

# **NATIONAL TRAINING FACILITY FOR HYDROGEN SAFETY FIVE-YEAR PLAN FOR HAMMER**

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## **ABSTRACT**

A suitably trained emergency response force is an essential component for safe implementation of any type of fuel infrastructure. Because of the relative newness of hydrogen as a fuel, however, appropriate emergency response procedures are not yet well understood by responder workforces across the United States and around the world. A significant near-term training effort is needed to ensure that the future hydrogen infrastructure can be developed and operated with acceptable incident risk. Efforts are presently underway at the HAMMER site in Washington State to develop curricula related to hydrogen properties and behavior, identification of problems (e.g., incorrect equipment installation) and appropriate response, and other relevant information intended for classroom instruction. In addition, a number of hands-on training props are planned for realistic simulation of hydrogen incidents in order to convey proper response procedures in high-pressure, cryogenic, high-leakage or other high-risk accident situations. Surveys of emergency responders, fire marshals, regulatory authorities, manufacturers and others are being undertaken to ensure that the capabilities developed and offered at HAMMER will meet the acknowledged need. This paper describes the training curricula and props anticipated at HAMMER, and is intended to provide useful information to others planning similar training programs.

## **1.0 INTRODUCTION**

Safety in all aspects of the future hydrogen economy is a major priority for the U.S. Hydrogen Fuel Initiative that was announced in the 2003 State of the Union Address. Public concerns over the safety of hydrogen must be resolved in order for the hydrogen economy to succeed. The U.S. Department of Energy's (DOE) National Hydrogen Energy Roadmap (U.S. DOE, November 2002) states that

“Consumers may unnecessarily fear hydrogen if they are misinformed about its safety, and may hold misconceptions about the risk of using it in their homes, businesses and automobiles. Fear may also stem from a lack of understanding about the dangers associated with fuels that consumers use today. The following message needs to be communicated: like all fuels, hydrogen can be handled and used safely with appropriate sensing, handling, and engineering measures.”

Future components of the Hydrogen Fuel Initiative will be focused on specific safety elements, such as the development of sensors, hydrogen-resistant materials, and fail-safe storage system designs. In addition, proper design and deployment of these technologies and techniques, including third-party inspection and verification of their correct application, are needed.

Unfortunately, no system can be made 100% safe despite the most concerted effort. Accidents or other system failures can and do occur on a regular basis, as clearly illustrated in the historical record of traditional fuel use. Therefore, for any fuel, a suitably trained emergency response force is an essential component of a viable infrastructure.

The Volpentest Hazardous Materials Management and Emergency Response (HAMMER) Training and Education Center is the impressive result of a \$29.9 million federal investment completed in 1997. The center is located in the city of Richland, Washington at the southern boundary of the U.S. Department of Energy (DOE) Hanford Site. HAMMER was established to provide critical training in fire operations, hazardous materials handling and transport, occupational safety and health, and other areas relevant to the Hanford mission. Existing HAMMER capabilities include classroom, long-distance, and computer-based learning, as well as hands-on practice with life-sized “training as real as it gets” props.



Figure 1. Fire training is essential for all fuels.

Because the Hydrogen Fuel Initiative identified training of emergency response personnel, permitting/code enforcement officials, and others as one of the critical needs for developing the future hydrogen economy, DOE plans to expand current training capabilities at HAMMER to include hydrogen safety and related subject matter. Planned activities at HAMMER will expand life-sized prop training capabilities to include a number of additional props devoted specifically to hydrogen safety. These props will be representative of a variety of possible hydrogen release scenarios in order to teach the basic procedures of appropriate emergency response to the various audiences that need them.



Figure 2. Aerial view of HAMMER.

HAMMER is intended to be a national focal point for hydrogen safety training activities, involving the collaboration of numerous agencies from both the public and the private sectors. Potential collaborators expressing formal interest to date include the U.S. Department of Transportation, the National Association of State Fire Marshals, the International Code Council, the National Hydrogen Association, and the California Fuel Cell Partnership. In addition, numerous individuals from manufacturers, trade associations, and other international organizations have expressed support for the planned effort.

