Training for Drivers and Inspectors of Commercial Motor Vehicles Using Hydrogen

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1. Introduction

The Federal Motor Carrier Safety Administration (FMCSA) is the agency in the U.S. Department of Transportation (USDOT) that regulates the safety of trucks and motorcoaches engaged in interstate, certain intrastate and foreign commerce. The purpose of carrying out this project is for FMCSA to ensure the safe operation and maintenance of commercial motor vehicles using hydrogen as an alternative fuel.

A commercial motor vehicle means any self-propelled or towed motor vehicle used on a highway in interstate commerce to transport passengers or property when the vehicle -

- Has a gross vehicle weight rating or gross combination weight rating, or gross vehicle weight or gross combination weight of 10,001 pounds, or more, whichever is greater; or

- Is designed or used to transport more than eight passengers, including the driver, for compensation, or

- Is designed or used to transport more than 15 passengers, including the driver, and is not used to transport passengers for compensation, or

- Is used in transporting material found by the Secretary of Transportation to be hazardous under 49 U. S. C. 5103 and transported in a quantity requiring placarding under regulations prescribed by the Secretary under 49 CFR, subtitle B, chapter I, subchapter C.[4]

FMCSA envisions hydrogen being used as a near-term alternative fuel technology for commercial vehicles in two ways:

- To provide auxiliary power (i.e., refrigeration, lighting, and air conditioning) in order to avoid diesel idling[5] and

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[4] 49 CFR 390.5 - Definitions
[5] The U.S. Department of Energy (DOE) has been funding the development of a solid oxide fuel cell for use in heavy-duty trucks as an auxiliary power unit to reduce idling. DOE also recently made an award for development and demonstration of a "SuperTruck" (highly efficient and clean diesel engine heavy-duty truck) that includes a fuel cell auxiliary power unit.

- To provide propulsion power in local, urban fleets of delivery trucks.

On the other hand, FMCSA does not envision utilization of hydrogen for long-haul trucks at this time because the energy density of hydrogen does not favor hydrogen as a replacement for diesel fuel in such operations.

Under the President's Hydrogen Fuels Initiative, FMCSA in 2006 implemented a two-year project to determine the proposed changes necessary to accommodate the use of hydrogen as an alternative fuel in commercial vehicles. As a result of this project, FMCSA in 2007 published the following:

- *Guidelines for Use of Hydrogen Fuel in Commercial Vehicles* [1]
- *System Safety Plan for Commercial Vehicles Using Hydrogen as an Alternative Fuel* [2]
- *Changes to Consider in the Federal Motor Carrier Safety Regulations & North American Standard Inspection Procedures to Accommodate Hydrogen as an Alternative Fuel* [3]

Reference [1] recommended that commercial drivers be given hydrogen hazard awareness training. Reference [3] noted that the fuel system is a critical safety component and recommended Out-Of-Service criteria for removing a commercial motor vehicle from operation in the event of an onboard hydrogen leak. However, commercial motor vehicle inspectors are familiar neither with hydrogen nor onboard hydrogen fuel systems. Therefore, it follows that commercial motor vehicle inspectors should be trained on recognizing the properties of hydrogen, examining a hydrogen fuel system, and detecting hydrogen leaks.

FMCSA is now implementing the above recommendations with respect to training. Supported by funding from USDOT's Research and Innovative Technology Administration, FMCSA awarded a contract to develop instructional design guides to train drivers on recognizing the hazards of hydrogen fuel systems on board commercial vehicles and inspectors on examining the safety of hydrogen fuel systems on board commercial vehicles. The development of these instructional design guides commenced in May 2010 and is due for completion in one year. The work consisted of conducting site visits, summarizing findings, and proposing the content for the two types of training. The rest of this paper discusses the highlights of each of these work elements.

2. Site Visits

In carrying out the development of instructional design guides for the two types of training, the authors followed the ADDIE Model[6] of training design. The objective of

[6] The ADDIE Model of training design consists of five phases: Analysis, Design, Development, Implementation, and Evaluation.

the site visits was to gather information in order to analyze the training needs and to design the training objectives, and develop the training course contents.

