VIII.10 Enabling Hydrogen Infrastructure Through Science-Based Codes and Standards

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

Overall Objectives

- Enable the growth of hydrogen infrastructure through science and engineering-based codes and standards
- Enable industry-led codes and standards revision and safety analyses by providing a strong science and engineering basis for code improvements
- Eliminate barriers to deployment of hydrogen fuel cell technologies through scientific leadership in codes and standards development efforts

Fiscal Year (FY) 2015 Objectives

- Apply hydrogen-specific quantitative risk assessment (QRA) tools and methods to support code decisions and to enable risk-equivalent code compliance option
- Optimize cost and time for station permitting by demonstration of alternative approaches to code compliance
- Revise/update codes and standards that address critical limitations to station implementation

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Safety, Codes and Standards section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(D) Lack of Hydrogen Knowledge by AHJs (Authorities Having Jurisdiction)

(G) Insufficient Technical Data to Revise Standards

(H) Insufficient Synchronization of National Codes and Standards

(K) No Consistent Codification Plan and Process for Synchronization of R&D and Code Development

Contribution to Achievement of DOE Safety, Codes & Standards Milestones

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

- Milestone 2.8: Publish risk mitigation strategies (2Q, 2014)
- Milestone 2.19: Validate inherently safe design for hydrogen fueling infrastructure (4Q, 2019)
- Milestone 4.7: Complete risk mitigation analysis for advanced transportation infrastructure systems (1Q, 2015)
- Milestone 4.8: Revision of NFPA 2 to incorporate advanced fueling storage systems and specific requirements for infrastructure elements such as garages and vehicle maintenance facilities (3Q, 2016)

FY 2015 Accomplishments

- Developed a template of performance-based design of a hydrogen refueling station which demonstrates the use of QRA methods, promotes safety through the use of performance criteria rather than explicit prescriptive requirements, and enables a risk-informed compliance option
- Initiated a hydrogen mitigations forum that identified and prioritized research and development activities for evaluating and crediting safety features that mitigate hydrogen system risks
- Led the development of ISO TR_19880-1 Gaseous Hydrogen-Fueling Stations Part 1: General Requirements by incorporating QRA and safety assessments into the standard

INTRODUCTION

DOE Fuel Cell Technologies Office has identified safety, codes, and standards as a critical barrier to the deployment of hydrogen, with key barriers related to the availability and implementation of technical information in the development of regulations, codes and standards (RCS). This project provides the technical basis for assessing the safety of hydrogen fuel cell systems and infrastructure using QRA and physics-based models of hydrogen behavior. The risk and behavior tools are used to support both alternate methods of code compliant hydrogen infrastructure as well as direct support of code committees in support of science-based revisions that address critical limitations to refueling station implementation.

This project provides the scientific basis to ensure that code requirements are consistent, logical, and defensible.

APPROACH

State-of-the-art integrated hydrogen behavior and QRA models are applied to relevant technologies and systems to provide insight into the risk level and risk mitigation strategies with the aim of enabling the deployment of fuel cell technologies through revision of hydrogen safety codes and standards. In the short-term focus of providing alternative methods for code compliance, a template demonstrating a credible approach to a performance-based design is developed in order to provide hydrogen information and risk analysis methods to authorities having jurisdiction. This educational effort will enable hydrogen refueling stations that are unable to explicitly meet prescription code requirements to utilize alternate means allowed by the current code. Implementing the template at a real world hydrogen station planned in California will provide precedence for a performance-based design and will allow the cost and schedule for developing this type of station design to be optimized.

Toward the longer term goal of achieving science-based revisions of codes and standards, a mitigations forum of hydrogen experts from industry and research will allow code revisions to account for safety features that are not currently credited in the code requirements. Additionally, a review and revision of the risk-informed code requirements for bulk gaseous hydrogen storage will enable behavior models and technology not available during the 2009 revision to be incorporated in to the risk criteria used to determine these requirements. The bulk liquid hydrogen storage code requirements will also be revised following a similar process once the cold plume release model is validated.

