



# Lessons Learned: U.S. Department of Energy Hydrogen Codes and Standards Program

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# Goal of the Safety Codes and Standards Subprogram

To develop and implement the practices and procedures that will ensure safety in the operation, handling, and use of hydrogen and hydrogen systems for all DOE funded projects; to ***perform underlying research to enable codes and standards to be developed for the safe use of hydrogen in all applications; and to facilitate the development and harmonization of domestic and international codes and standards.***

**Codes and standards development is a lengthy and ongoing process: a process that does not easily respond to the urgency of our energy issues.**



# Hydrogen Codes and Standards Program

- Program focuses on data required by the codes and standards process
- Facilitates communication
- Partially funds administrative costs of the SDO/CDO consensus process

- Significant progress has been made in the development of codes and standards through leveraging of limited resources

- 9 active US Codes and Standards Organizations working on hydrogen
- 22 C&S published, 10 of which are under revision
- 28 draft C&S under preparation/review
- 4 International C&S published, 13 under preparation/review
- See [www.fuelcellstandards.com](http://www.fuelcellstandards.com)



# Federal Role

Because of the large number of interested parties in Codes and Standards activities – parties which represent competitive entities and which are both national and international – the Federal government is uniquely positioned to facilitate progress towards harmonized Codes & Standards and improved safety

- Lead Research
- Coordinate international participation
- Facilitate working relationships among cooperative and competing industries
- Publish and disseminate results
- Collaborate with multiple government agencies including Federal, State, and Local governments
- Educate codes and standards officials, first responders, and policy makers – in cooperation with DOE Hydrogen Education activity
- Critical DOT roles in hydrogen pipelines, vehicle safety, and international regulations



# Facilitating Codes and Standards Development is a Communications Issue





# “National Templates” for Hydrogen Codes and Standards

**National Template for Hydrogen Generators and Stationary and Portable Fuel Cells**

**Controlling Authority:**  
 OSHA, Emissions – EPA,  
 Pipeline: Office of Pipeline Safety  
 State, Local Government  
 Zoning, Building Permits

**Electrolyzers:** UL, CSA,  
**Reformers:** UL, CSA, API  
**Performance Test Procedures:** ASME, CSA  
**Chemical Hydrides:** UL, CSA, NFPA

**Hydrogen Generator**

Leads will change depending on type of environment.

**Installation Piping:** ASME, CSA, CGA, NFPA, ICC  
**Storage:** ASME, CGA, CSA, API, NFPA  
**Compressors Safety Certification:** CSA, UL  
**Compressor Design, Performance & Safety:** API,  
**Sensors/Detectors:** UL, CSA, NFPA  
**Fuel specifications:** CGA, SAE  
**Weights/Measures:** NIST, API, NCWM  
**Dispensers:** CSA, UL, NFPA, SAE  
**Non-vehicle Dispensing:** CGA, SAE  
**Codes for the Built Environment:** ICC, NFPA, CGA  
**Interconnection:** IEEE, UL, NFPA

**Interface**

**Controlling Authority:** CPSC, DOT (Methanol),  
 State, Local Govt. (Zoning, Building Permits)

**Handheld Systems:** UL, CSA  
**Portable Systems:** CSA, UL, CGA, SAE  
**Handheld Fuel Containers:** CSA, UL, CGA, SAE  
**Portable Fuel Containers:** CGA, SAE, UL, CSA  
**H2 Fuel Specifications:** CGA, SAE, UL, CSA  
**Performance Test Procedures:** ASME, SAE



## National Template for Vehicle Systems

### Vehicles

**Controlling Authority:**  
 NHTSA (Crashworthiness),  
 EPA (Emissions)

**Fuel Cell Vehicle Systems:** SAE  
**Fuel Delivery Systems:** SAE,  
**Containers:** SAE  
**Reformers:** SAE  
**Emissions:** SAE  
**Recycling:** SAE  
**Service/Repair:** SAE

### Interface

**Fuel Specs:** SAE  
 ASTM, API  
**Wts/Measures:** NIST,  
 API, ASME  
**Fueling/Defueling:** SAE  
**Sensors/Detectors:** UL,  
 NFPA, SAE, CSA  
**Connectors:** SAE, API,  
 CSA  
**Communications:** SAE  
 UL, CSA, API, IEEE

### Fuel Delivery, Storage

**Controlling Authority:**  
 RSPA (Over-road Transport,  
 Pipeline Safety)

**Composite Containers:** ASME  
 CSA, CGA, NFPA  
**Pipelines:** ASME, API, CGA, AGA  
**Equipment:** ASME, API, CGA,  
 AGA  
**Fuel Transfer:** NFPA, API