To analyze the training needed for commercial drivers, the authors needed to ascertain information about the characteristics of drivers: average age, average gender, attitudes towards training, attitudes towards the subject matter of hydrogen safety, average educational level, proficiency in English, literacy in technology (in particular, hydrogen technology), and literacy in computers. Such characteristics about the population of commercial drivers would be used to custom tailor training to accommodate the needs, abilities, and cognitive levels of the target population. For example, knowing whether the majority of commercial drivers are computer literate would help determine whether a training delivery option of online distance learning, learning from a compact disk, or a blend of classroom and computer learning would be appropriate. Another example, knowing whether the majority of commercial drivers are literate in hydrogen technology would help determine whether basic properties of hydrogen and principles of hydrogen combustion would be appropriate to include in a hazard awareness training course for drivers.

The authors also decided that it was important to determine from site visits whether there was already any training in place that had been delivered for drivers or inspectors of commercial vehicles using hydrogen. If there was such training delivered, the authors would take advantage of the lessons learned and the materials that were available.

Taking the above considerations into account, the authors started planning for site visits by selecting organizations of which the authors were aware that had experience with operating commercial vehicles using hydrogen and organizations of which the authors thought that had experience with inspecting commercial vehicles using hydrogen.

Most of the organizations of which the authors were aware that were operating commercial vehicles using hydrogen consists of transit agencies[7]. Consequently, the authors sought the cooperation of the USDOT's Federal Transit Administration, which administers the National Fuel Cell Transit Bus Program and provides grants to transit agencies. The authors consulted with the Federal Transit Administration in obtaining point of contact information and coordinating site visits to transit agencies.

The only organization of which the authors were aware that had experience inspecting commercial vehicles using alternative fuels was the California Highway Patrol. The authors contacted the California Highway Patrol to ascertain whether it had progressed to the point of developing an inspection checklist and procedures specifically for commercial vehicles using hydrogen since the authors last visited them in 2006. The reply of the California Highway Patrol was negative due to severe budget constraints.

Prior to conducting the site visits, the authors developed a detailed agenda for what the authors wanted to say to each site manager (e.g., goals and objectives), what the authors

[7] Commercial motor vehicles operated by state government (including subdivisions, such as cities and counties) are exempt from certain Federal Motor Carrier Safety Regulations.

wanted to discuss in each meeting (e.g., lessons learned) and what the authors wanted to observe at each site (e.g., vehicle fuel systems, alarms, and detectors).

The planning resulted in site visits to the organizations with the commercial motor vehicles using hydrogen listed in and on the dates given in Table 1 below.

Table 1. List of Site Visits

Organization Visited	Location	Fleet	Date of Visit
Alameda – Contra Costa Transit District (AC Transit)	Oakland, CA	12 hydrogen fuel cell hybrid buses	Aug. 9, 2010
Santa Clara Valley Transportation Authority (VTA)	San Jose, CA	3 hydrogen fuel cell engine buses	Aug. 10, 2010
Port of Los Angeles	San Pedro, CA	1 terminal tractor with battery-range extender charged by hydrogen fuel cell	Aug. 11, 2010
Sunline Transit Agency	Thousand Palms, CA	1 hydrogen fuel cell hybrid bus, 1 hydrogen hybrid internal combustion engine bus, and 1 Class 8[8] tractor with hydrogen fuel cell auxiliary power unit	Aug. 12, 2010
British Columbia Transit (BC Transit)	Victoria, BC	20 hydrogen fuel cell engine buses	Aug. 25, 2010

[8] Commercial vehicles are classified by their gross vehicle weight (actual weight) into eight classes. A Class 8 vehicle is a vehicle with a gross vehicle weight of more than 33,000 lbs.

Connecticut Transit (CT)	Hartford, CT	1 hydrogen fuel cell engine bus	Sept. 13, 2010

As can be seen, the majority of the organizations visited are transit bus agencies and their locations are in California. This is not surprising in light of the influence of the California Air Resources Board (CARB) and the California Energy Commission (CEC). CARB is enforcing a legislative mandate to reduce greenhouse gas emissions to 1990 levels by 2020 and is implementing a Hydrogen Highway Initiative in the state [4]. CEC has provided generous grants to promote hydrogen technology in the state.