## 2.0 IDENTIFICATION OF TRAINING AUDIENCES

HAMMER works with existing partnerships in the emergency response, government, and technical communities, as well as new partnerships that are being developed within the hydrogen community, to collect input for the development of world-class hydrogen safety training. During the Hydrogen and Fuel Cells Summit VIII in Coral Gables, Florida on June 16, 2004, workshop participants were asked to provide feedback on DOE’s hydrogen safety education and training activities, identify any gaps that need to be filled, and determine priorities for education and training. Target audiences were identified and then prioritized using two criteria:

- The specific audience could be subject to an accident or incident that could derail the hydrogen economy.
- The impact of public funding for training this specific audience could help enable the hydrogen economy.

The resulting prioritized list of target audiences is as follows:

1. Emergency responders
2. Permitting and code enforcement officials
3. Industrial users, O&M workers, and construction contractors
4. Designers, engineers, and researchers
5. Environmentalists and consumer advocates

The U.S. National Research Council (NRC, 2004) recently reached similar conclusions. Their findings state that one of the main challenges to the transition to a hydrogen economy is “the need to develop hydrogen safety competence among local emergency-response and zoning officials.” The document warns that although timely attention to hydrogen safety issues cannot by itself draw hydrogen into the marketplace, ignoring safety issues will raise formidable barriers to wide-scale consumer acceptance and use of hydrogen.

The National Research Council’s report also states that “the training of local fire and rescue officials in the special procedures required for dealing with any emergencies involving hydrogen should proceed in step with the development and deployment of the technology. Model safety training programs should be prepared on the national level, but in consultation with local officials.”

## **2.1 Emergency Response**

The consensus appears to be that the highest-priority audience for hydrogen safety training is fire fighters. This audience is known to be quite large, but getting a more precise estimate of future training needs is difficult. In the United States, employment figures published by the Bureau of Labor Statistics include only paid career firefighters and do not account for volunteer firefighters, who perform the same duties and often comprise the majority of firefighters in a residential area. According to the U.S. Fire Administration, nearly 70% of fire companies are staffed by volunteer firefighters. Providing the needed education and training to this majority component of the primary target audience will be challenging due to severely limited travel and training budgets.

Due to the direct relationship between conventional fossil fuels and fire incidents in the current economy, virtually all emergency responders typically receive some sort of training related to conventional fuels. Hydrogen can be expected to require at least a similar level of preparedness. Therefore, as a rough estimate, we believe that approximately one million fire fighters should receive some form of hydrogen safety training in just the United States alone if hydrogen is to become the commercial fuel envisioned. Several times this number can be anticipated in the international arena.

Early surveys of personnel involved in the hydrogen and fuel cell industry have identified the following safety training gaps where hands-on props are needed:

- A prop that demonstrates the time required for a pressure relief device to empty a tank
- A prop that simulates an accident between a hydrogen vehicle and a gasoline vehicle

- A prop that shows the locations of safe extrication cut lines (both hydrogen and electrical)
- A prop that depicts bulk transport of hydrogen
- A prop that simulates a hydrogen storage canopy and fuel-dispensing station for hydrogen vehicles

The California Fuel Cell Partnership (CaFCP), located in Sacramento, California, has already published an Emergency Response Guide for Hydrogen Fuel Cell Vehicles. CaFCP staff currently use this document to train emergency responders in Sacramento, San Francisco, and Los Angeles in the areas of hydrogen properties, fuel cell vehicle technology, and emergency response.

