HYDROGEN EMERGENCY RESPONSE TRAINING FOR FIRST RESPONDERS

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ABSTRACT

The U.S. Department of Energy supports the implementation of hydrogen fuel cell technologies by providing hydrogen safety and emergency response training to first responders. A collaboration was formed to develop and deliver a one-day course that uses a mobile fuel cell vehicle (FCV) burn prop designed and built by Kidde Fire Trainers. This paper describes the development of the training curriculum, including the design and operation of the FCV prop; describes the successful delivery of this course to over 300 participants at three training centers in California; and discusses feedback and observations received on the course. Photographs and video clips of the training sessions will be presented.

1.0 INTRODUCTION

Safety in all aspects of a future hydrogen economy is a top priority, and safety is a key concern of all projects funded by the U.S. Department of Energy (DOE) Fuel Cell Technologies Program. But despite the most concerted effort, no energy system can be made 100% risk-free. Therefore, for any fuel and energy system, a suitably trained emergency response force is essential for a viable infrastructure. DOE has made training emergency response personnel a priority, not only because these personnel must understand how to respond to a hydrogen incident, but also because fire fighters and other emergency responders are influential in their communities and can be a positive force in the introduction of hydrogen and fuel cell technologies into local markets [1]. Emergency responders must understand that although hydrogen is different from other commonly used fuels, it is not more dangerous. Like other fuels, hydrogen can be used safely when appropriate guidelines are followed.

DOE's hydrogen safety training efforts are addressing several barriers to the commercialization of hydrogen and fuel cell technologies:

- Lack of readily available, objective, and technically accurate information
- Disconnect between hydrogen information and dissemination networks
- Lack of educated trainers and training opportunities
- Lack of hydrogen knowledge by authorities having jurisdiction
- Lack of hydrogen safety training facilities for emergency responders.

This project uses the Occupational Safety and Health Administration (OSHA) and National Fire Protection Association (NFPA) frameworks for hazardous materials emergency response training [2,3] to develop a tiered hydrogen safety education program for emergency responders. The first-responder education program was developed over several years, starting with the development and distribution of the awareness-level web-based course in 2006 and 2007. A more advanced course and educational materials were developed in 2008 and 2009, complementing the design, construction, and operation of a fuel cell vehicle (FCV) prop.

Pacific Northwest National Laboratory (PNNL) works with subject matter experts in hydrogen safety and first responder training (e.g., the Hydrogen Safety Panel, other national laboratories, and the California Fuel Cell Partnership) to develop hydrogen safety course materials. Draft materials are prepared and undergo considerable review and revision before being released. The PNNL team works with DOE to make stakeholders aware of training opportunities and to provide "live" training when appropriate. The operations-level course was initially given at the Hazardous Materials Management and Emergency Response (HAMMER) Training and Education Center in Richland, WA in 2009 and 2010. Later in 2010 it was given at three training centers in California in order to reach larger audiences in areas where hydrogen and fuel cell technologies are currently being deployed. Offsite deployments will continue to be the preferred method of providing operations-level training to first responder communities.

2.0 DEVELOPMENT OF AWARENESS-LEVEL COURSE

OSHA and NFPA use a tiered approach for training emergency responders on appropriate responses to incidents involving hazardous materials. Since emergency responders are already familiar with this approach, we followed the same approach for hydrogen safety training. The four tiers of training correspond to four levels of specialization: awareness, operations, technician, and specialist. Our training courses focus on the first two levels.

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 not take any further action beyond this. Our awareness-level hydrogen safety training is intended for fire, law enforcement, and emergency medical personnel who may witness or discover a hydrogen release and must initiate an emergency response sequence. The course was developed to help first responders:

- Understand the properties of hydrogen, how it compares to other fuels, and the safety mechanisms of hydrogen systems
- Recognize and identify hydrogen vehicles, stationary power generators, storage containers, and refueling equipment
- Identify typical ignition sources and other potential hazards
- Execute initial awareness-level response actions.

The awareness-level course, *Introduction to Hydrogen Safety for First Responders* (http://www.hydrogen.energy.gov/firstresponders.html), is divided into modules that cover hydrogen basics, transport and storage, hydrogen vehicles, hydrogen dispensing, stationary facilities, codes and standards, and emergency response [4]. After completing all of the modules, the user takes a comprehensive quiz on the course material and receives a certificate of completion if they score 80% or higher. The course also includes a library of supporting documents and videos, as well as links to related websites. Two pilot courses were held at the HAMMER facility in 2005, with approximately 40 participants including fire fighters, trainers, police, fire marshals, and code enforcement officials. The participants provided a great deal of feedback to improve the course materials. Before the online course was launched, more than 100 people provided detailed comments and suggestions for improvement. All of their comments were addressed prior to the launch.