Canada's BC Transit has the largest fleet of commercial vehicles using hydrogen in North America; the inaugural deployment of their fleet occurred in Whistler, BC with Winter Olympic Games of 2010. There is temperature inversion in Whistler, BC so environmental air quality is a prevailing concern there. The next largest fleets of commercial vehicles using hydrogen in North America are concentrated in the San Francisco Bay Area, in which is located the Zero Emissions Bay Area (ZEBA) coalition of transit agencies operating transit buses using hydrogen. ZEBA is comprised of San Francisco Municipal Transportation Agency; Golden Gate Bridge, Highway and Transportation District, San Mateo County Transit (three agencies which the authors did not have sufficient time for visitation), AC Transit, and VTA (two agencies which the authors did visit).

The only organization visited that was planning the operation of a truck using hydrogen is the Port of Los Angeles (later, the Port of Long Beach joined this effort). The Ports of Los Angeles and Long Beach, the largest ports in the U.S., envision the eventual replacement of drayage trucks (which are generally the oldest, and hence, most polluting heavy-duty vehicles in the trucking industry) with the cleanest possible heavy-duty vehicles.

Sunline Transit Agency has a Class 8 (cf. footnote 8) tractor with a hydrogen fuel cell auxiliary power unit, which it developed with the technical assistance of Southwest Research Institute under a cooperative agreement with the U.S. Army. This tractor has been used to tow a compressed hydrogen gas tube trailer.

At each site, the authors engaged in discussions that lasted mostly no more than about 2 hours with hands-on superintendents, managers, or instructors. Additional time was allotted for observing the commercial vehicles using onboard hydrogen fuel systems, alarm panels, and hand-held instruments used for detecting hydrogen leaks. No site visit lasted for more than a half day.

3. Findings

The findings are split between the training for drivers (Section 3.1) and the training for inspectors (Section 3.2) below.

3.1 Training for Drivers

All the visited organizations, except for the Port of Los Angeles, provided training to drivers before operating a commercial vehicle using hydrogen. They all agreed that drivers should be provided with training on hydrogen awareness because hydrogen fuel poses hazards different from those of conventional diesel fuel. On the other hand, the Port of Los Angeles has no current training program in place and does not plan on providing one. Port officials believe that the responsibility for safety falls on the private companies operating the commercial vehicles using hydrogen. The Port currently requires a "maintenance plan" from all private companies operating in the Port. Port officials are thinking about expanding that requirement to a "maintenance and safety plan".

All the visited organizations, except for the Port of Los Angeles, indicated that novice commercial motor vehicle drivers as well as the general public harbor misconceptions about hydrogen. All the organizations have heard drivers express concerns about hydrogen due to the Hindenburg Incident[9] or about hydrogen bombs. No organization was overly concerned about hydrogen fuel when it was introduced; rather, the visited organizations believed that hydrogen was safe if handled properly. It is clear that any proposed driver training needs to dispel these misconceptions about hydrogen and to show that hydrogen can be as safe as, or safer than, diesel fuel if handled properly.

The majority of visited organizations agreed that an overview of hydrogen properties and hydrogen combustion should be provided, but that this overview should be kept simple. Most organizations visited indicated that safety concerns other than hydrogen *per se* but associated with the consequences of using hydrogen technology, namely, compressed gas hazards, high voltage hazards, and the quietness[10] of the propulsion system should be addressed.

The majority of visited organizations not only provided hazard awareness training to drivers of commercial motor vehicles using hydrogen but also to emergency responders.

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[9] The Hindenburg Incident occurred on Thursday, May 6, 1937, when the German passenger airship, *Hindenburg*, caught fire and was destroyed during an attempt to dock with a mooring mast in Lakehurst, New Jersey. Of the 97 on board, 35 people died. There was one additional fatality on the ground. The disaster was the subject of spectacular news coverage. The actual cause of the fire remains unknown, although several hypotheses have been put forth. However, the least likely hypotheses are those asserting that the hydrogen ignited first. Nonetheless, the incident served to shatter public confidence in the passenger airships.

[10] Quietness is a safety issue because a bystander may not be able to hear the approach of a quiet vehicle to avoid getting into its path. Commercial vehicles with diesel engines produce a noise that allowed bystanders to detect the approach of such vehicles. Commercial vehicles with fuel cell engines are extremely quiet.