RESULTS

Develop Design Brief to Enable Performance-Based Compliance Option

NFPA 2, Hydrogen Technologies Code, allows for the use of performance-based design (PBD) for hydrogen facilities as a means of complying with the code without strict adherence to the prescriptive code requirements. While Hydrogen Risk Assessment Models (HyRAM) can be used as a means of evaluating the risk of alternate designs, it can also be used to quantitatively evaluate risks associated PBD options. The establishment and demonstration of PBD option will directly increase the availability of locations for hydrogen fueling stations, reduce the effort required by industry to use the PBD approach and lay the groundwork for similar QRA-backed design processes for other alternative fuels. In order to initiate real-world application of science-based risk analysis, a Cooperative Research and Development Agreement was initiated with a major hydrogen fueling station provider.

The HyRAM software was used to calculate the risk metrics for a station that is fully compliant with the prescriptive code requirements in order to establish a baseline for these metrics for a specific station configuration. The performance criteria utilized for each of the required credible scenarios are shown in Figures 1 and 2. Currently, a station design with key modifications to the prescriptive requirements is being evaluated with input from the industry partner for a real-world station that will be processed through the permitting process for a hydrogen station in California. Additionally, lessons learned in applying a performance-based design to a hydrogen refueling station will be used to identify improvements to the current code requirements this type of approach.

Mitigations Forum

With the application of QRA to hydrogen infrastructure, there is a need to characterize and quantify the impact of methods to reduce the risk profile associated with such infrastructure. These methods are commonly referred to as mitigations or safety features. They can be either administrative controls or passive or active engineering controls. Characterizing the risk impacts of these controls is necessary to determine any credit or impact on the separation distances or other code requirements as ongoing code improvements proceed. Currently, a task group under NFPA 2 is actively exploring revisions to the safety distances in the code for bulk liquefied and bulk compressed gaseous hydrogen systems. In order to determine a path forward and identify research gaps, a Hydrogen Mitigations Forum was hosted by SNL.

The forum consisted of a group of hydrogen and risk experts with experience designing and operating hydrogen

