



DOE Hydrogen Program

# Hydrogen Safety: First Responder Education

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Project ID:  
ED-3

Pacific Northwest  
National Laboratory  
Operated by Battelle for the  
U.S. Department of Energy

# Overview

## Timeline

- ▶ Project start date: 10/2004\*
- ▶ On-going
- ▶ Percent complete, FY07: ~40%

## Budget

- ▶ Funding in FY06: \$325K
- ▶ Funding in FY07: \$450K

(100% DOE funded)

\* Pre-FY06 funding came from another part of the Safety, Codes and Standards program element.

## Barriers Addressed

- ▶ Lack of Readily Available, Objective, and Technically Accurate Information
- ▶ Disconnect Between Hydrogen Information and Dissemination Networks
- ▶ Lack of Educated Trainers and Training Opportunities

## Partners

- ▶ PNNL is working with the Volpentest Hazardous Materials Management and Emergency Response (HAMMER) Training and Education Center on education and outreach



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# Objectives

## ▶ **Long-term Objective:**

Support the successful implementation of hydrogen and fuel cell demonstration projects and market transformation by providing technically-accurate and objective information about hydrogen to first responders\*

## ▶ **Objective for FY07:**

Develop and disseminate education materials that pertain to hydrogen safety, aimed at the first-responder\* audience

\*Focus is on first responders (fire, law enforcement, and emergency medical personnel), who must know how to handle potential incidents; their understanding can also facilitate local project approval

# Approach in FY07

## ▶ Task 1: Awareness-level Course (100% complete)

Complete (and maintain) a stand-alone, interactive, web-based “awareness-level” course -- “Introduction to Hydrogen Safety for First Responders”

(This also creates an information set that others can draw from to supplement their ongoing or planned education programs involved in the use of hydrogen and fuel cells)

## ▶ Task 2: Awareness-level Outreach (60% complete)

Conduct outreach activities related to the “Introduction to Hydrogen Safety for First-Responders” course, and disseminate related materials

## ▶ Task 3: Prop-based Course (5% complete)

Begin development of more-advanced course modules based on use of a mobile hydrogen fuel cell vehicle prop (under development in a companion project funded under the Hydrogen Safety, Codes and Standards program element)

# Pre-FY07 Accomplishments: Awareness-level Course

- ▶ First responder outreach/interviews
- ▶ Internal DOE technical review
- ▶ Hydrogen Safety Panel review
- ▶ Pilot tests of course – given in person at HAMMER
  - August 2005 – industry experts, some first responders
  - April 2006 – first responders at Washington State Hazardous Materials Workshop Conference



August 2005 pilot



April 2006 pilot

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# Pre-FY07 Accomplishments: Awareness-level Course (cont'd)

Broad review of on-line course (Summer 2006) included more than 100 representatives from the hydrogen and emergency-response communities

- ✓ Auto companies
- ✓ Energy companies
- ✓ Fuel cell companies
- ✓ FreedomCAR and Fuel Partnership C&S Tech Team
- ✓ National C&S Coordinating Committee
- ✓ Hydrogen/fuel cell trade associations – NHA/USFCC
- ✓ National Laboratories
- ✓ Other Federal agencies – DOT, DHS/USFA
- ✓ Hydrogen-related state organizations/entities – CAFCP, NextEnergy
- ✓ International partners – IPHE, HySafe, JARI, EC
- ✓ Fire protection/prevention membership associations – IAFF, NASFM
- ✓ Individual firefighters and law enforcement personnel and other emergency response experts – Extrication.com
- ✓ College fire science programs
- ✓ Alternative fuel experts
- ✓ Others (universities/nonprofits) involved in education, graphics design

