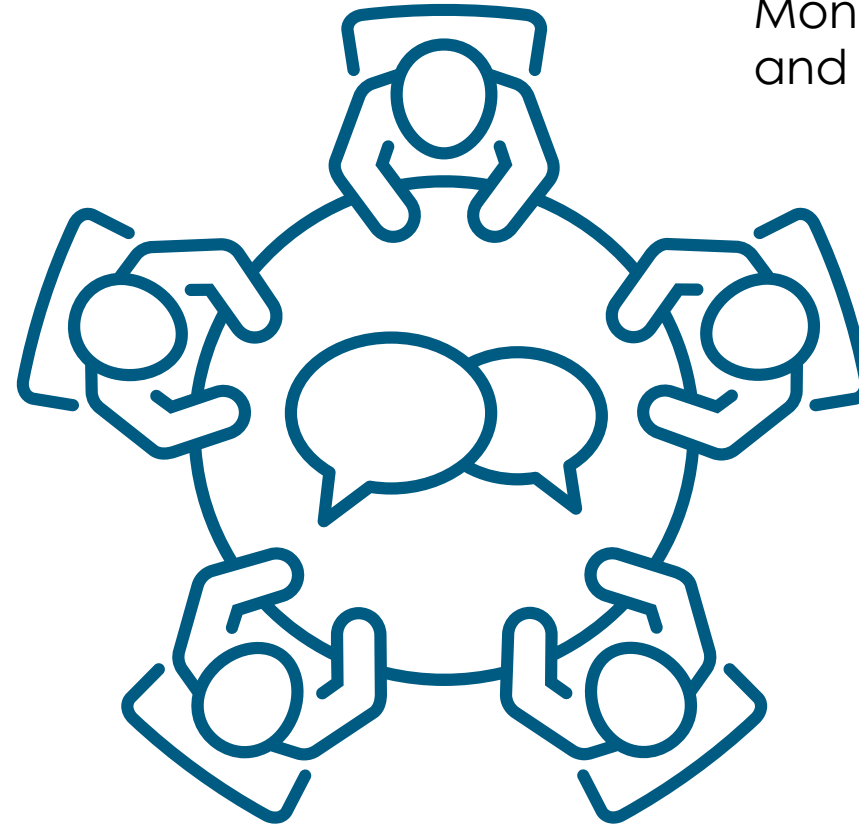
Members share thoughts and ask questions related to incidents

Conferences

Venues to share learnings, see what others are working on, and create connections

Member Meetings

Monthly forum to update members and get collective feedback



Working Groups

Small groups facilitate discussions around domain-specific topics

Webinars

Engage members on relevant and important topics

CHS Member Feedback

- ▶ Member feedback is a driver for CHS activities and developing our safety community
- ▶ Feedback collected during member onboarding is posted on CHS website
- ▶ Feedback has directly led to:
 - New educational resources
 - Focused member meeting discussions
 - Working groups
 - Additional member benefits
 - Member participation in development of safety resources

	Feedback	CHS Response	Status
1	Provide more training in Spanish for first responders.	Send the National Training Template to member to translate materials	In Progress
2	Conference presentations should be made available for all members.	CHS will soon launch member-only resources and this will be included	Complete
3	Member is currently working on introducing hydrogen gas to existing natural gas system	Form working group around topic of H ₂ and NG pipelines	Complete
4	Member identified need for a training course specific to Engineers and Operators	AIChE will consider this further as we apply for funding for the H2@Scale Training opportunity	Complete
5	CHS should develop a white paper on cryogenic hydrogen material data and testing	CHS will consider this request and work with the requestor to get more information	In Progress
6	Member suggested a list of hydrogen applications beyond transportation	CHS will consider the value of creating an infographic	In progress

Hydrogen Safety Conferences

October 2019

Sacramento, CA – 75 attendees

September 2020:

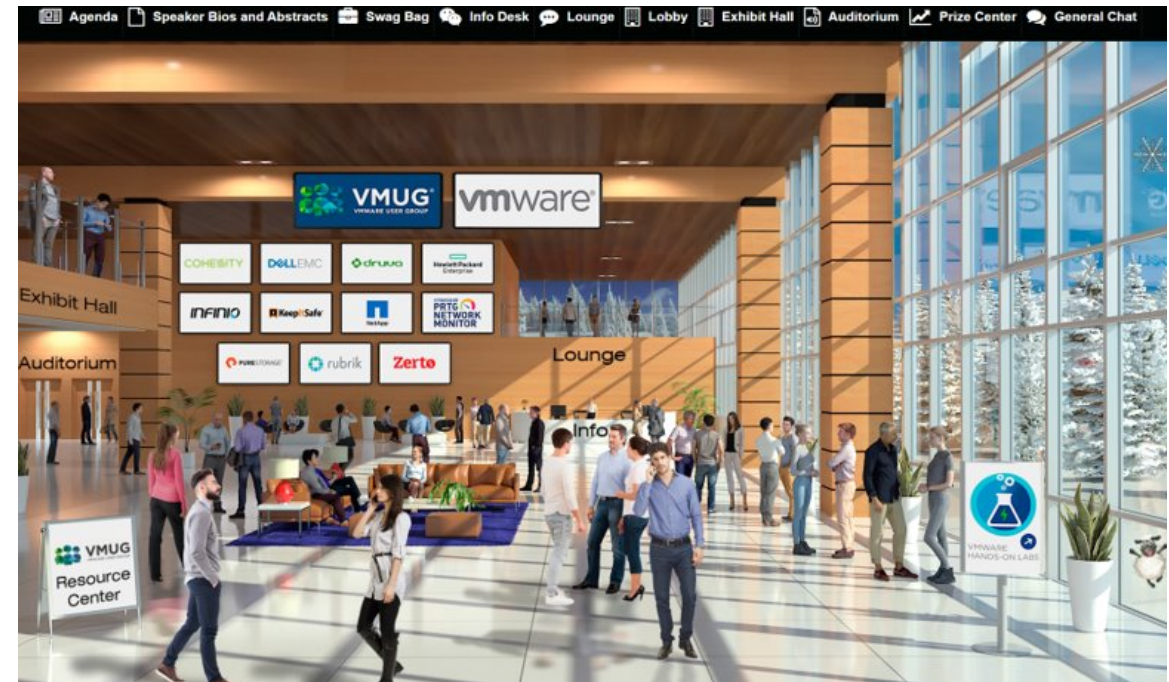
US Virtual Conference

October 2020:

Europe Virtual Conference

Late 2020

South Korea – TBD



Virtual Events:

The best of both online content and in-person events

In-Person Event

Virtual Event

Cost	High + travel + hotel	Low
Access	Regional and Limited global due to travel cost	Global
Networking	Face-to-face, limited by time and place	A/V/text chat throughout conference; easily find all attendees in one place
Presentations	Live quality subject to preparation and AV quality; short live audience engagement	Pre-record content + live Q&A for best quality; chat engagement with live audience; content available following presentation
Proceedings	Only abstracts available	All content available (including video)
Grants	Support few participants	Support up to 5x more participants

Membership Levels



Government (\$25K USD/per year)



Industry (\$15K USD/per year)



Small Business/Startups (\$5K USD/per year)



National Laboratory (\$5K USD/per year)



University (\$2K USD/per year)



Executive Board (\$50K USD/per year)

For more info: www.aiche.org/chs

Impact of Membership

- ▶ Demonstrate that safety is a fundamental principal for those deploying the technology
- ▶ Ensure that neutral and trustworthy hydrogen safety resources will be sustained and have global impact
- ▶ Ensure safety is not a significant impediment to stakeholder and public acceptance of hydrogen technologies

CHS will facilitate a safe and timely transition to hydrogen and fuel cell technologies, contribute to stakeholder and public acceptance of hydrogen technology, and help assure the safe operation of hydrogen facilities