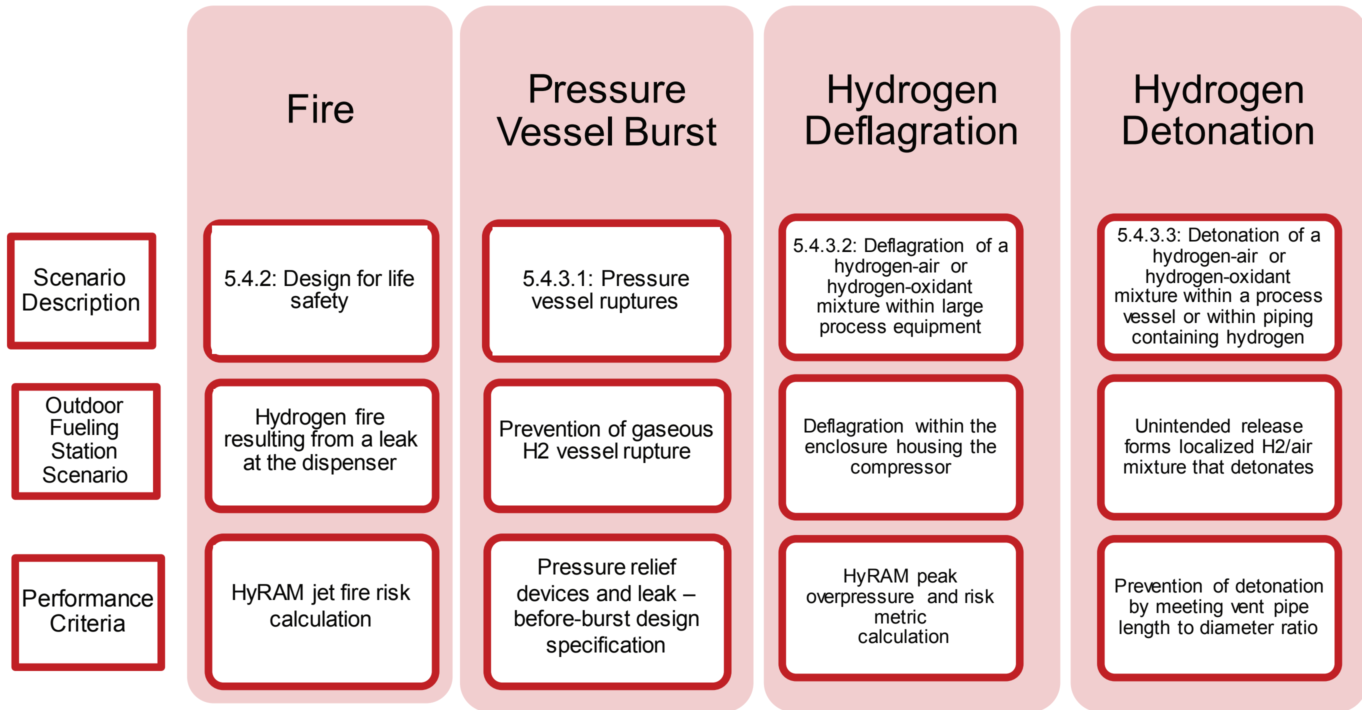

FIGURE 1. Performance criteria utilized for the explosion scenarios in the PBD template

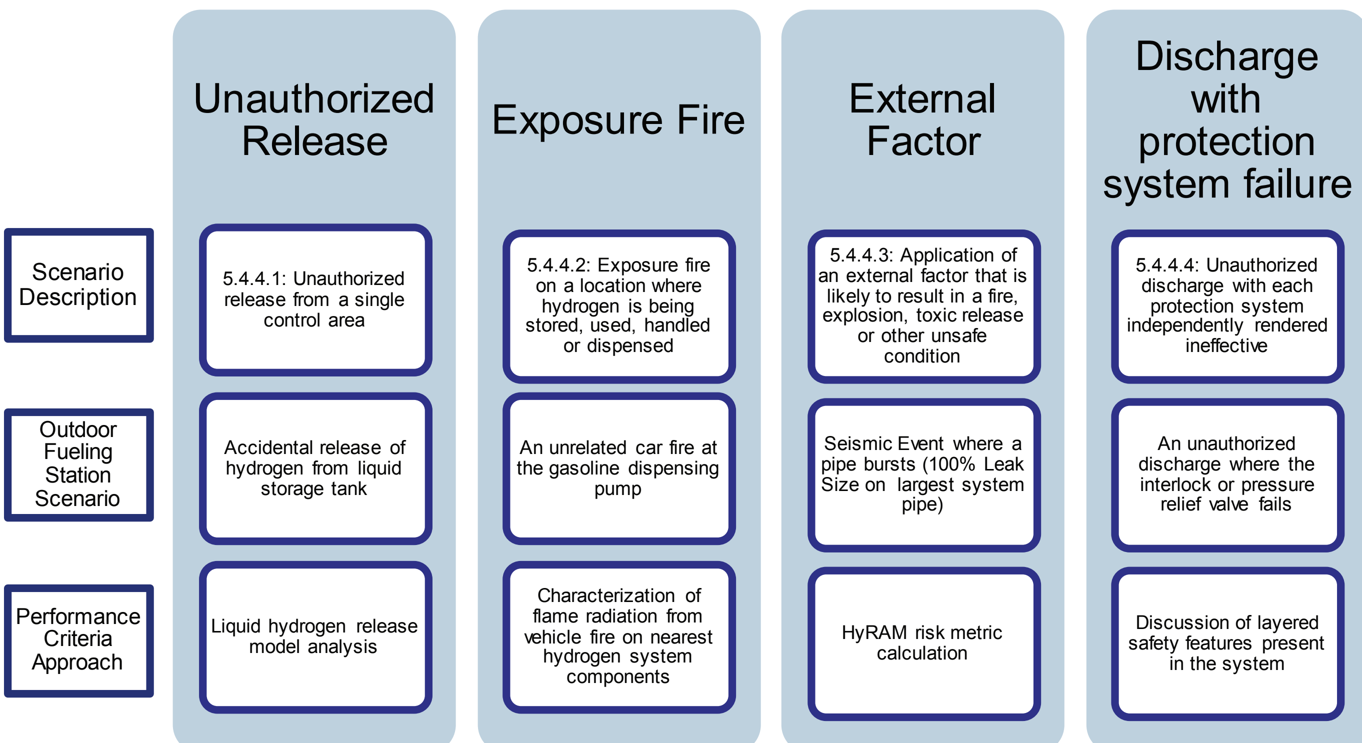

FIGURE 2. Performance criteria utilized for the hazardous material scenarios in the PBD template

systems. Mitigations can be categorized into six groups: release prevention, release detection, release consequence, ignition prevention, ignition detection, and ignition consequence. These groups provide a way to prioritize and credit the safety features based on when they would come into play in a hydrogen release event. It is generally agreed that the closer to the start of an unintentional hydrogen release a feature acts, the smaller the release event and lower potential consequence. In exploring feasible methodologies and strategies for determining these impacts, several gaps in a variety of research areas were identified. In this way, gaps in quantification of risk mitigations can be evaluated and opportunities for advancements in mitigation strategies can be identified. This information will be provided to the code development committees to aid code development activities. Additionally, the gap assessment will provide direction on opportunity to bring science to the code development process, in particular, identification of methods to establish safety credit (e.g., reduction of safety distances) for added mitigations.

