Safety, Codes and Standards Subprogram Overview

INTRODUCTION

The Safety, Codes and Standards subprogram identifies and performs research and development (R&D) that provides a fundamental understanding of the relevant physics, critical data, and safety information used to develop and revise technically sound and defensible codes and standards. These codes and standards provide the technical basis to facilitate and enable the safe deployment and commercialization of hydrogen and fuel cell technologies in multiple applications. The subprogram identifies and evaluates safety and risk management measures that can be used to define requirements and close the gaps in codes and standards in a timely manner. Additionally, the subprogram promotes collaboration among government, industry, codes and standards development organizations (CDOs and SDOs), universities, and national laboratories in an effort to harmonize regulations, codes, and standards (RCS) both internationally and domestically. An emphasis on communication and collaboration among codes and standards stakeholders, the federal government, industry, and national labs maximizes the impact of the subprogram's R&D.

GOALS

The subprogram'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 subprogram's key 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 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 2019 TECHNOLOGY STATUS AND ACCOMPLISHMENTS

The subprogram continues to perform R&D to provide the scientific basis for codes and standards development with projects in a wide range of areas, including hydrogen behavior, hazard analysis, materials and components compatibility, and hydrogen sensor technologies. Using the results from these R&D activities, the subprogram continues to actively participate in discussions with SDOs such as the National Fire Protection Association (NFPA), the International Code Council (ICC), SAE International, the CSA Group, and the International Organization for Standardization (ISO) to promote domestic and international collaboration and harmonization of RCS.

A number of codes and standards relevant to the hydrogen industry were published or revised during Fiscal Year (FY) 2019. These RCS are listed below[1]:

- NFPA 2 Hydrogen Technologies Code, 2020 Edition (published June 2019)

[1] The full text of the listed RCS can be found at their respective CDO and SCO websites: ISO (https://www.iso.org/home.html); SAE International (https://www.sae.org/); International Electrochemical Commission (https://www.iec.ch/); American National Standards Institute (https://www.ansi.org/), and NFPA (https://www.nfpa.org/).

- NFPA 55 Compressed Gases and Cryogenic Fluids Code, 2020 Edition (published April 2018)
- ISO 17519 Gas cylinders — Refillable permanently mounted composite tubes for transportation (published June 2019)
- ISO 19881 Gaseous hydrogen — Land vehicle fuel containers (published October 2018)
- ISO 19882 Gaseous hydrogen — Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers (published November 2018)
- ISO 21087 Gas analysis — Analytical methods for hydrogen fuel — Proton exchange membrane (PEM) fuel cell applications for road vehicles (published June 2019)
- ISO 21266-1 Road vehicles — Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel systems — Part 1: Safety requirements (published October 2018)
- ISO 21266-2 Road vehicles — Compressed gaseous hydrogen (CGH2) and hydrogen/natural gas blends fuel systems — Part 2: Test methods (published October 2018)
- CSA/ANSI HGV 2-2014 (R2019) Compressed hydrogen gas vehicle fuel containers (reaffirmed March 2019)
- CSA/ANSI HGV 3.1-2015 (R2019) Fuel system components for compressed hydrogen gas powered vehicles (reaffirmed February 2019)
- CSA/ANSI HGV 4.2-2013 (R2019) ANSI/CSA HGV 4.2-2013 — Hoses for compressed hydrogen fuel stations, dispensers and vehicle fuel systems (reaffirmed February 2019)
- CSA/ANSI HGV 4.3-2019 Test methods for hydrogen fueling parameter evaluation (published July 2019)
- CSA/ANSI HGV 4.10-2012 (R2019) Standard for fittings for compressed hydrogen gas and hydrogen rich gas mixtures (reaffirmed February 2019)
- SAE J3089_201810 Characterization of On-Board Vehicular Hydrogen Sensors (published October 2018).

The H2Tools website[2] provides up-to-date information relevant to the status of the subprogram's activities and enables dissemination of key safety knowledge resources, including several that were updated in FY 2019:

- Safety Planning for Hydrogen and Fuel Cell Projects (updated in FY 2019)
- Hydrogen Lessons Learned Database (updated in FY 2019)
- Codes and Standards—Permitting Tools, including the National Permitting Guide (Standard Permitting Template added in FY 2019).

In FY 2019, the Safety, Codes and Standards subprogram continued to make progress in several key areas, including hydrogen behavior and risk assessment, and demonstrating a novel laser diagnostic with the ability to measure hydrogen concentrations at a distance of 40 feet. Cryogenic hydrogen behavior validation using this diagnostic technique is expected to enable modifications to the bulk liquid hydrogen storage separation distances in the next edition of NFPA 2.