CHS Membership

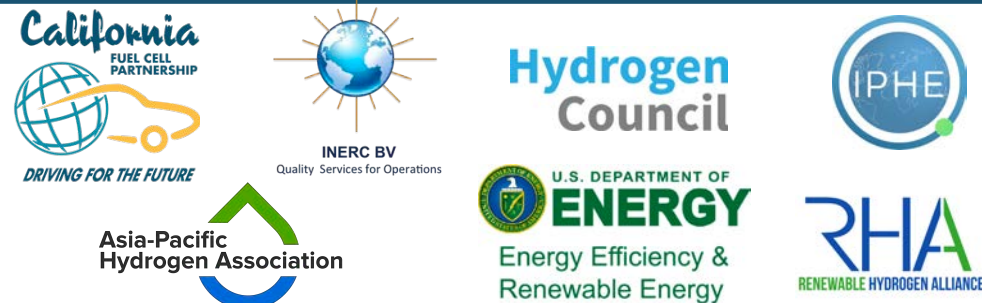
EXECUTIVE BOARD



GOVERNMENTS



STRATEGIC PARTNERS



INDUSTRY



SMALL BUSINESSES



UNIVERSITIES



NATIONAL LABS



Join Our Global Community and Get Involved



- ▶ Become a member



- ▶ Utilize the resources to remove barriers and safeguard your mission



- ▶ Participate in working groups, workshops and conferences
 - Network
 - Share knowledge
 - Help plan conferences and other events



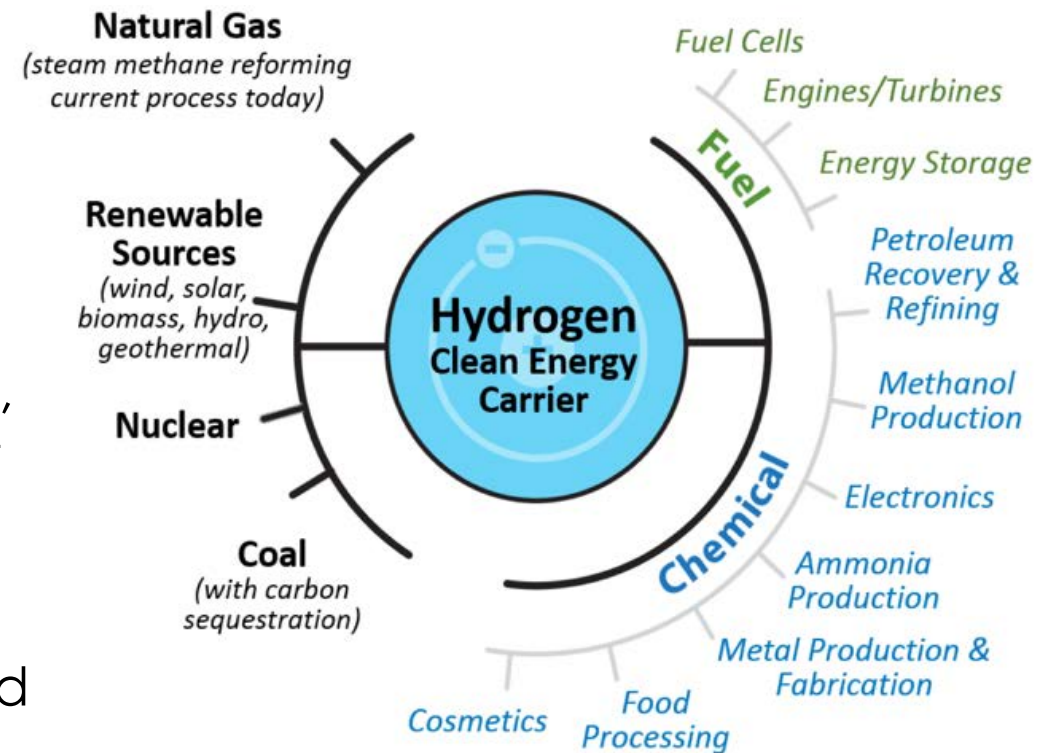
Recent member comments:

“The timely incident response call after a recent incident was a huge benefit to our company and employees who had questions about the incident. Industry incident communications are crucial to prevent accidents from happening again.”

“The Hydrogen Safety for First Responders training is incredibly useful for our organization when we hold safety trainings with local First Responders.”

Concluding Thoughts

- ▶ The future will likely see an increase in the use of hydrogen and fuel cell technologies
- ▶ Because hydrogen as a fuel is still relatively new, best methods of handling, storage, transport, and use may not be well understood by participants
- ▶ Safe practices for production, storage, distribution, and use of hydrogen are essential for deployment of hydrogen and fuel cell technologies
- ▶ The Center for Hydrogen Safety and its resources are available to users and stakeholders understand and apply safe practices





The #H2IQ Hour Q&A

Please type your questions into the **Q&A Box**

Q&A ×

All (0)

Select a question and then type your answer here, There's a 256-character limit.

Send Send Privately...

INCREASE YOUR

H₂IQ

The #H2IQ Hour

Thank you for your participation!

Learn more:

energy.gov/fuelcells
hydrogen.energy.gov