VIII.0 Safety, Codes & Standards Sub-Program Overview

INTRODUCTION

The Safety, Codes and Standards sub-program identifies and performs high priority research and development (R&D) that provides an experimentally validated, fundamental understanding of the relevant physics, critical data, and safety information needed to define the requirements for technically sound and defensible codes and standards. This information is used to facilitate and enable the widespread deployment and commercialization of hydrogen and fuel cell technologies. In Fiscal Year (FY) 2017, the sub-program continued to identify and evaluate safety and risk management measures that can be used to define the requirements and close the gaps in codes and standards in a timely manner.

The sub-program promotes collaboration among government, industry, codes and standards development organizations, universities, and national laboratories in an effort to harmonize regulations, codes, and standards (RCS) both internationally and domestically. Communication and collaboration among codes and standards stakeholders, the Federal government, industry, national labs, and trade associations is emphasized in order to maximize the impact of the sub-program's efforts and activities in international RCS development. To support these efforts, in FY 2017 the Inter-Laboratory Research Integration Group was created to identify research needs across the national laboratories, which can be integrated into science-based revisions of NFPA 2 (National Fire Protection Association's hydrogen technologies code) and other hydrogen RCS.

GOALS

The sub-program's key goals are to provide the validated scientific and technical basis required for the development of codes and standards, to promulgate safety practices and procedures to allow for the safe deployment of hydrogen and fuel cell technologies, and to ensure that best safety practices are followed in Hydrogen and Fuel Cells Program activities.

OBJECTIVES

The sub-program's objectives are to:

- Support and facilitate development and promulgation of essential codes and standards to enable widespread deployment and market entry of hydrogen and fuel cell technologies and completion of all essential domestic and international RCS.
- Conduct R&D to provide critical data and information needed to define requirements in developing codes and standards.
- Ensure that best safety practices underlie research, technology development, and market deployment activities supported through DOE-funded projects.
- Develop and enable widespread sharing of safety-related information resources and lessons learned with first responders, authorities having jurisdiction, and other key stakeholders.

FY 2017 TECHNOLOGY STATUS AND ACCOMPLISHMENTS

The sub-program continues to support R&D to provide the scientific basis for codes and standards development, with projects in a wide range of areas, including fuel specification, separation distances, materials and components compatibility, and hydrogen sensor technologies. Utilizing the results from these R&D activities, the sub-program continues to actively participate in discussions with standards development organizations such as the National Fire Protection Association (NFPA), the International Code Council, SAE International, the CSA Group, and the International Organization for Standardization to promote domestic and international collaboration and harmonization of RCS. The sub-program has also collaborated with the National Institute for Standards and Technology, specifically on the standard for hydrogen metering accuracy. Previously, the standard was unachievable with current technology; however, as a result of collaborations between the National Renewable Energy Laboratory and the National Institute for Standards and Technology and through support by the State of California, a modified hydrogen metrology standard

of 5% was accepted in FY 2017, which will incrementally decrease to allow for technology improvements over the next several years.

In FY 2017, the sub-program built on results from the previous year, specifically by releasing the Hydrogen Risk Assessment Model (HyRAM) version 1.1 for public use. HyRAM enables quantitative risk assessment and performance-based design, while also incorporating hydrogen behavior models that were developed through the sub-program. Version 1.1 has improved capabilities including reductions in processing time and expanded models. In addition, model development and validation was begun for cryogenic hydrogen releases in the newly built cryogenic laboratory to help inform separation distances for liquid hydrogen. Finally, risk assessment was applied to real-world scenarios for the use of fuel cell electric vehicles in tunnels, and a risk analysis framework was developed and scenarios of concern identified.

The sub-program continues to advance its materials R&D for both metallic and non-metallic hydrogen compatibility. For metallic materials, the testing burden for qualification in high-pressure service was reduced through a performance-based fatigue metric proposed to the SAE Fuel Cell Safety Task Force. Last year's stakeholder feedback on non-metallic materials helped to identify polymers and elastomers of interest, leading to tribology testing to evaluate performance in high-pressure hydrogen. In the area of fuel quality assurance, the prototype in-line fuel quality analyzer developed at Los Alamos National Laboratory demonstrated its capability of detecting low carbon monoxide concentrations (<50 ppm) in dry hydrogen.