In the area of hydrogen safety, Pacific Northwest National Laboratory (PNNL) partnered with the American Institute of Chemical Engineers (AIChE) to establish the Center for Hydrogen Safety (CHS), thus enabling long-term sustainability and broader impact of key safety resources. The subprogram continued to make progress in the areas of materials compatibility, hydrogen fuel quality assurance, and codes and standards harmonization. Some of the project accomplishments are highlighted below.

[2] H2Tools, http://h2tools.org.

Hydrogen Behavior, Risk Assessment (Sandia National Laboratories [SNL])

- Integrated quantitative risk assessment (QRA) flexibility into the Hydrogen Risk Assessment Model (HyRAM) by enabling users to directly input external fault tree results. This allows the model to incorporate outside information and applications beyond refueling stations.
- Obtained an open-source license for HyRAM 2.0 and released installer and source code to the public. This allows users and researchers to avoid a lengthy licensing process, view and verify models, and contribute improvements to HyRAM.
- Worked with the NFPA 2/55 bulk hydrogen storage task group to develop an improved leak frequency estimation method, supporting improved risk assessments and code requirements for liquid hydrogen stations.
- Developed and demonstrated (in the laboratory) a novel laser diagnostic that can measure cryogenic hydrogen concentrations from a standoff distance of 40 feet, which could be applied to vent stack releases and large pooling and vaporization scenarios.

Hydrogen Sensors (National Renewable Energy Laboratory [NREL])

- Designed, built, and demonstrated an analyzer for verifying that hydrogen levels in fuel cell electric vehicle (FCEV) exhaust are within the levels prescribed by Global Technical Regulation No. 13. Demonstrated the analyzer on a commercial FCEV in collaboration with Environment and Climate Change Canada.
- Quantitatively characterized the behavior of indoor hydrogen releases using computational fluid dynamic models. This data set was used to (1) improve our understanding of the effects of forced vs. on-demand ventilation on indoor hydrogen dispersions and (2) develop preliminary guidance for strategies on indoor sensor placement.
- Deployed Hydrogen Wide Area Monitoring (HyWAM) to characterize liquid hydrogen releases at the Health and Safety Executive test site in the United Kingdom for use in profiling cold hydrogen dispersions during releases.

Hydrogen Quality (Los Alamos National Laboratory [LANL])

- Demonstrated successful field operation of LANL's hydrogen contaminant detector (HCD) technology with an external humidification system.
- Down-selected a polybenzimidazole-based membrane to eliminate external humidification from the LANL HCD design.
- Determined that the new HCD design demonstrated a stable baseline current response in clean hydrogen, even when the flowrate was varied.

Hydrogen Safety Panel, Databases, and First Responders (PNNL)

- Partnered with AIChE to establish the CHS, thus enabling long-term sustainability and broader impact of the Hydrogen Safety Panel, first responder training, and safety knowledge resources.
- Conducted 16 reviews (including safety plans and project designs) to support the safe implementation of DOE Fuel Cell Technologies Office project activities.
- Provided stakeholder and educational sessions in Massachusetts, Maryland, New Jersey, and New York. The sessions were attended by code officials, energy policy makers, project proponents, and others interested in the deployment of hydrogen and fuel cell technology. Approximately 150 persons attended the sessions.

Materials Compatibility (SNL, PNNL, Oak Ridge National Laboratory)

- The ASME Boiler and Pressure Vessel Code, Section VIII committee accepted Code Case 2938 that formalizes design curves for seamless Cr-Mo and Ni-Cr-Mo pressure vessel steels (SA-372 and SA-723) in gaseous hydrogen, which improves the design basis for high-pressure vessels.

- Demonstrated fatigue crack growth results near threshold in gaseous hydrogen for the first time, suggesting a pathway to quantify fatigue threshold in high-pressure gaseous hydrogen.
- The SAE Fuel Cell Standards Committee approved standard SAE J2579 with a performance method for materials evaluation; the project team led international consensus on the evaluation method, which is being contributed to Global Technical Regulation No. 13 Phase 2.
- Conducted advanced ex situ imaging of model elastomer materials after hydrogen exposure to elucidate damage mechanisms, and determined that: (1) the compression set in nitrile butadiene rubber material compounds is significant (with nearly a 40% increase after high-pressure hydrogen exposure) while ethylene propylene diene monomer rubber is not significantly affected; (2) high-pressure hydrogen exposure can increase plasticizer mobility; and (3) zinc oxide or zinc sulfide particles appear to nucleate nano to micro voids after high pressure hydrogen exposure.
- Developed a mesoscale model for investigating gas bubble expansion and polymer volume change during rapid decompression and made significant progress in developing the molecular dynamics model.