### Fueling, Service

**Controlling Authority:** State, Local Govt.  
 Zoning, Building Permits

**Storage Tanks:** ASME, CSA, CGA, NFPA,  
 API  
**Piping:** ASME, CSA, CGA, NFPA  
**Dispensers:** CSA, UL, NFPA,  
**On-site H2 Production:** CSA, UL, CGA, API  
**Codes for the Built Environment:** ICC, NFPA

### Parking Facility

Lead SDO underlined



# National Hydrogen and Fuel Cells Codes & Standards Coordinating Committee

**Mission:** Working collaboratively to support and facilitate development of needed new hydrogen and fuel cell codes and standards and/or facilitate incorporation of safety requirements into existing codes and standards

**Includes representatives from:**

- SDOs and CDOs
- Hydrogen and energy industry
- Fuel cell industry
- OEMs producing products that use hydrogen and/or fuel cells
- National laboratories (NREL)
- Federal and state agencies (DOE, DOT, NIST)
- Other interested stakeholders (e.g., California Fuel Cell Partnership, etc.)



**For more Information:  
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# Other Collaboration

## Critical to Success



- **FreedomCAR and Fuel Partnership Codes and Standards Tech Team**
- **HIPOC (ICC/NFPA harmonization)**
- **International:**
  - Sharing of data
  - Sharing of Lessons Learned
  - Harmonization of Codes and Standards
- **Hydrogen Quality R&D**



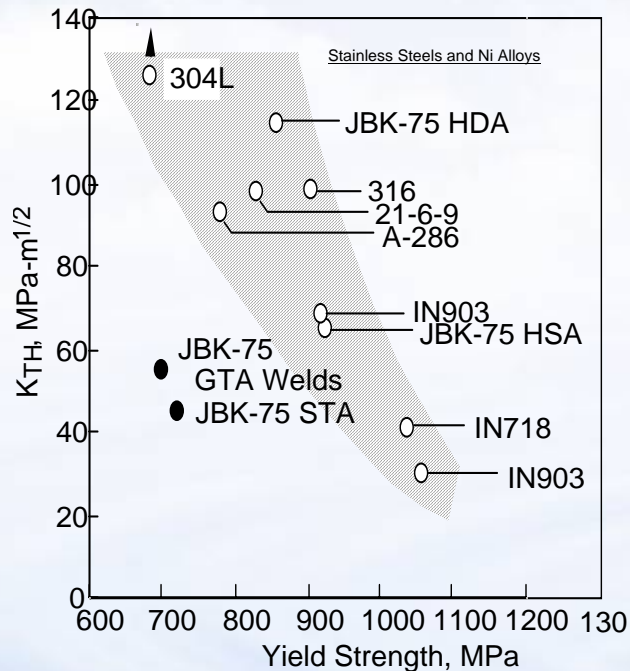


# V1.0 of *Technical Reference for H<sub>2</sub> Compatibility of Materials* Complete

<http://www.ca.sandia.gov/matsTechRef/>

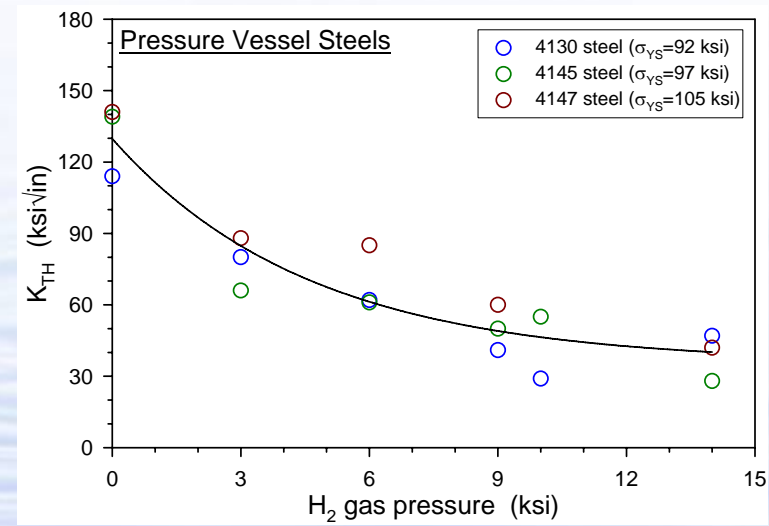


## Effect of Strength on Cracking in H<sub>2</sub>



- Increased material strength lowers threshold for H<sub>2</sub>-assisted crack growth