The training to emergency responders familiarized them with a commercial motor vehicle using hydrogen and covered what actions to take and what actions not to take.

The most recent census is the year 2000 census. The 2000 census data showed 1,150,000 truck drivers. However, the target population for driver training would be probably less than a thousand because the number of commercial motor vehicles using hydrogen is expected to be less than 50[11]. According to the census data, the average age of a truck driver is 43, the average gender is male, and the average educational level is at least a high school diploma. The average truck driver is proficient in the English language[12] He also has limited literacy in technical (scientific and engineering concepts) and has limited computer literacy (mirroring that of the general public).

More recent data [5] support the following initial conclusions for driver training:

- Online learning is a possible delivery mechanism.
- English is the primary language for training materials (except for drayage truck drivers).
- Training materials created at an eighth-grade reading level are suitable.

The proportion of Hispanic drivers to the overall driver population has been increasing slowly, and this trend is likely to continue. An analysis of projected future truck driver shortages for the American Trucking Associations projected that by 2014, 18.7 percent of all truck drivers would be Hispanic males, up from 14.6 percent in 2004 [5]. However, this trend is not significant enough to indicate that primary English-language training would not be viable for this group of learners.

In the findings, the authors have selected classroom training as the training delivery option for drivers. The reasons are as follows:

- All current commercial driver training on hydrogen awareness is conducted in the classroom.
- All visited organizations stated that "hands-on" with the vehicle strongly enhanced the effectiveness of the training. Hands-on training is classroom training.

3.2 Training for Inspectors

The authors did not do the same rigorous process to analyze the characteristics of inspectors as the authors did for drivers. The reason is that there are already two FMCSA courses for training personnel to inspect commercial vehicles and any proposed training for inspectors would supplement these two existing courses, which are described below.

[11] Because many fleet operators told us that even if there is only one or two commercial vehicles using hydrogen in the fleet, the fleet operators would rather have the entire fleet of drivers, which could number as many as 200, be trained than restricting the operation of those one or two vehicles to designated drivers.

[12] Notwithstanding that the average truck driver is fluent in the English language, the subpopulation of drayage truck drivers is non-English speaking. At the Port of Los Angeles, most drayage truck drivers speak Spanish.

To perform as a commercial vehicle inspector under FMCSA's Motor Carrier Safety Assistance Program, an individual must first complete FMCSA course [510002] "North American Standard—Part B"; to maintain certification as an inspector, an individual must conduct 32 North American Standard (Level 1 or Level 5) inspections per year. Otherwise, the individual must obtain a waiver or take the FMCSA course [38162] "North American Standard Level I Inspection Review". Both FMCSA courses consist of 40 hours of classroom training[13]. Because the two courses are predicated predominantly on diesel fuel as the conventional fuel[14] used in commercial motor vehicles, the courses need to be supplemented with familiarizing inspectors with hydrogen as a fuel and how hydrogen fuel systems differ from diesel fuel systems. This supplement is important due to the fact that the fuel system is regarded as a safety-critical component of a commercial vehicle.

The total population of commercial vehicle inspectors is about 10,200 with about 200 Federal inspectors and 10,000 State inspectors. However, the authors believe that the target population of inspectors for the supplementary hydrogen training would not be more than 1,000. The number of commercial vehicles using hydrogen is expected to be not more than 50. Because commercial vehicles using hydrogen are not expected to travel cross country at this time and because of the lack of a nationwide hydrogen infrastructure, the travel of such vehicles will be localized. Thus, most of these inspectors would be in California where most of the commercial motor vehicles using hydrogen are concentrated with some more in a dozen other States[15].

Characteristics of inspectors, such as average age, average gender, attitudes towards training, attitudes towards the subject matter of hydrogen safety, average educational level, proficiency in English, literacy in technology, and literacy in computers, had already been taken into account in the design and development of the two existing FMCSA training courses. The average age of an inspector is not known, but age is not a critical factor for developing a classroom training course. The average gender of an inspector is male. The average educational level of an inspector is at least high school diploma. The average inspector is proficient in the English language. He or she also has literacy in technical concepts (e.g., scientific and engineering concepts) and has literacy with computers. Commercial vehicle inspectors are also required to take training in hazardous materials regulation and cargo securement, which involve basic scientific and engineering concepts beyond what a lay person would know. Inspectors have literacy with computers because they use computers on the job to input and retrieve safety information about a commercial driver, commercial motor vehicle, or motor carrier.