In separate support of the identified needs, the National Association of State Fire Marshals (NASFM) in the United States has declared its intent to work with HAMMER as the country's premier advanced emergency responder training facility for the future hydrogen economy. Because State Fire Marshals either direct or are a major factor in their respective states, NASFM will assist DOE by increasing emergency responder awareness of HAMMER's leadership role in this area. In addition, NASFM will also provide an effective communication mechanism for informing its members and other emergency responders regarding the availability of new training programs and other educational materials on hydrogen safety.

## **2.2 Regulatory Community**

The second-highest-priority audience identified for hydrogen safety training is permitting and code enforcement officials. There are approximately 44,000 members of this target audience in the United States. Early surveys have also identified the following gaps (needs) related to permitting and code enforcement officials:

- Need to synthesize all existing activities and coordinate efforts.
- Need to design a training program to implement all the existing guides.
- Need to review all existing activities intended for code officials to make sure they are consistent.
- Need to expand the overall level of effort to reach the entire audience of code officials.

Hydrogen safety training at HAMMER will be designed to address all of these needs.

The International Code Council (ICC), based in the U.S., is a nonprofit organization dedicated to developing a single set of comprehensive and coordinated national model construction codes. These include building, fire, mechanical, fuel gas, electrical and a number of others. Since August of 2000, the ICC Ad-Hoc Committee on Hydrogen (AHC) has worked collaboratively with DOE focusing on the safe use of hydrogen as a fuel in motor vehicle-related infrastructure (i.e., refueling and service stations, repair garages, parking garages) and in portable utilization and power generating scenarios (i.e., dispensers, compressors, generators, portable devices and appliances used in and around buildings, and fueled by hydrogen) as well as the facilitation of market acceptance of the technology through coordinated codes and standards activity.

The AHC continues to work together with a diverse group of technical and advisory parties to review current codes and standards applicable to hydrogen, determine the adequacy of its coverage in the ICC International Codes, and propose changes, as necessary, to the International Building, Fire, Fuel Gas and Mechanical codes through the ICC Code Development Process consistent with their findings. As an outgrowth of this activity, ICC has embarked on a collaborative effort with DOE and HAMMER to coordinate and fund the participation of fire marshals and building safety professionals from several large urban areas throughout the U.S. in the pilot training class and in the survey activities under

preparation. ICC is considering accreditation of the course once it is finalized, including the aspect of offering Continuing Education Unit (CEU) credits. ICC is a certified provider of CEUs, bringing added value and incentive for local stakeholders to participate in HAMMER's training and education seminars.

### 3.0 TRAINING CATEGORIES

#### 3.1 Non-Hands-On Training

##### 3.1.1. Training facilities

In order to establish a National Training Facility for Hydrogen Safety, HAMMER must address training needs that extend beyond the utilization of its props for hands-on training. The training media being considered for hydrogen safety training delivery include:

- *Onsite classroom training* - Delivery of classroom-based subject media to complement hands-on activities.
- *Long-distance training* – Use of HAMMER's videoconferencing capabilities to provide distance learning programs and reach training audiences located across the country.
- *Videos of prop training activities* – In instances where limitations preclude actual participation in hands-on training with the props, videos of the prop activities can be used in the classroom to provide realistic case studies for classroom discussion. These videos can also be incorporated for use in training conducted outside of the facility.
- *Train the trainer* – As a National Training Facility for Hydrogen Safety, HAMMER must be able to export its training capabilities. The sheer numbers of staff to be trained on at least some aspects of safety in making the national transition to hydrogen is greater than any single facility can address. The challenge is further amplified by the expectation of refresher training on a periodic basis. One means of accomplishing this formidable goal is to provide hydrogen safety training and materials to instructors who will then use them to provide training to their own target audiences on a regional basis. This type of training has been successfully provided at HAMMER on a variety of subjects in the past.

##### 3.1.2. Tiered Approach

Both the U.S. Occupational Safety and Health Administration (OSHA) and the National Fire Protection Association (NFPA) employ a four-tiered approach for training emergency responders in the area of hazardous materials. As emergency responders are already familiar with this methodology, a logical approach is thereby to follow the same format for hydrogen safety training. The four tiers of training correspond to the level of specialization emergency responders possess for a given hazard, and include: awareness; technician; operations; and specialist levels.