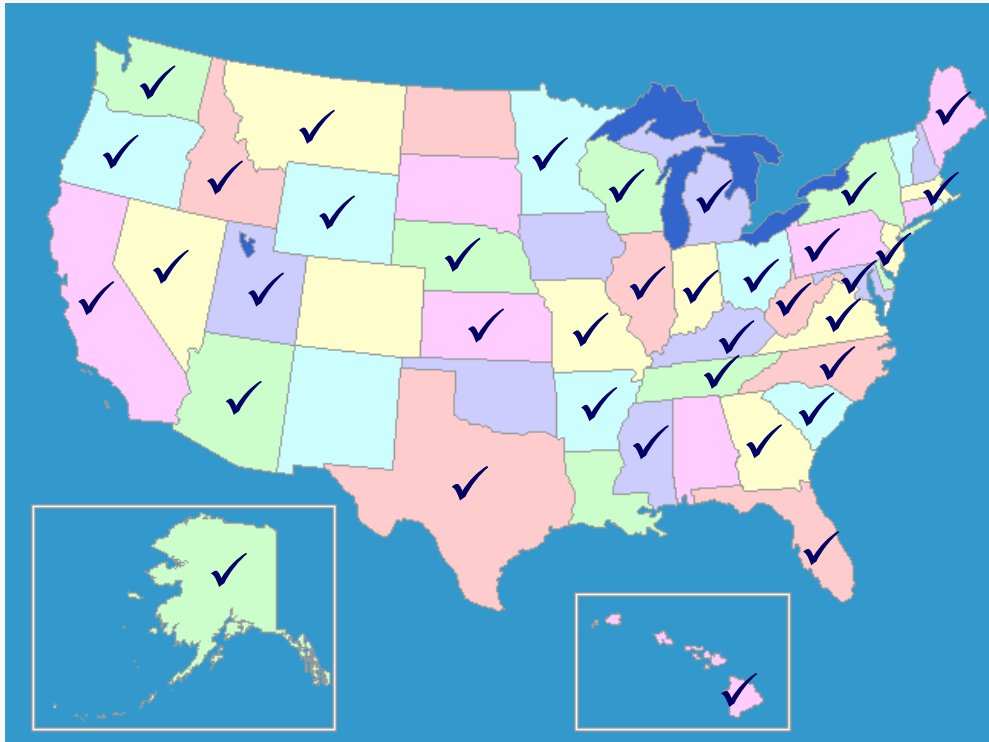
# FY07 Accomplishments:

## Task 1 – Awareness-level Course

- ▶ Final version of web-based course (in both Flash and accessible HTML), incorporating comments received, launched on January 24, 2007
  - <http://hydrogen.energy.gov/firstresponders.html>
- ▶ Announcement of course distributed to:
  - Broad review list
  - State firefighter training centers
  - International Association of Fire Fighters
  - International Association of Fire Chiefs
  - Federal Law Enforcement Training Center

# Awareness-level Course: Usage and Feedback

The first 11 weeks (Jan 24 – Apr 10) averaged  
~240 unique visitors/course reviewers per week



Also UK, Japan, Taiwan, Canada,  
Sweden, Korea

## *Who's Taking the Course?*

- ✓ Fire prevention/protection community
  - Firefighters
  - Fire department education coordinators
  - Fire marshals
  - Fire plans examiners/inspectors
- ✓ Law enforcement
- ✓ Industry
- ✓ Universities
- ✓ Military
- ✓ Non-profits



# A Sample of Comments Received

*Very informative, we all need to see this.*

Lt. Gary Brown  
Fort Worth Fire Dispatch Office

*Good online class!*

George J. Fielden Jr., CFI  
Deputy Fire Marshal  
King of Prussia, PA

*Good information.  
Quick study. Thanks!*

Charles J. Gluck  
Battalion Chief  
Watsonville, CA  
Fire Station #1

*Great course.*

Captain David L. Coble  
In Service Coordinator  
Fire Educational Services  
Fort Worth Fire Dep't

*Did this course during my lunch hour and really enjoyed it. Nice slides and well written instructions. Thank you for a pleasant learning experience.*

Susan Wulf  
Firefighter  
South Frontenac Fire Department

*Very informative presentation.*

Jim Sills  
Planning, Building Inspection, and Code Enforcement Dep't  
Florence, South Carolina

# Course Overview


Address <http://www.ehammertraining.us/energy/hydrogen/controller.cfm> Go Links >>

## Introduction to Hydrogen Safety for First Responders

U.S. Department of Energy  
Hydrogen Program  
[www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)

COURSE MATERIALS LIBRARY EXIT ▶

Hydrogen Basics  Transport & Storage  Hydrogen Vehicles  Hydrogen Dispensing  Stationary Facilities  Codes & Standards  Emergency Response  Summary



The Course Materials cover the following topics:

- Hydrogen Basics
- Transport & Storage
- Hydrogen Vehicles
- Hydrogen Dispensing
- Stationary Facilities
- Codes & Standards
- Emergency Response

You can view the topic modules in sequence or select them in random order using the top navigation bar.