The one attitude among inspectors that the authors opined to differ from both drivers and mechanics is the attitude towards hydrogen. Because inspectors are trained on hazardous materials regulations and are exposed routinely to bulk shipments of hazardous materials,

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[13] See 49 CFR Part 385 Subpart C – for FMCSA auditors, investigators, and safety inspectors.

[14] Propane, compressed natural gas, and liquefied natural gas may also be found as fuels for commercial motor vehicles but they may not be common.

[15] Other States where commercial vehicles using hydrogen are being deployed or demonstrated include Alabama, Connecticut, Delaware, Florida, Hawaii, Massachusetts, Michigan, New York, Pennsylvania, Texas, and South Carolina.

they do not harbor the same misconceptions about hydrogen that novice drivers and mechanics have. Hazardous materials commonly shipped include flammable liquids, pressurized gases, cryogenic fluids, and corrosive materials. Hydrogen is just one more hazardous material.

In the findings, the authors have selected classroom training as the training delivery option for inspectors although inspectors would be suited for either online training or a blend of online and classroom training. The reasons are as follows:

- All current commercial vehicle inspector trainings are conducted in the classroom.
- The proposed course will require training on leak detection. Training on leak detection is most effective when done "hands-on." Hands-on training is classroom training.

4. Proposed Training

The proposed training is discussed separately for drivers (Section 4.1) and inspectors (Section 4.2) below.

4.1 Proposed Training for Drivers

The training course for drivers would be a total of 4 hours encompassing a classroom part and a tour of a commercial vehicle using hydrogen. The authors propose that the training course for drivers be presented in English, consist of 2.5 hours of classroom, and contain the following subjects:

- MODULE 1—Hydrogen Properties, and Comparison to Other Fuels
- MODULE 2—High Pressure Gas Storage and High Voltage
- MODULE 3—Hydrogen Vehicle Safety Principles
- MODULE 4—Hydrogen Vehicle Safety Features
- MODULE 5—Things to Do in an Emergency Situation

The content for the above modules would be drawn from the *Guidelines for the Use of Hydrogen Fuel in Commercial Vehicles* [1]. In addition, the training course for drivers would include 1.5 hours of a tour of a commercial vehicle using hydrogen. The objectives of the vehicle tour are to:

- Enable operators to learn (from a subject matter expert) about hydrogen-related components of the vehicle.
- Allow operators to demonstrate use of safety procedures in a field setting.

The authors envision that the owners or operators of the commercial motor vehicles using hydrogen provide the training for drivers. If FMCSA were to offer this training course, it would be a new course at the FMCSA's National Training Center.

4.2 Proposed Training for Inspectors

The authors propose that the new training course for inspectors would supplement the two existing FMCSA courses because the only new material that needs to be introduced is hydrogen fuel systems.

The authors propose that the training course for inspectors be presented in English, consist of 6 hours of classroom, and contain the following subjects:

- MODULE 1—Hydrogen Properties, Comparison to Other Fuels, and Safety Principles
- MODULE 2—High Pressure Gas Storage, High Voltage, and Vehicle Safety Features
- MODULE 3—Conducting a Leak Test with a Combustible Gas Detector
- MODULE 4—Commercial Vehicle Inspections: Hydrogen-fueled Vehicles vs. Diesel-fueled Vehicles[16]

The content for the above modules would be drawn from the *Guidelines for the Use of Hydrogen Fuel in Commercial Vehicles* [1]. FMCSA would most likely offer the above supplementary training course described above as a new course through its National Training Center.

5. Next Steps

Following the ADDIE Model for training design (see footnote 6), the next steps are follow-on projects to develop and deliver the two above proposed training courses. The USDOT's Research and Innovative Technology Administration plans to fund a portion of the project to develop and deliver the driver training course. The authors anticipate that the pilot for the driver training course will take place in California at one of the Zero-Emissions Bay Area coalition transit agencies.

6. Acknowledgments

[16] Similarities between hydrogen and natural gas or propane could be pointed out if appropriate and the audience is familiar with these alternative fuels.

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