Since the online course was launched in January 2007, there have been more than 18,000 unique visitors to the website. The site still averages almost 300 unique visitors each month from nearly every state and many foreign countries. Typical users include the fire prevention and protection community, fire fighters, fire department education coordinators, fire marshals, fire plan examiners/inspectors, code officials, law enforcement officials, and representatives from industry, universities, the military, and non-profit organizations. Feedback on the course has been very positive.

3.0 DEVELOPMENT OF OPERATIONS-LEVEL COURSE

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, and the environment from the effects of the release. They are trained to respond defensively without actually trying to stop the release.

The operations-level curriculum, *Hydrogen Emergency Response Training for First Responders*, is focused on teaching first responders how hydrogen and FCVs are different from conventional fuels and vehicles, and how they are the same. Course evaluation forms are distributed and feedback is obtained at each class to help us improve the course content and delivery. Based on feedback from twelve sessions held in 2009 and 2010, we concluded that first responders who have participated in the course are more comfortable with hydrogen and are better prepared to operate safely and effectively should a hydrogen incident occur in their jurisdiction.

The operations-level course is divided into modules that cover hydrogen and fuel cell basics, hydrogen vehicles, stationary facilities, and emergency response [5]. After these modules, participants are divided into teams and each team is assigned an incident scenario. Teams must analyze their scenarios, determine appropriate response actions, and present their findings to the class. This exercise is followed by a 25-question quiz that is graded and discussed in class. Finally, the group suits up for a realistic hands-on exercise with the FCV burn prop. The burn prop, shown in Fig. 1, simulates conditions that could be encountered during the control and suppression of an FCV fire. It has been used to simulate several different accident scenarios, including those involving multiple vehicles and other props as shown in Fig. 2.

Figure 1. FCV burn prop fabricated by Kidde Fire Trainers. A nearly invisible hydrogen flame is burning from the top of the FCV. Here the instructor is demonstrating the relative lack of radiant heat from a hydrogen flame compared to other flammable gases such as propane.

Figure 2. Team of fire fighters responding to a simulated multi-vehicle accident involving a hydrogen FCV (middle) and conventional vehicles. The team prepares to rescue a "victim" while suppressing fire around the FCV with hose streams.

In a typical exercise, a dispatch message informs the students that a two-vehicle collision has occurred; one vehicle is reported to be on fire, one vehicle appears to be a hydrogen vehicle, and at least one victim appears unconscious in the hydrogen vehicle. The first unit arrives, evaluates the scene, and calls for support. The first unit establishes a straight water stream at the vehicles to control the spread of fire and protect exposures. A two- to three-person team initiates its approach to the hydrogen vehicle to extricate the victim. Before approaching further, a high-pressure hydrogen release and fire are observed coming from the rear of the hydrogen vehicle. The team verifies the hydrogen fire with thermal imaging equipment while putting up a water spray to protect the victim and the rescue team. The rescue team extricates the victim and moves the victim from danger. See Fig. 3.

The team protects other exposures and allows the hydrogen fire to burn out before moving in to extinguish the secondary fire, which continues in the conventional vehicle. (In most cases, a full tank of hydrogen will completely vent in less than 2 minutes.) The team then moves in, opens the engine hood of the conventional vehicle, and extinguishes the fire. When the fire is extinguished, the exercise is terminated. This exercise reinforces an important aspect of the training. The operations-level class about hydrogen, its properties and attributes, and those of FCVs builds on the skills, training, and knowledge that the students already have as first responders in settings that are familiar to them (e.g., a multi-car accident) [6,7].

Figure 3. In another scenario, a team of fire fighters has rescued the "victim" from the hydrogen FCV while continuing to suppress fire in and around the vehicles.

4.0 DEPLOYMENT OF OPERATIONS-LEVEL COURSE

Twice in 2009 and once in 2010, a one-day operations-level class was held onsite at the HAMMER facility in Richland, WA, with approximately 30 fire fighters from across the country in attendance. DOE paid for their travel and living expenses. Feedback was very positive; most participants were interested in having the course brought to their areas for their fellow fire fighters.

From the beginning, an objective of the operations-level course was for the FCV burn prop to be transportable for offsite deployment of the training. Kidde Fire Trainers designed and fabricated a trailer (Fig. 4) to transport the prop to emergency response training facilities around the country.

California was chosen for the first offsite deployments of the training because of the activity with light duty hydrogen fuel cell vehicles in Los Angeles and Orange County and with hydrogen fuel cell-powered public transit in the San Francisco Bay Area [8]. Three training facilities were selected in California: 1) the Rio Hondo Community College Fire Academy in Santa Fe Springs, CA; 2) the Orange County Fire Authority (OCFA) in Irvine, CA; and 3) the Sunnyvale Public Safety Department in Sunnyvale, CA. Arrangements for training were made through the training officers at those sites.

Figure 4. The burn prop is transported to training facilities in this trailer that also contains hydrogen, compressed air, and propane used in the live-fire training exercises.