A short quiz follows at the end of the course. User responses will be collected but will not be attributed to you as an individual.

Begin the Course ▶

Done Internet

# Example Course Module: Hydrogen Basics

Introduction to Hydrogen Safety for First Responders

COURSE MATERIALS LIBRARY EXIT ▶

Hydrogen Basics Transport & Storage Hydrogen Vehicles Hydrogen Dispensing Stationary Facilities Codes & Standards Emergency Response Summary

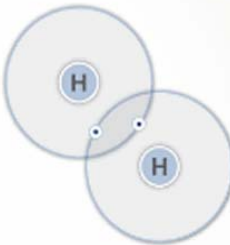
**INCREASE YOUR H<sub>2</sub>IQ**  
www.hydrogen.energy.gov

Like gasoline or natural gas, hydrogen is a fuel that must be handled properly; it can be used as safely as other common fuels when simple guidelines are observed.

Hydrogen is colorless, odorless, and tasteless. It's non-toxic and non-poisonous; it's non-corrosive, but can

### Hydrogen Properties and Behaviors

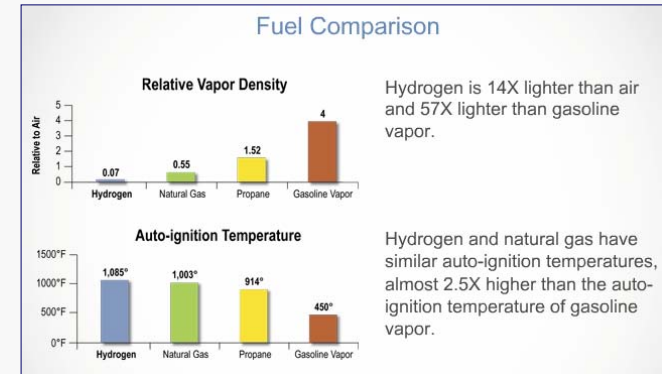
- Colorless, odorless, tasteless, non-toxic, non-corrosive and non-poisonous
- Lightest and smallest element
- A gas at ambient conditions
- Fourteen times lighter than air, it rises and disperses rapidly
- Exists as a liquid at -423°F (-253°C)
- Volume ratio of liquid to gas is 1:848



Molecular Hydrogen

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### Designing Safe Systems - Gaseous Hydrogen

Characteristic	Potential Hazard	Control
• Colorless, odorless, tasteless	• Impossible for human senses to detect	• Detection sensors
• Low viscosity • Very small atom (can be absorbed into materials)	• Leaks • Embrittles certain materials; can result in structural failure	• Leak detection systems • Ventilation • Material selection
• Low volumetric energy density	• Stored at high pressures	• Storage container design • Pressure relief devices

- ✓ Basic properties
- ✓ Comparisons with other fuels
- ✓ Industry designs for safe systems

# Example Course Module: Hydrogen Dispensing

Introduction to Hydrogen Safety for First Responders

U.S. Department of Energy  
Hydrogen Program  
[www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)

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Hydrogen Basics  Transport & Storage  Hydrogen Vehicles  Hydrogen Dispensing  Stationary Facilities  Codes & Standards  Emergency Response  Summary

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**H<sub>2</sub>IQ**  
[www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)

You can learn more about hydrogen vehicle refueling by viewing the following video.

A. Paul: Steve, will you show us how to refuel this car?

S. Mathison: Sure! It's actually quite

Hydrogen Dispensing



Video: Hydrogen 2000, Hydrogen, The Safe and Clean Fuel

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- ✓ Refueling demonstration (video)
- ✓ Comparison to refueling with other fuels

# Example Course Module: Stationary Facilities

Introduction to Hydrogen Safety for First Responders

U.S. Department of Energy  
Hydrogen Program  
www.hydrogen.energy.gov

COURSE MATERIALS LIBRARY EXIT ▶

Hydrogen Basics Transport & Storage Hydrogen Vehicles Hydrogen Dispensing Stationary Facilities Codes & Standards Emergency Response Summary