## Effect of Pressure on Cracking in H<sub>2</sub>

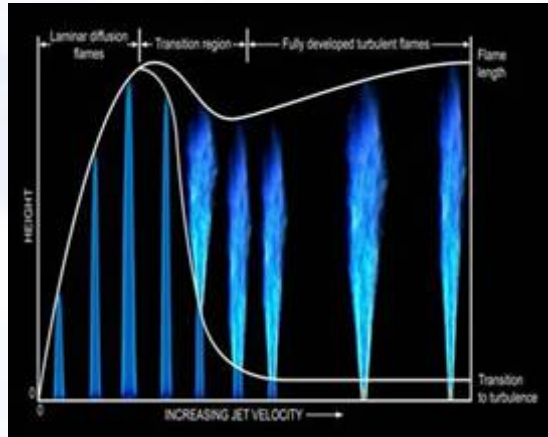


- Increased H<sub>2</sub> gas pressure lowers threshold for H<sub>2</sub>-assisted crack growth

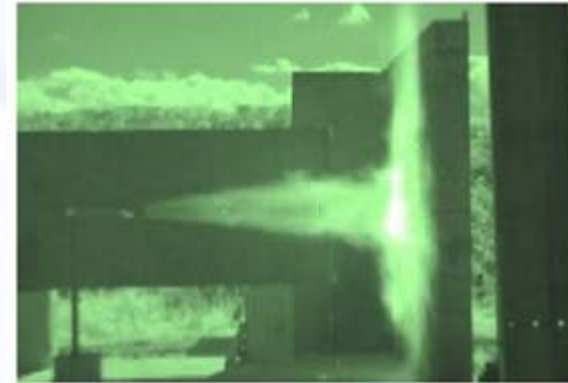


# Data Published: Hydrogen Combustion and Release Scenarios

## Flame Characterization



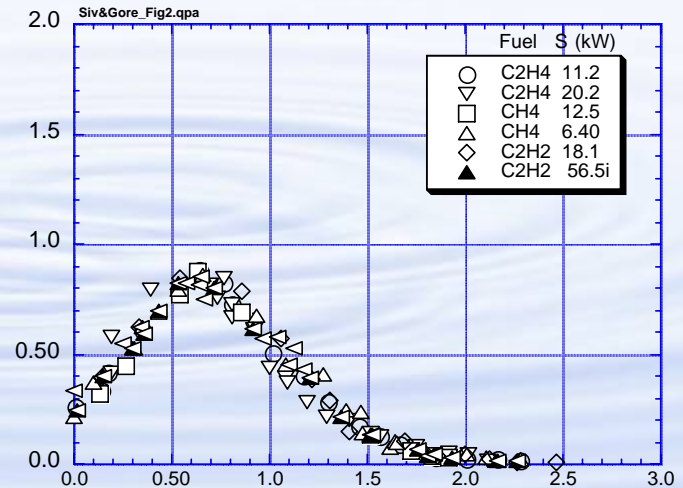
## Experimentally Measure Heat Flux



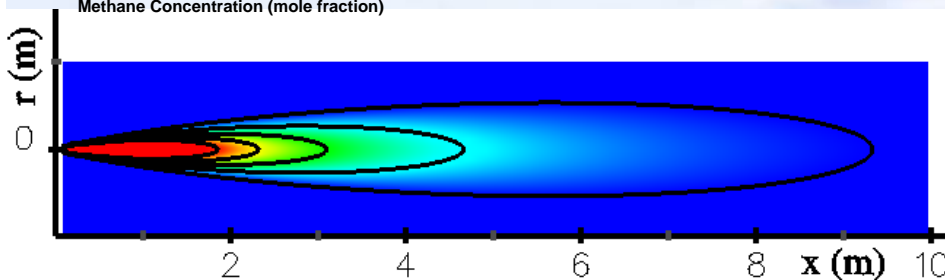
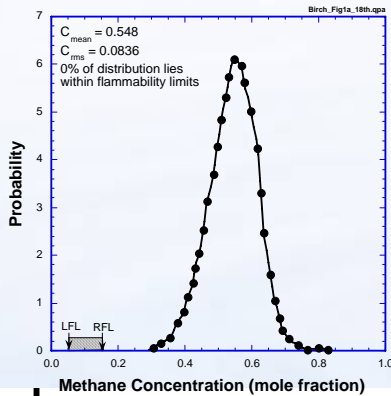
Impinging jet, 10 ft impingement diameter

## Thermal Radiation Models

$$C^*(x/L) = 4 \pi R^2 q_{rad}(x/L) / S_{rad}$$



## Flammability Limits & Ignition Probabilities





# Safety Program Highlights – Web Resources

- **H2 Incidents Database**
  - Information on hydrogen incidents and lessons learned
  - 103 incidents documented as of February 2007
  - [www.h2incidents.org](http://www.h2incidents.org)

**H2Incidents**  
Hydrogen Incident Reporting Tool

About H2Incidents | Search

### Incident Report

Equipment: Introduction of Stainless Steel Spatula Elicits Flame

Factors:

Funding Source:

11 January 2005

NO FUNDING SOURCES DEFINED

Severity: **Incident**

Was Hydrogen released? **No**

Was there Ignition? **Yes**

No Ignition Source Defined.