Coordination of Codes and Standards Development, Domestic and International, and Codes and Standards Outreach (SNL, NREL, Fuel Cell and Hydrogen Energy Association)

- Developed new permitting and codes and standards training tools for hydrogen technologies deployment that includes an overview of NFPA 2 at H2Tools.org.

BUDGET

The subprogram received an appropriation of $7 million in FY 2019. FY 2019 funding provided continued support for codes-and-standards-related R&D as well as domestic and international RCS collaboration and harmonization efforts that are essential for the safe and timely deployment of hydrogen and fuel cell technologies. Figure 1 shows subprogram funding in FY 2019.

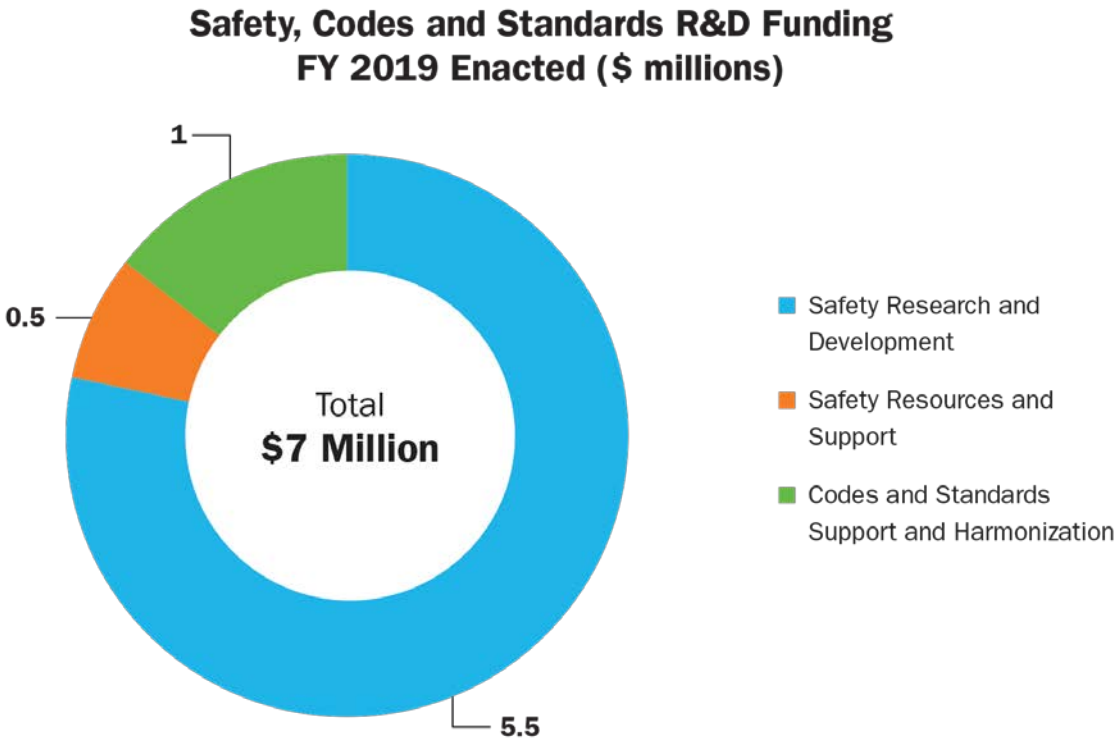

Figure 1. Safety, Codes and Standards subprogram FY 2019 enacted budget

The Safety Research and Development category includes hydrogen behavior R&D, risk assessment, and modeling and validation R&D; metallic and non-metallic materials compatibility R&D for hydrogen service; and hydrogen sensor, fuel quality, and station R&D to enable footprint reduction. The Safety Resources and Support category includes the Hydrogen Safety Panel and safety knowledge resources. The Codes and Standards Support and Harmonization category includes work to integrate R&D learnings into codes and standards and support of international harmonization of RCS.

UPCOMING ACTIVITIES AND PLANS

In FY 2020, the Safety, Codes and Standards subprogram will continue to support R&D to enable safe deployment of hydrogen technologies through materials compatibility R&D, hydrogen behavior and risk R&D, component failure R&D, safety R&D, and hydrogen fuel quality analysis. The subprogram will continue to work with CDOs and SDOs to ensure that the R&D performed enables science-based hydrogen-specific codes and standards.

The subprogram will also continue to perform R&D necessary to promote the domestic and international harmonization of test protocols as well as the harmonization of RCS for hydrogen fuel quality and other key international standards. This will be enabled by working with the appropriate domestic and international organizations such as the NFPA, ICC, SAE International, the CSA Group, and ISO.

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