The sub-program continues to utilize the expertise of the Hydrogen Safety Panel to disseminate relevant information and implement safe practices pertaining to the operation, handling, and use of hydrogen and fuel cell technologies. The Safety Panel, with over 400 years of experience in the hydrogen industry, provides recommendations on the safe conduct of DOE-funded project work and non-DOE efforts, as well as lessons learned and best practices that can be of broad benefit to the sub-program. Furthermore, the State of California has leveraged the Safety Panel as a resource in their 2017 Grant Funding Opportunity. The sub-program continues to share current safety information and knowledge with the community through the continued development of resources for the Hydrogen Tools Portal (http://h2tools.org) which serves as a centralized resource for hydrogen safety information, news, and user-specific content. In FY 2017, the Hydrogen Equipment Certification Guide was made available for public download, and the Hydrogen Tools Portal expanded its resources, adding the Hydrogen Analysis Resource Center, as well as presentations and papers from the International Conference on Hydrogen Safety.

The sub-program continued to make progress in several key areas, including the following.

Hydrogen Behavior, Risk Assessment (Sandia National Laboratories)

- Publically released the HyRAM 1.1 software for risk analysis of hydrogen infrastructure systems, which benefits from improved capabilities such as reduced computing time. HyRAM capabilities were expanded by adding new models, such as three-dimensional positioning for flame targets, improved flame modeling, updated heat flux radiation modeling, and a TNT Mass Equivalence[1] calculator.
- Developed a new analytical technique to simultaneously measure cryogenic hydrogen concentration and mixture temperature, providing high-quality data for model validation. This project also initiated the validation process by comparing the data to an existing model of cold hydrogen dispersion that will be used for risk assessment and to provide the scientific basis for risk-informed safety distances.

Materials Compatibility (Sandia National Laboratories, Pacific Northwest National Laboratory, Oak Ridge National Laboratory)

- Documented fracture and fatigue performance of high hardenability pressure vessel steels in high-pressure hydrogen, showing that these alloys perform similarly to the pressure vessel steels currently used for stationary storage. Also proposed a performance-based fatigue metric for qualifying materials for high-pressure service to the SAE Fuel Cell Safety Task Force, significantly reducing the testing burden for materials qualification, as well as supporting the Global Technical Regulation 13 Phase II effort. Identified four polymers and elastomers of interest (Viton™, ethylene propylene diene monomer, nitrile, polytetrafluoroethylene), temperature and pressure of interest, and tests of interest through feedback from 25 stakeholders.

[1] TNT equivalent is a convention for expressing energy, which defines a "ton of TNT" as being equivalent to 4.184 gigajoules, which is the approximate energy released in the detonation of a metric ton of trinitrotoluene (TNT).

Hydrogen Quality (Los Alamos National Laboratory)

- Continued a parametric study of impurities to quantify carbon monoxide (CO) and hydrogen sulfide tolerance levels of low-loaded membrane electrode assemblies (0.15 mg Pt/cm^2), in order to establish data sets to assist in the advancement of developing predicative mechanistic models.
- Developed an in-line fuel quality analyzer prototype (patent applied for) and demonstrated its capability of detecting low CO concentrations (<50 ppm) in dry hydrogen. Additional performance capabilities include demonstrated CO sensitivity of less than 50 ppm, a demonstrated response time of less than 10 min, and demonstrated sustained operation under dry hydrogen for over one month.

Coordination of Codes and Standards Development, Domestic and International, and Codes and Standards Outreach (Sandia National Laboratories, National Renewable Energy Laboratory, Fuel Cells and Hydrogen Energy Association)

- Performed calculations and risk analysis for revised bulk gaseous separation distances using revised risk criteria for adoption by the NFPA 2/55 technical committees, which will enable more sites to readily accept hydrogen infrastructure.
- Developed risk analysis framework and identified scenarios of concern for tunnel access for hydrogen fuel cell electric vehicles. Completed computational fluid dynamics and heat transfer models to evaluate hydrogen fire impact on steel structure and concrete in passenger vehicle tunnels. Submitted proposal to NFPA 52 technical committee on characterizing hydrogen releases in tunnels.
- Created the Inter-Laboratory Research Integration Group to integrate research across the DOE laboratories into NFPA 2 and other hydrogen codes and standards. Submitted key proposals through the Inter-Laboratory Research Integration Group to NFPA 2 on adding flexibility to the bulk liquid hydrogen storage requirements.
- Supported the Telecommunications Industry Association publication of its Reference Guide to Regulations, Codes, and Standards for the Deployment of Stationary Fuel Cells.