Codes and Standards Participation

- CSA HGV 4.9—Hydrogen Fueling Station guidelines has been reviewed by industry and comments received. The CSA standard will be issued following the resolution and dispositioning of all comments and is estimated in FY 2016.
- Hydrogen Safety Panel—SNL participated in several hydrogen safety plan reviews for innovative industrial hydrogen implementations.
- ISO TR-19880-1—SNL has participated in incorporating QRA and safety assessment methodologies into the standard.
- NFPA 2—SNL is providing ongoing technical leadership in the Bulk Hydrogen Storage Task Group of NFPA 2: Hydrogen Technologies Code. The Task group has begun work on revision and update of the prescriptive requirements for both liquefied and gaseous hydrogen separation distances for the next revision cycle of the code.

CONCLUSIONS AND FUTURE DIRECTIONS

- The template for implementing the performance-based approach in NFPA 2 Chapter 5 will be used to demonstrate a credible alternate means of code compliance option and will be utilized as part of the permitting process to demonstrate acceptance of the approach by an authority having jurisdiction.
  - (Future) Extend performance-based design template to other hydrogen application where an alternative solution is needed
- The storage of liquid hydrogen is limited by the existing code requirements and predictive behavior models for liquid hydrogen releases.
  - (Future) Use a validated cold plume release model to characterize the unintended release of liquid-vapor mixed-phase hydrogen releases to revise bulk hydrogen storage code requirements
  - (Future) Identify research gaps in evaluating and prioritizing mitigation features in hydrogen systems
  - (Future) Incorporate recent research and technological advancements into further revisions to the bulk gaseous storage requirements

FY 2015 PUBLICATIONS/PRESENTATIONS

1. LaFleur, C., "Introduction to Hydrogen-Specific Risk Methods and Tools," Presented to Open Public Meeting associated with Hydrogen Safety Panel meeting, March 2, 2015.

2. LaFleur, C., "Performance-Based Approach to Siting Hydrogen Refueling Stations," presentation to DOE H2 CSTT, February 12, 2015.

3. Groth, K.M., "Safety distance working group status update," Presentation to ISO TC197 WG24 sub-team on risk, January 29, 2015.

4. LaFleur, A.C., Muna, A.B., "Draft Fire Protection Engineering Design Brief Template: Hydrogen Refueling Station," Draft Milestone publication, January 2015.

5. LaFleur, C., "Application of Quantitative Risk Assessment (QRA) for Performance-Based Permitting of Hydrogen Fueling Station," Presented at Society of Fire Protection Engineers Annual Meeting, Long Beach, CA, November 14, 2014.

6. San Marchi, C., "Development of Hydrogen Safety Standards in the United States," Presentation at the Workshop on International Trends in Hydrogen Safety Standards, Seoul, Korea, November 14, 2014.

7. Groth, K.M., "Safety distance working group status update," Presentation to ISO TC197 WG24, Munich, Germany, October 13, 2014.

8. Groth, K.M., "Risk-informed method for safety distances," Presentation to ISO TC197 WG24 sub-group on safety distances, Munich, Germany, October 9, 2014.

9. Groth, K.M. "Brief intro to quantitative risk assessment for H_2 C&S." Presentation at ISO TC197, WG24 Meeting, Washington, DC, June 2014.

10. LaFleur, A.C., Muna, A.B., Groth, K.M. "Fire Protection Engineering Design Brief Template: Hydrogen Refueling Station," SAND2015-4500, Sandia National Laboratories, June 2015.

11. LaFleur, A.C., "Enabling Hydrogen Infrastructure Through Science-based Codes and Standards," Presented at the 2015 DOE Hydrogen and Fuel Cells Program and Vehicle Technologies Office Annual Merit Review and Peer Evaluation meeting, June 2015.