Description:

During preparation of a new hydrogen storage material, ammonia borane (AB) loaded onto mesoporous carbon, an unexpected incident was observed. As with all procedures with new materials the work is conducted on a small scale and in a laboratory fume hood. They followed the procedure that they had used for absorption of ammonia borane onto mesoporous silica without incident. To absorb the solid AB onto a scaffold material they dissolve AB in a glycerol/water solvent. The saturated solution of AB in

- **Bibliographic Database**
  - Contains approximately 400 publications related to hydrogen safety
  - [www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)

U.S. DEPARTMENT OF ENERGY

Hydrogen Program

hydrogen.energy.gov

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SEARCH

Home » Safety » Bibliography Database

### Hydrogen Safety Bibliographic Database

The [Hydrogen Safety Bibliographic Database](#) provides references to reports, articles, books, and other resources for information on hydrogen safety as it relates to production, storage, distribution, and use. The database includes references related to the following topics:

- Hydrogen properties and behavior



# Related Education Activities: First Responders

- **Introduction to Hydrogen Safety for First Responders**
  - 7-module, web-based basics course (includes quiz and video, animations, graphics for visual audience)
  - Print and CD versions available for free from DOE Information Center
  - Development included broad review involving hydrogen industry and emergency response community
  - Averaged 240-250 unique users/week since course launch in Jan 2007
  - Positive feedback from emergency response community – users include fire fighters, fire department training coordinators, fire marshals, fire plans inspectors/examiners, law enforcement personnel, industry, military, others



[www.hydrogen.energy.gov/firstresponders](http://www.hydrogen.energy.gov/firstresponders)



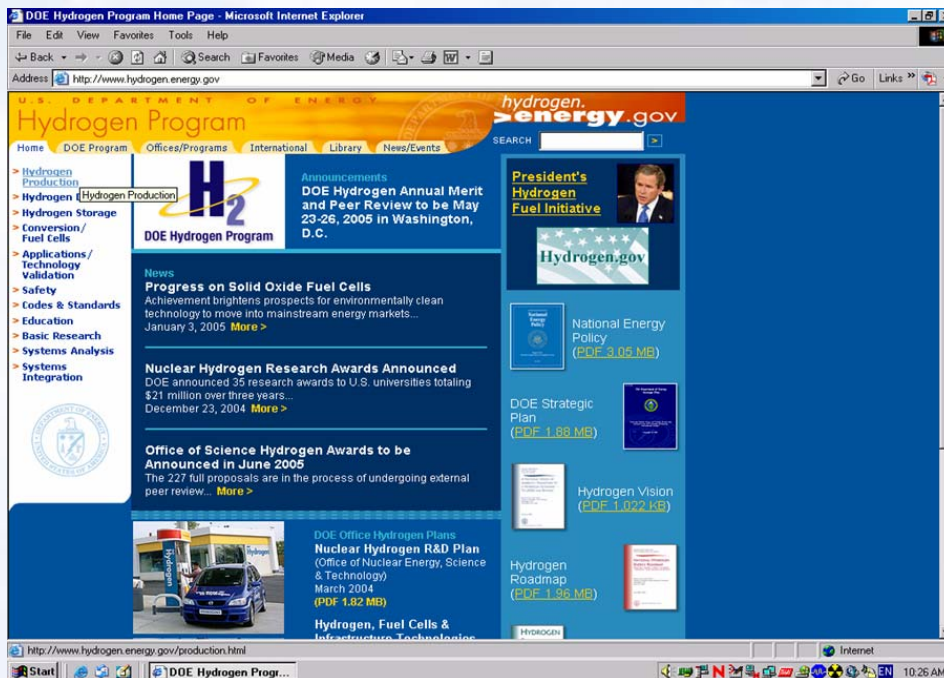
A "Cliffs Notes" poster is available for fire houses, free from the DOE Information Center



# For More Information

Website:  
[www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)

# Annual Progress Report



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