VIII.13 Hydrogen Safety Training for Researchers and Technical Personnel

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Project End Date: Project continuation and direction determined annually by DOE

Fiscal Year (FY) 2011 Objectives

- Prepare safety training materials for researchers running H_2 laboratory experiments.
- Prepare advanced safety training materials for personnel in charge of hydrogen systems.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Safety section (3.8) of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(H) Lack of Hydrogen Knowledge by Authorities Having Jurisdiction
(I) Lack of Hydrogen Training Facilities

Contribution to Achievement of DOE Hydrogen Safety, Codes & Standards Milestones

This project will contribute to achievement of the following DOE milestones from the Hydrogen Safety section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

- **Milestone 17**: Identify user needs for basic safety information

FY 2011 Accomplishments

- Released a final version of the Web-based "Hydrogen Safety Class for Researchers."
- Acquired Web domain www.h2labsafety.org for intuitive, easy to remember access.
- Registered 100+ Web class completions.
- Procured materials and equipment for hands-on class.
- Completed lesson plan for hands-on class.

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Introduction

LLNL has been conducting hydrogen research for more than 50 years, starting with national security applications and continuing with energy research. For many of these years, LLNL was designated as the pressure safety training facility for the whole DOE complex and other government institutions such as the National Aeronautics and Space Administration. Many technicians and researchers visited LLNL to receive training on many aspects of pressure safety, including hydrogen technology, cryogenics, leak detection, and vacuum technology.

The national security hydrogen and high-pressure research conducted at LLNL demanded unique testing facilities, and these were built with funding from DOE National Nuclear Security Administration. These facilities include a high pressure laboratory equipped with four hydrogen-compatible test cells, each rated for 80,000 psi, and 4 pounds of trinitrotoluene (TNT) equivalent stored energy. LLNL also has a high explosive test facility (Site 300) for experiments with many pounds of TNT equivalent and many kg H_2. Experiments at Site 300 are typically conducted in outdoor firing tables and monitored from the safety of a bunker. The remote location of this facility protects employees and property from any hazard.

These unique facilities and the expertise necessary to operate them are now being made available for hydrogen energy research through the development of training materials that may contribute to safe operation within the many institutions working on hydrogen technology.

Approach

We are pursuing a two-pronged approach to hydrogen safety training:

- Researchers conducting laboratory experiments can benefit from basic training on hydrogen and pressure safety. This Web-based training can be completed in ~4 hours.
- Technical personnel in charge of setting up experimental equipment require comprehensive hands-on training on all aspects of hydrogen systems. This extensive training is planned for three full days.

Results

The Web-based hydrogen safety class (www.h2labsafety.org) was publicly released in September of 2010. Since then we have registered over 100 completions from universities, government institutions, and private companies from five countries (USA, Canada, United Kingdom, Japan, and Mexico). Before public release, class materials were thoroughly reviewed by a panel of safety experts through two rounds of peer review, focusing on the technical aspects as well as on the teaching aspects of the class. Further improvement is always possible, however, and we therefore invite readers to take the class and submit comments to the authors that may improve the learning experience, update the class information, and/or report bugs or malfunctions. Class authors can be contacted by e-mail at any time during the course, by clicking on the "help" button in the top menu (or use author's e-mail address listed above).

In addition to the Web-based fundamentals class, we are developing a hands-on hydrogen safety class for pressure operators. This comprehensive training includes basic hydrogen safety, regulators, relief devices, leak detection, and flash arrestors, followed by hands-on assembly and test of a hydrogen pressure system and a final evaluation. Training can be conducted during a three-day session at LLNL, or at remote institutions if appropriate facilities (classroom, compressed gas supply, and pressure testing laboratory) exist.