To illustrate, the first tier, or *Awareness Level*, is defined by OSHA as follows (CFR, 1999):

First responders at the awareness level are individuals who are likely to witness or discover a hazardous substance release and who have been trained to initiate an emergency response sequence by notifying the proper authorities of the release. They would take no further action beyond notifying the authorities of the release. Training shall be based on the duties and function to be performed by each responder of an emergency response organization. The skill and knowledge levels required for all new responders, those hired after the effective date of this standard, shall be conveyed to them through training before they are permitted to take part in actual emergency operations on an incident.

Employees who participate, or are expected to participate, in emergency response, shall be given training in accordance with the following:

- An understanding of what hazardous substances are, and the risks associated with them in an incident.
- An understanding of the potential outcomes associated with an emergency created when hazardous substances are present.
- The ability to recognize the presence of hazardous substances in an emergency.
- The ability to identify the hazardous substances, if possible.
- An understanding of the role of the first responder awareness individual in the employer's emergency response plan including site security and control and the U.S. Department of Transportation's Emergency Response Guidebook.
- The ability to realize the need for additional resources, and to make appropriate notifications to the communication center.

Similarly, the other tiers in the OSHA/NFPA approach are briefly detailed as follows.

*Operations Level.* First responders at the operations level are individuals who respond to releases or potential releases of hazardous substances as part of the initial response to the site for the purpose of protecting nearby persons, property, or the environment from the effects of the release. They are trained to respond in a defensive fashion without actually trying to stop the release.

*Hazardous Materials Technician.* Hazardous materials technicians are individuals who respond to releases or potential releases for the purpose of stopping the release. They assume a more aggressive role than a first responder at the operations level in that they will approach the point of release in order to plug, patch or otherwise stop the release of a hazardous substance.

*Hazardous Materials Specialist.* Hazardous materials specialists are individuals who respond with and provide support to hazardous materials technicians. Their duties parallel those of the hazardous materials technician, however, those duties require a more directed or specific knowledge of the various substances they may be called upon to contain. Also, the specialist undertakes leadership training in the area of incident command and acts as the site liaison with Federal, state, local and other government authorities in regards to site activities. At present, training at HAMMER is only planned for the first three levels.

Generally, police officers are the first to arrive at an emergency scene and should, therefore, be trained to the first responder Awareness Level since they are likely to witness or discover a hazardous substance release. Firefighters are usually considered to be first responders at the Operations Level since they are the individuals who respond to releases, or potential releases, of hazardous substances as part of the initial response. Emergency responders trained to the hazardous materials Technician Level are individuals who respond to releases, or potential releases, for the express purpose of stopping the release. Training to each of these three levels will be available at HAMMER. Course content will be continually reexamined and updated, in part, through feedback obtained from course participants.

## 3.2 Hands-On Training Scenarios

### 3.2.1 Emergency Response

The Safety section of DOE's Hydrogen Multi-Year Program Plan (US DOE, 2003) states that, "Personnel must be trained in safety methods and must understand the potential failure modes and responses. As practical experience is highly effective in failure situations, hands-on experience and training are priorities. A first responder curriculum must be developed and integrated into the Education program element activities to assist local officials."

The following three hydrogen burn props are under consideration at present for hands-on hydrogen safety training applications:

*Fueling Station Prop* – The fueling station prop will simulate scenarios involving accidental hydrogen releases and fires from multiple sources, including the vehicle, dispensing hose and/or connection, fuel pump, and fuel tank. The prop fires will also be remotely controlled and will incorporate redundant safety features to ensure safe and reliable operation.