**Common Stationary Facility Safety Systems**

- Pressure relief devices - rupture disks, pressure relief valves, and safety vents
- Leak detection, flame detection
- Design elements -
  - Siting to established codes
  - Engineering safety margins and analysis
  - Use of hydrogen-compatible materials
- Monitoring, controlled access, and emergency stops

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www.hydrogen.energy.gov

In general, stationary facilities are equipped with pressure relief devices including rupture disks, pressure relief valves, and safety vents. Vent stacks are standard for liquid hydrogen storage systems. Excess gaseous hydrogen (created from boil-off of liquid to gas) is routinely vented, a practice commonly

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- ✓ Overview of bulk storage, stationary fuel cells, refueling stations
- ✓ Common safety systems

## Bulk Storage

- Includes both liquid and gaseous hydrogen storage in cylinders, tubes, and tanks
- Typically located at –
  - Refineries or other hydrogen production sites
  - Fueling facilities
  - Some stationary fuel cell installations
  - Research and development, testing, and manufacturing facilities
- Can be above ground (including on the canopy at a fueling station) and below ground



Photo: NREL  
Liquid hydrogen is stored at Santa Clara Valley Transit Authority (CA), which operates fuel cell buses

## Stationary Fuel Cells

- Generate electricity (and heat)
  - Uninterruptible power supply
  - Backup power
  - Power for remote locations
- Some direct-hydrogen units use on-site hydrogen storage
- Others (primarily larger units, >10kW) use natural gas or other fuel and an internal reformer



Photo: Plug Power, Inc.

Fuel cell (left) and hydrogen storage (right) near Albany International Airport



Photo: NYSERDA

Fuel cells at a municipal wastewater treatment plant in New York City, NY

## Hydrogen Fueling Stations

- Typically combine bulk storage with refueling dispenser(s)
- May be designed to fuel cars, buses/large trucks, or forklifts with gaseous hydrogen, liquid hydrogen, or both
- Can be on private or industrial property, or in consumer retail settings, such as multi-fuel stations that provide gasoline and other fuels



Photo: NREL

This station owned by the Alameda-Contra Costa Transit District (CA) serves cars and buses



Photo: Shell Hydrogen

Washington, DC Shell fueling station (gasoline, diesel, hydrogen)

# Example Course Module: Emergency Response

## Introduction to Hydrogen Safety for First Responders



COURSE MATERIALS

LIBRARY

EXIT ▶

Hydrogen Basics  Transport & Storage  Hydrogen Vehicles  Hydrogen Dispensing  Stationary Facilities  Codes & Standards  Emergency Response  Summary

### Initial Protective Actions

- Keep unauthorized personnel away
- Stay upwind
- Listen for venting gas, watch for thermal waves that would signal hydrogen flames
- Eliminate ignition sources
- Do not touch or walk through product
- Allow hydrogen-fed fire to burn, if safe to do so; protect adjacent exposures – do not spray water into the pressure vent

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**H<sub>2</sub>IQ**  
www.hydrogen.energy.gov

When approaching an incident, keep unauthorized personnel away and stay upwind. Listen for venting gas and watch for thermal waves that could signal hydrogen flames. Use portable flame detectors, if possible.

Eliminate all potential ignition sources,

### Identifying Hydrogen Vehicles

- Blue Diamond
- Society of Automotive Engineers recommended practice for *hydrogen-fueled vehicles*



Photo: CaFCP

### Detecting Hydrogen

- Colorless, odorless, and tasteless so human senses cannot detect gaseous hydrogen
- Listen for high-pressure gas leak (loud hissing sound)
- Use portable hydrogen detectors
- Gas and flame detectors may be installed in storage facilities and fueling stations; listen and watch for audible or visual alarms



### Securing a Fuel Cell Vehicle

- Never cut into hydrogen lines
  - No standard markings, most are silver (stainless steel)
- Do not cut high-voltage cables (typically orange)
  - 200-500 volts
  - 200-300 amps
- Avoid cutting through the floorline



- ✓ Recognition and identification of hydrogen equipment
- ✓ Detection of hydrogen releases, flames
- ✓ Initial protective actions
- ✓ Additional information sources