The hands-on training class starts with a full day of classroom instruction covering essential topics of pressure system assembly and operation (Table 1). Classroom instruction focuses on identifying hazards, safety precautions, personal protective equipment, and pressurized hydrogen system components and their function. This class greatly expands the descriptions from the Web-based hydrogen safety class, going into detailed operational information about every component in pressure systems, describing their inner functionality, applicability, and recommended use. Teaching is aided by segmented components that reveal their inner operational details (Figure 1). At the end of classroom instruction, students will be able to identify (i) the main hydrogen pressure system components, (ii) pressure and hydrogen based hazards, (iii) the types of personal protective equipment that are used for pressurized hydrogen systems, and (iv) the pressurized hydrogen system component categories and their functions. In the final activity of the day, students are tested on the class materials.

Days two and three will be spent in the laboratory for practical application of the classroom information from day one. On day two, students will be handed a safety document and instructed to assemble the pressure system described therein (Figure 2). Students will have to select, inspect and install pressure components, bend tube, install pipe and compression fittings, and assemble the entire system.

On day three this system will be leak checked with a mass spectrometer helium leak detector with a leak rate of no more than 1.0×10^{-5} atm-cc/sec helium. The pressure system will then be connected to the data acquisition system and pressure tested remotely at 150% of the maximum allowable working pressure. The last leak test will be conducted using liquid leak detection fluid at the system's maximum operating pressure. Finally, the students will operate the system to reach a desired pressure.

TABLE 1. Hands-On Safety Class Structure

	Modules
Day 1	**Classroom Teaching**
	1. Definitions 2. Hazards 3. Personal Protective Equipment 4. Gas Cylinders 5. Gas Cylinder Manifold 6. Pressure Reducing Regulators 7. Gauges/Pressure Transducers 8. Regulator Safety Manifold 9. Relief Devices 10. Valves 11. Fittings 12. Tubing and Piping 13. Flash Arrestors 14. Quiz
Day 2	**Pressure system assembly**
	Given a system schematic and description, select components, inspect and install, cut and bend tube, apply various fittings, and assemble full system
Day 3	**System leak test and operation**
	Leak test using a mass spectrometer leak detector; setup data acquisition; conduct remote pressure test; leak test at maximum operating pressure using leak detection fluid; operate system to reach a desired pressure

During the two days of laboratory work, students will be tested as they build and test the system. On day two, tests will focus on correct system assembly (select appropriate components, inspect them, install them in the right place, bend tubing correctly, install plumbing at the correct place, and install pipe and compression fittings). On day three, students will be tested during leak checks and necessary system rebuilds to meet the leak test criterion. At the end of day three, based on the successful completion and testing of the assembled panel, students will be awarded a Certificate of Completion for "LLNL Hands-On Hydrogen Safety Training".

The hands-on class is still under development. Two working benches and instructional materials including segmented pressure components (regulators, valves, gauges, Figure 1) have been prepared as teaching materials to best instruct component function. Classroom instruction materials are being prepared.

Conclusions and Future Directions

LLNL is contributing to safe hydrogen operations by developing instructional materials for researchers and technical operators:

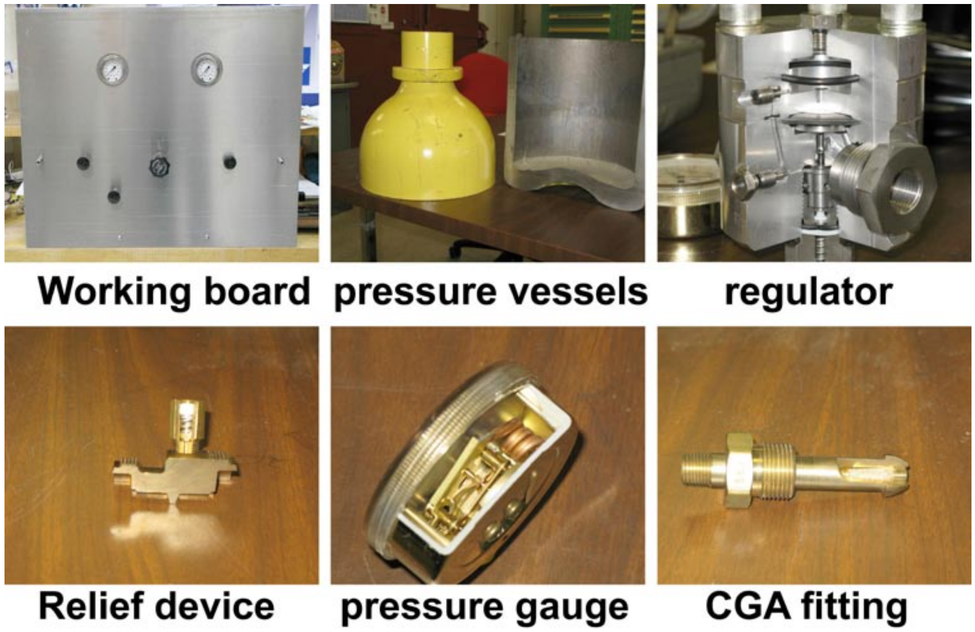

FIGURE 1. Working board and different pressure components segmented to illustrate internal structure and operability.

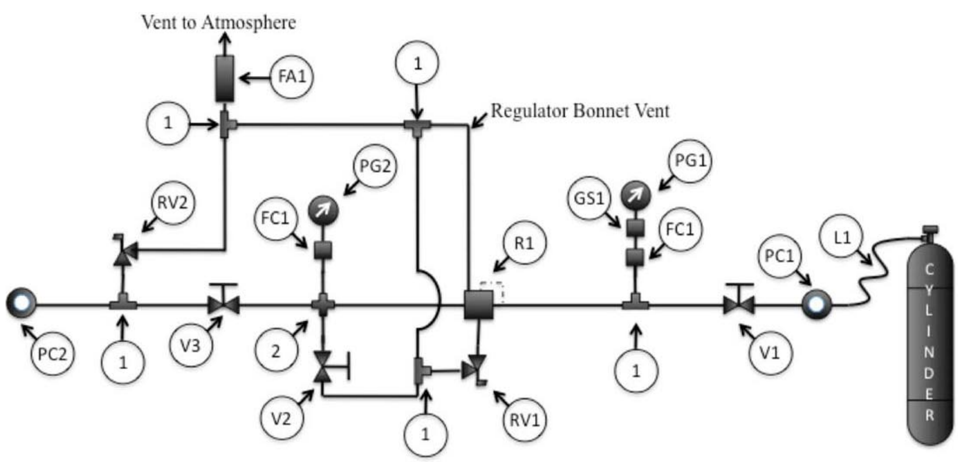

FIGURE 2. Piping and instrumentation diagram for the pressure system to be assembled during the hands-on hydrogen safety class.

- *Laboratory researchers* can obtain basic hydrogen safety information from a 4-hour Web-based class (free online access at http://www.h2labsafety.org/) addressing hydrogen fundamentals: properties, pressure and cryogenic safety, emergency response and codes and standards.
- *Technical operators* in charge of building and testing experimental hydrogen equipment require more in-depth information than provided by the Web-based class. We are therefore preparing a 3-day hands-on safety class that presents detailed information for installation, testing, and operation of hydrogen pressurized systems. The hands-on class includes a full day of classroom instruction followed by two days of laboratory work where students assemble, test and operate a pressure system based on a schematic and component description.

We strongly encourage participation of the members of the hydrogen community to improve the technical and educational aspects of the class by providing feedback and comments.

FY 2011 Publications/Presentations

1. Aceves, S.M., Espinosa-Loza, F., Petitpas, G., Ross, T.O, and Switzer, V.A., "Hydrogen Safety Training for Researchers and

Technical Personnel," Accepted for Publication, International Conference on Hydrogen Safety, San Francisco, CA, 2011.

2. Petitpas, G., Aceves, S.M., "Modeling of Sudden Hydrogen Expansion from Cryogenic Pressure Vessel Failure," Accepted for Publication, International Conference on Hydrogen Safety, San Francisco, CA, 2011.