Hydrogen Safety Panel, Databases, Props, and First Responders (Pacific Northwest National Laboratory)

- The Hydrogen Safety Panel conducted 33 project reviews (including safety plans and project designs) from July 2016 to July 2017.
- Provided four first responder training classes at three locations in the northeastern United States with approximately 250 attendees.
- Published the completed Hydrogen Equipment Certification Guide for public download in January 2017. Expanded available resources on the Hydrogen Tools Portal (http://h2tools.org), adding the Hydrogen Analysis Resource Center and presentations and papers from the International Conference on Hydrogen Safety.

Hydrogen Sensors (National Renewable Energy Laboratory)

- Co-organized a Hydrogen Sensor Workshop entitled "Hydrogen Safety Sensors and Their Use in Applications with Hydrogen as an Alternative Fuel," in collaboration with the European Joint Research Centre and the Fuel Cell and Hydrogen Joint Undertaking. In this workshop, critical gaps in hydrogen safety sensor performance were identified, and the resulting gap analysis is to be presented at the 7th International Conference on Hydrogen Safety.
- Developed a prototype analyzer to verify that hydrogen levels in fuel cell electric vehicle exhaust are within the regulated levels as prescribed by the Global Technical Regulation No. 13. The exhaust analyzer will ultimately be used by the U.S. Department of Transportation's National Highway Traffic Safety Administration for compliance verification.

BUDGET

The sub-program received an appropriation of $7 million in FY 2017. FY 2017 funding has allowed for continued support of codes and standards related R&D and of the domestic and international collaboration and harmonization efforts for codes and standards that are needed to support the commercialization of hydrogen and fuel cell technologies. The Safety Research and Development category includes such activities as hydrogen behavior, risk assessment and mitigation, materials compatibility, hydrogen fuel quality, metering, sensors, and component testing. The Safety Resources and Support category includes the Hydrogen Safety Panel, databases, training, and props. The Codes and Standards Support and Harmonization category includes codes and standards and permitting activities, continuous codes and standards improvement, and resource dissemination.

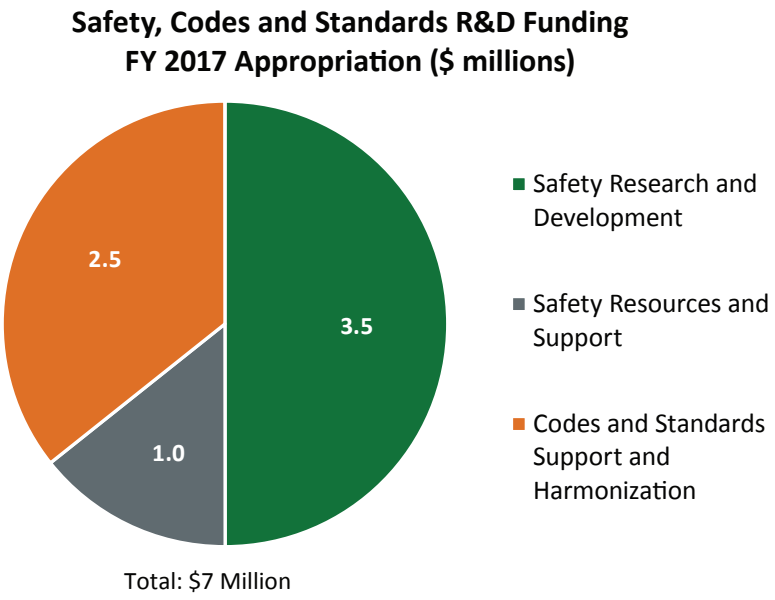

FIGURE 1. FY 2017 Appropriations

UPCOMING ACTIVITIES AND PLANS

The Safety, Codes and Standards sub-program will continue to support rigorous technical R&D—including assessment of materials compatibility for component designs and high-pressure tank cycle testing—and continue to promote a performance-based quantitative risk assessment approach to analyze risks and establish protocols to identify and mitigate risk. The sub-program will continue to work with codes and standards development organizations to ensure that the R&D performed enables science-based hydrogen-specific codes and standards.

The sub-program will also continue to perform the R&D necessary to promote the domestic and international harmonization of test protocols for qualification and certification as well as the harmonization of RCS for hydrogen fuel quality and other key international standards. This harmonization will be enabled by providing R&D results to the appropriate domestic and international organizations such as the NFPA, the International Code Council, SAE International, the CSA Group, and the International Organization for Standardization. Future activities are subject to appropriations.

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