*Vehicle Fire and Extrication Prop* – The vehicle prop will simulate both a hydrogen leak fire and a vehicle cab fire impinging on a hydrogen fuel tank. The prop will be remotely controlled and will incorporate redundant safety features in the event emergency situations arise. Additional features will be incorporated into the vehicle to facilitate training for extrication of accident victims. These features will simulate high-voltage electrical and high-pressure relief lines that are typical of hydrogen-fueled vehicles, and which must be controlled by emergency responders.

*Bulk Storage Facility Prop* – The bulk storage fire prop will include a large tank with piping, valves, and pumps and will simulate scenarios involving accidental hydrogen releases and fires from multiple sources. The prop will also be remotely controlled and will incorporate redundant safety features to ensure safe reliable operation.

Potential incident scenarios to be portrayed using these props may include:

- Fueling Station
  - Dispenser break-away
  - Dispenser impact with excess flow control failure
  - Dispenser impact with pipe failure preventing excess flow control
  - Hydrocarbon fueled vehicle fire at hydrogen dispenser
- Vehicle Fire and Extrication
  - Single vehicle accident
  - Two vehicle accident (hydrogen/hydrogen or hydrogen/hydrocarbon)
  - Vehicle component failure
- Bulk Storage Facility
  - Unloading event
    - Tank vehicle pull away
    - Impact of tank vehicle
    - Unloading hose failure
    - Stationary container overfill or over-pressurization
  - Exposure fire with thermal impact to hydrogen storage container
    - Hydrocarbon fuel in above-ground tank
    - Unloading event with fire
    - Structure fire
  - Hydrogen container
  - Pressure relief valve operation without fire
  - Hydrogen vent stack fire

Other incident scenarios to consider may include transportation events involving the impact or off-loading of tube trailers (MCC-331) or insulated tank trailers (MCC-338).

### 3.2.2 Code Inspection

*Fueling Station* – The fueling station prop will also be used to facilitate practical training for code compliance inspectors. The prop will be constructed to meet applicable codes and standards for a hydrogen fueling station, however specific simulated catch points which do not meet applicable codes will be incorporated into the prop for students to find.

*Bulk Storage Facility* – This prop also will be constructed to facilitate practical training for code compliance inspectors. Like the fueling station prop, the bulk storage facility prop will be constructed to meet applicable codes and standards with specific simulated catch points incorporated which do not meet applicable codes.

### 3.2.3 Equipment Use

*Stationary Hydrogen-Fueled Generator* – The use of stationary hydrogen-fueled generators for emergency back-up power is a growing trend for both civilian and military use. To ensure safe operations, the installation of these generators must also meet applicable codes and standards. This generator will provide a model installation for compliance inspection, as well as operations and maintenance.

### 3.2.4 Demonstration Laboratory

Demonstration equipment will provide students with basic knowledge of how hydrogen behaves when it is released to the atmosphere. Demonstrations may include:

- Pressure-relief device release with ignition from an automobile
- Small leaks under a vehicle with ignition
- Leak from a compressed gas storage container with ignition
- Standing flame in small passages
- Impingement of hydrogen flames on surfaces
- Ignition of hydrogen flame.

## 4.0 TIMELINE

Table 1 outlines the currently anticipated five-year roadmap for development of the National Training Facility for Hydrogen Safety at HAMMER. It includes annual activities to be undertaken for:

- hydrogen burn prop design and construction (including an open-air demonstration facility for observation of hydrogen behavior characteristics)
- hydrogen safety training curriculum development and delivery
- proposed purchases of commercially available equipment (a hydrogen vehicle and a hydrogen fueling station) for hands-on demonstrations of vehicle fueling



