Safety, Codes and Standards Subprogram Overview

INTRODUCTION

The Safety, Codes and Standards subprogram identifies and performs early-stage 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 scientific basis to facilitate and enable the safe widespread deployment and commercialization of hydrogen and fuel cell technologies. 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 early-stage R&D.

In fiscal year (FY) 2018, the Safety, Codes and Standards subprogram continued to make substantial progress in the area of hydrogen behavior and risk assessment, completing validation of the ColdPlume model for cryogenic hydrogen behavior using a world-first imaging diagnostic. This validation, combined with modeling and other experimental data, will ultimately enable a reduction in the separation distance requirements in current editions of the code.[1] To expand on this progress, experimental designs were completed for large-scale optical measurement of the concentration of hydrogen from real-world releases. The diagnostic is expected to provide key measurements of liquid hydrogen vent stack dispersion and vaporization profiles from liquid hydrogen pools. In the area of hydrogen sensing, an updated gap analysis identified critical R&D gaps while validated computational fluid dynamic models enabled profiling of indoor hydrogen releases for an improved understanding of indoor hydrogen dispersion. The subprogram also made significant progress in the area of materials compatibility R&D. A newly developed universal design curve for pressure vessel steels will enable pressure vessel design for high-pressure hydrogen service without further testing requirements. Metallic materials compatibility R&D enabled a test methodology proposal to the UN Global Technical Regulation (GTR) 13 Phase II Working Group. A testing program for model elastomer compounds led to the development of a first-of-its-kind database of the behavior of various polymers for hydrogen service. In hydrogen safety, a new partnership with the American Institute of Chemical Engineers to establish the Center for Hydrogen Safety will broaden the impact of the Hydrogen Safety Panel and safety knowledge resources.[2] Other critical R&D areas that made progress in FY 2018 include hydrogen fuel quality R&D, work to enable the integration of R&D with the domestic and international codes and standards community, and activities that support the H2@Scale initiative through RCS development.

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.

[1] NFPA 2: Hydrogen Technologies Code, 2016 Edition, https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=2

[2] The Center for Hydrogen Safety, https://www.aiche.org/CHS

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 early-stage 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 2018 TECHNOLOGY STATUS AND ACCOMPLISHMENTS

The subprogram continues to perform early-stage R&D to provide the scientific basis for codes and standards development with projects in a wide range of areas, including fuel specifications, separation distances, 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 developed or revised during FY 2018. These RCS are listed below[3]:

- ISO 19880-3:2018 Gaseous hydrogen – Fueling stations – Part 3: Valves (published June 2018)
- ISO 16111:2018 Transportable gas storage devices – Hydrogen absorbed in reversible metal hydride (published August 2018)
- SAE J2579: Standard for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles (revised June 15, 2018)
- IEC 62282-5-100 Portable Fuel Cell Power Systems – Safety: Ed 3 (published April 2018)
- SAE J3089: Characterization of On-board Vehicular Hydrogen Sensors Technical Information Report (passed second ballot in FY2018)
- ANSI FC 5 – CSA ballot for U.S. adoption of ISO 16110: Portable Hydrogen Generators (approved and published in mid-2018).

The H2Tools website[4] provides up-to-date information relevant to the status of the subprogram's activities and enables dissemination of key safety knowledge resources, including:

- Technical Reference for Hydrogen Compatibility of Materials

[3] The full text of the RCS listed can be found at their respective CDO and SCO websites: International Organization for Standardization (https://www.iso.org/home.html); SAE International (https://www.sae.org/); International Electrochemical Commission (https://www.iec.ch/); and the American National Standards Institute (https://www.ansi.org/).
[4] H2Tools, http://h2tools.org

- Safety Planning for Hydrogen and Fuel Cell Projects
- Hydrogen Lessons Learned Database
- Hydrogen Safety Best Practices Manual
- National Hydrogen and Fuel Cell Emergency Response Training Resource
- Introduction to Hydrogen for Code Officials
- Hydrogen Safety for First Responders
- Codes and Standards – Permitting Tools, including the National Permitting Guide.