# Summary & Quiz

Introduction to Hydrogen Safety for First Responders

COURSE MATERIALS LIBRARY EXIT ▶

U.S. Department of Energy  
Hydrogen Program  
www.hydrogen.energy.gov

Hydrogen Basics Transport & Storage Hydrogen Vehicles Hydrogen Dispensing Stationary Facilities Codes & Standards Emergency Response Summary

**Summary**

- Hydrogen has been safely used by industry for many decades; it is no more dangerous than conventional fuels when handled properly
- Leaking gas and burning gas may be difficult to detect
- Once vented, hydrogen rises and disperses very quickly
- Emergency response: Follow standard response protocol and remember -
  - Look for recognizable signage, listen for escaping gas, watch for thermal waves
  - Let a hydrogen fire burn, if safe to do so
  - Never cut through hydrogen lines or high voltage electrical lines
  - For vehicles, avoid cutting through the floorline, as hydrogen lines and high voltage electrical lines and devices are commonly located there

Take the quiz Submit Comment About This Slide

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In summary, although using hydrogen as a consumer fuel is a relatively new concept, industry has used it safely for many decades. It's no more dangerous than conventional fuels when handled properly. Hydrogen is colorless, odorless, and burns with a nearly invisible flame, so leaking or burning gas may be difficult to

Introduction to Hydrogen Safety for First Responders Quiz

1. Hydrogen flames are nearly invisible in daylight.

True  False

The correct answer is TRUE. Hydrogen burns with a pale blue flame that is nearly invisible in daylight; if sodium is present in the air, there may be a slight yellow color to the flame.

Introduction to Hydrogen Safety for First Responders Quiz

3. Hydrogen flames radiate heat comparable to hydrocarbon flames.

True  False

The correct answer is FALSE. Hydrogen flames have low radiant heat, although the flame itself is just as hot.

Introduction to Hydrogen Safety for First Responders Quiz

6. When released in an open environment, hydrogen will pool on the ground.

True  False

The correct answer is FALSE. Hydrogen is 14x lighter than air, so if released in an open environment, it will rise quickly and disperse into a nonflammable concentration.

- ✓ Most important “need-to-know” information in summary
- ✓ 13-question quiz tests knowledge/reinforces learning

# Accomplishments:

## Task 2 – Awareness-level Outreach

- ▶ Outreach plan completed
- ▶ Full version of course on CD and PDF (hard-copy) version available for free from DOE/EERE Information Center
  - 877-EERE-INF/877-337-3463
- ▶ Flyer produced to promote course at conferences, etc.
- ▶ Article submitted to *Firehouse Magazine*
- ▶ Three major first-responder conference events planned to demonstrate the course (Baltimore, Atlanta, and Orlando)
- ▶ “Cliffs Notes” version – laminated poster with critical response information for distribution to firefighters for display in fire stations
- ▶ Web-cast of course (500-1000 viewers at a time) in the planning stage



# Accomplishments:

## Task 3 – Prop-based Course

- ✓ In early stages of development
- ✓ Some materials gathered for use in preparing course
- ✓ Discussions initiated with partners interested in endorsing and conducting the course

### Prop Under Development

- Designed to realistically and safely simulate an actual emergency response event
- Mobile for on-site use (transported by trailer)
- Scenarios will demonstrate:
  - Safe approach to a fuel cell vehicle
  - Extinguishment of a compartment fire
- Will include typical FCV components (e.g. high-pressure H<sub>2</sub> lines)
  - Extrication techniques
  - Hydrogen venting during a compartment fire

# Future Work

- ▶ Continue to address comments and to field questions on the Awareness-level course
- ▶ Complete planned outreach activities for Awareness-level course (publications, conferences, webcast)
- ▶ Complete planning and begin development of prop-based course (will continue into FY08)
- ▶ Conduct prop-based course in appropriate forums in the latter part of FY08

# Project Summary

- ▶ **Relevance** – Education of first responders is a critical element of introducing hydrogen and fuel cell technology
- ▶ **Approach** – Develop and disseminate education materials that pertain to hydrogen safety, aimed at the first-responder audience
- ▶ **Accomplishments** – Web-based awareness-level course completed; very well-received. Outreach plan complete and a wide range of activities underway. Prop-based course planning has begun.
- ▶ **Future work** – Continue to maintain, refine, and disseminate Awareness-level course. Work with appropriate organizations to develop prop-based course.