Each training deployment was conducted with three different classes of students, typically representing the A, B, and C shifts of the participating fire departments. This allowed broader participation from the departments. The level of expertise at each site varied from fire academy recruits with little or no fire experience to veteran fire fighters with more than 30 years of experience. The live-fire training activity with the burn prop also varied; some captains were satisfied with their fire fighters observing the hydrogen flame through the thermal imaging camera, with further explanation from the instructor, while others had their fire fighters in full turnouts performing the entire evolution (as described above).

The first classes were presented at the Rio Hondo Community College Fire Academy. The course was taught on three consecutive days to approximately 100 students total, with one of the days consisting entirely of academy recruits (many having no previous live-fire experience). Participants for the other two days of classes consisted of experienced fire fighters from the surrounding community.

The prop was transported next to the OCFA training center (Fig. 5). OCFA represents dozens of fire stations and hundreds of fire fighters in the Los Angeles area. The class was again taught on three consecutive days to about 100 participants total. All were experienced fire fighters, some with more than 30 years of service.

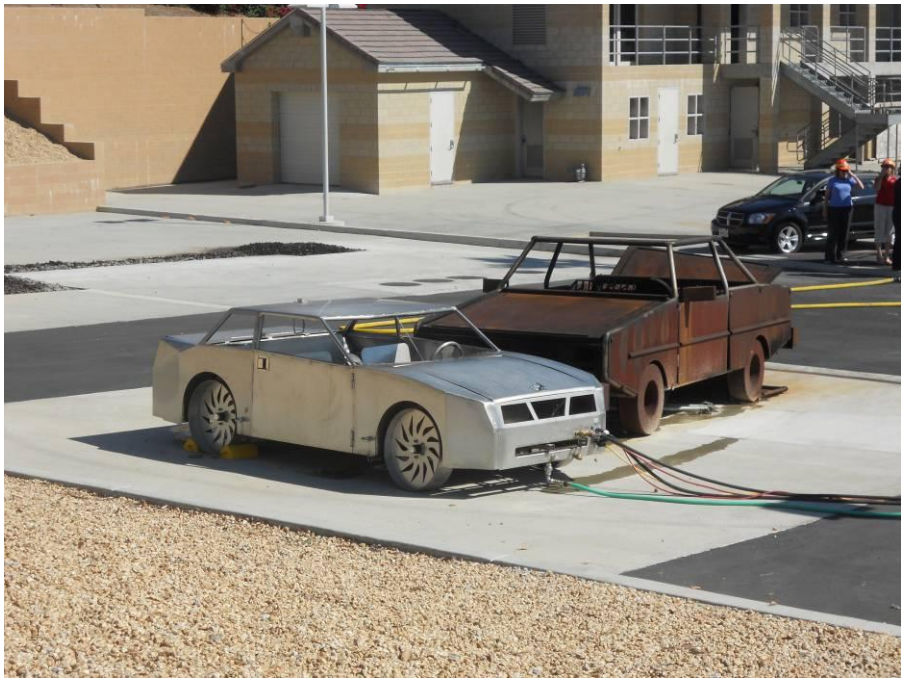

Figure 5. Hydrogen FCV burn prop (left) staged with OCFA propane-fueled burn prop for live-fire training/demonstration.

The prop was then transported to a training site for the Sunnyvale Department of Public Safety (DPS). (Fire fighters for Sunnyvale DPS are somewhat unique in that they also serve as police officers for the city of Sunnyvale.) The class was again taught on three consecutive days to about 100 participants total, again mostly experienced fire fighters with many years of service (Fig. 6).

To date, nearly 400 first responders have been trained in the operations-level curriculum. Feedback from the participants has been very positive. Many initially had serious concerns about dealing with hydrogen emergencies, even though other more common flammable gases did not give them similar concerns. (This is because their prior training had prepared them to respond to fires involving propane, natural gas, and other flammable gases.) But by the end of the class they said they better understood the properties of hydrogen and could respond to a hydrogen emergency with the same confidence as for other flammable gases.

Figure 6. Participants at Sunnyvale class working in groups on incident scenarios.

5.0 CONCLUSIONS

The web-based awareness-level course has been quite successful, based on the usage recorded and feedback received. The course is fulfilling a need expressed by the first responder community to receive more information about hydrogen and fuel cells so they will be prepared in the rare event of a hydrogen incident. The in-depth operations-level course builds on that success and is very useful in giving first responders a hands-on experience with simulated FCV incidents that integrates well with classroom training. At the beginning of the classes, many of the first responders expressed concerns about dealing with hydrogen emergencies. But by the end of the training they indicated they were much more confident that they could properly respond to such an emergency. PNNL will continue to update both courses as needed to reflect current applications and markets for hydrogen and fuel cells. As the market for hydrogen FCVs expands, the operations-level course will be available for deployment to those areas for timely presentation to the first responder community. The first responder community recognizes it is very important that training for hydrogen emergencies stay ahead of the emergence of private and commercial FCVs and development of hydrogen production and delivery infrastructure.

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