SAFETY, CODES AND STANDARDS ACCOMPLISHMENTS

In FY 2018, the Safety, Codes and Standards subprogram continued to make progress in several key areas. Some of the highlights are described below.

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

- Published a report documenting a hydrogen fuel cell electric vehicle (FCEV) tunnel safety study, which provided a scientific basis for allowing FCEVs in tunnels. The report is intended to enable the adoption of FCEVs in the northeast region.
- Completed a draft of the Hydrogen Risk Assessment Model (HyRAM) 2.0, which includes the customization of quantitative risk assessment analysis and will expand HyRAM capabilities beyond indoor refueling stations.
- Signed a cooperative research and development agreement with FirstElement Fuel to demonstrate a performance-based approach to a hydrogen refueling station design.
- Completed validation of the ColdPlume model with model comparisons to data collected using a unique, world-first, cryogenic hydrogen imaging diagnostic for 15 experimental release conditions, including five conditions with simultaneous velocity data. The validated model can be used to predict hazard distances from liquid hydrogen system leaks.
- Developed an optical design for light collection for a large-scale diagnostic enabling the measurement of hydrogen concentration for real-world releases from a stand-off distance of at least 20 ft. This first-of-its-kind diagnostic will be used to measure liquid hydrogen vent stack dispersion and vaporization profiles from liquid hydrogen pools. The data will be used to validate models and enable reductions to liquid hydrogen fueling station footprints.

Hydrogen Sensors (National Renewable Energy Laboratory [NREL])

- Filed a provisional patent (NREL Prov 17-94A: Interface for a High-Pressure Hydrogen Dispenser, 2018, W. Buttner and K. Harrison) that specifically addresses a means to provide gas samples at low-pressure gas compatible for analysis by all potential on-site hydrogen contaminant detectors.
- Published a gap analysis for hydrogen safety sensors that identified critical gaps in hydrogen safety sensor performance.
- Collaborated with the U.S. Department of Transportation to design, build, and demonstrate an analyzer capable of verifying that hydrogen levels in FCEV exhaust are within the levels as prescribed by GTR 13.

- Profiled indoor hydrogen releases through the development of empirically validated computational fluid dynamic models to enable an improved understanding of indoor hydrogen dispersion. This work is anticipated to be incorporated into NFPA 2 as a guidance document on sensor placement.

- Led the development of SAE Technical Information Report J3089 (Characterization of On-board Vehicular Hydrogen Sensors) under the auspices of the SAE Fuel Cell Standard Committee. The Technical Information Report passed ballot and has been published as a formal SAE document.

Hydrogen Quality (Los Alamos National Laboratory)

- Completed the planning and installation of an inline fuel analyzer in the field (H2Frontier) and conducted on-site baseline measurements while adding wireless capabilities for remote testing.

- Developed a method to create a strategy to externally humidify the analyzer and produce a stable baseline to implement the technology at hydrogen refueling stations where no water is available.

- Demonstrated an analyzer response time of <5 minutes using flow rates of 100 and 200 standard cubic centimeters per minute with 500 parts per billion and 50 parts per million carbon monoxide/hydrogen concentrations. The analyzer's response time is less than the time required to refuel two FCEVs.

- Successfully conducted testing with 200 parts per billion carbon monoxide/hydrogen (SAE level) and met the goal of obtaining a response within 2.5 minutes by adjusting the alarm trigger level.

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

- Partnered with the American Institute of Chemical Engineers to establish the Center for Hydrogen Safety enabling long-term sustainability and broader impact of the Hydrogen Safety Panel and safety knowledge resources.

- Updated the National Hydrogen and Fuel Cell Emergency Response Training Resource in support of in-person training conducted in the Northeast United States in early 2018.