Table 1. Current 5-Year Plan for HAMMER

FY06	Conduct First-Responder Awareness-Level training.
	Develop Code Enforcement training curriculum and obtain ICC endorsement.
	Develop compressed hydrogen behavior demonstration props.
	Develop First-Responder Operations-Level training.
	Begin design of first life-size hydrogen safety training prop.
FY07	Conduct First-Responder Awareness-Level and Operations-Level training.
	Conduct Code Enforcement training.
	Develop First-Responder Technician-Level training.
	Develop videoconference and web-based training methodologies.
	Design and construct Hydrogen Safety Demonstration Facility.
	Construct first life-size hydrogen safety training prop.
	Design second life-size hydrogen safety training prop.
FY08	Conduct First-Responder Awareness-Level, Operations-Level, and Technician-Level training.
	Conduct Code Enforcement training.
	Construct second life-size hydrogen safety training prop.
	Design third life-size hydrogen safety training prop.
	Purchase modest-size reformer to produce hydrogen at HAMMER.
FY09	Conduct First-Responder Awareness-Level, Operations-Level, and Technician-Level training.
	Conduct Code Enforcement training.
	Construct third life-size hydrogen safety training prop.
	Begin design and construction of additional classrooms as needed.
FY10	Conduct First-Responder Awareness-Level, Operations-Level, and Technician-Level training.
	Conduct Code Enforcement training.
	Complete design and construction of classrooms.
	Produce hydrogen safety tips CD/DVD.
	Purchase a fuel cell vehicle and a hydrogen fueling station for demonstration of fueling safety.

The near-term objective of the activities in Table 1 is to have a sufficiently prepared workforce to ensure that any reasonably predictable incident involving hydrogen is prevented or quickly contained. First responders will be responsible for performing whatever actions are necessary for containment and are thus a primary target audience of these activities. Code officials, a second target audience, will be in the position of approving or disapproving installations of hydrogen technologies and helping minimize the likelihood of incidents in the first place. The program will work to prioritize regions of the country where training should be focused due to active regional hydrogen and fuel cell vehicle demonstration programs, and will then collaborate with jurisdictions in those regions to secure the associated target audiences. Jurisdictions located along California’s anticipated “Hydrogen Highway” provide one example of a high-priority region.

## 5.0 CONCLUSION

Safety is an essential component of a future hydrogen economy. One critical element of safety is having an adequately trained emergency response force to respond to the variety of incidents that are certain to arise. Numerous activities are underway to develop a hydrogen safety training capability for emergency responders and other target audiences at the HAMMER site in southeast Washington State. This site will offer training in several areas identified as being of most value in terms of a future hydrogen infrastructure, and will be continually updated to ensure the facility continues to provide the needed capabilities. Because the large numbers of staff requiring training and education

in the transition to a hydrogen economy will eventually exceed the capabilities of any single facility, the ultimate use of multiple facilities around the nation (and world) is anticipated; HAMMER is intended to serve as a template for leading this international effort. Through this endeavor, HAMMER, the U.S. Department of Energy, the Pacific Northwest National Laboratory, and other participating organizations will provide a fundamental contribution to the development of the hydrogen economy.

## 6.0 REFERENCES

1. U.S. Department of Energy (US DOE), November, 2002. National Hydrogen Energy Roadmap. Downloadable at [http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/national\\_h2\\_roadmap.pdf](http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/national_h2_roadmap.pdf).
2. National Research Council (NRC), 2004. The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs. National Academies Press, Washington, D.C. Downloadable from <http://www.nap.edu/catalog/10922.html>.
3. U.S. Code of Federal Regulations (CFR) 1910.120, Revised 1999. Occupational Safety and Health Standards, Hazardous waste operations and emergency response. Downloadable from [http://www.access.gpo.gov/nara/cfr/waisidx\\_99/29cfrv5\\_99.html](http://www.access.gpo.gov/nara/cfr/waisidx_99/29cfrv5_99.html).
4. U.S. Department of Energy (US DOE), June 2003. Hydrogen, Fuel Cells and Infrastructure Technologies Multi-Year Research, Development and Demonstration Plan: Planned program activities for 2003-2010. Section 3.7 Hydrogen Safety. Washington, D.C. Downloadable from <http://www.eere.energy.gov/hydrogenandfuelcells/mypp/>.