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

- Developed and proposed design curves for American Society of Mechanical Engineers (ASME) pressure vessel steels (applicable to both Cr-Mo and Ni-Cr-Mo steels) to the ASME Pressure Vessel Committee as the basis for a code case that will allow pressure vessel design for high-pressure hydrogen without additional testing burden.

- Performed round-robin testing with international partners to show consistency in fatigue life measurements in high-pressure gaseous hydrogen at low temperature (in context of materials requirements for the SAE J2579 standard).

- Proposed a materials testing methodology for hydrogen compatibility to the UN GTR 13 Phase II Informal Working Group.

- Developed six ethylene propylenediamene (EPDM) and six nitrile butyl rubber (NBR) model compound materials for investigation of hydrogen effects with fillers. Carbon and silica fillers indicated a 10 parts per million hydrogen absorption in the material.

- Performed R&D to determine that the desorption rate of the EPDM polymer is nearly five times faster than the NBR polymer without any additives or fillers. The compression set of NBR was significantly influenced by hydrogen with a 37% increase whereas EPDM compression set was insignificant.

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 2018. FY 2018 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 essential to enable the safe and timely deployment of hydrogen and fuel cell technologies. Figure 1 shows subprogram funding in FY 2018. The Hydrogen Behavior and Risk category includes hydrogen behavior R&D, risk assessment, and modeling and validation R&D. The Materials Compatibility category includes metallic and non-metallic materials compatibility R&D for service in the hydrogen environment. Component R&D includes sensor R&D, hydrogen 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 Harmonization category includes work to integrate R&D learnings into codes and standards, collaboration with the Federal Energy Management Program, and support of international harmonization of RCS.

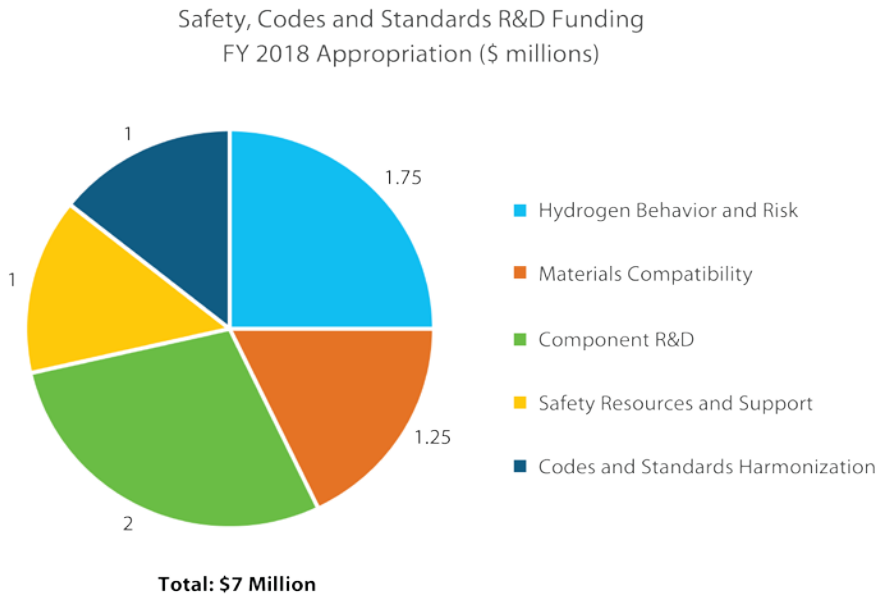

Figure 1. Safety, Codes and Standards subprogram FY 2018 appropriation

UPCOMING ACTIVITIES AND PLANS

The Safety, Codes and Standards subprogram will continue to support early-stage 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 Hydrogen Materials Compatibility Consortium (H-Mat) will launch in FY 2019 to assemble world-class expertise and facilities in materials compatibility R&D at the national laboratories and leverage these

capabilities in priority R&D tasks led by industry and academia. H-Mat has two primary R&D thrusts: hydrogen effects in metals, led by SNL, and hydrogen effects in polymers, led by PNNL.

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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