VIII.2 Risk-Informed Safety Requirements for H2 Codes and Standards Development

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

Fiscal Year (FY) 2012 Objectives

- Present results of indoor refueling risk assessment to the National Fire Protection Association (NFPA) 2 Fueling Working Group.
- Perform and document required risk assessment (with input from NFPA 2 and others) for developing science-based risk-informed codes and standards for indoor refueling of hydrogen lift trucks or other vehicles.
- Perform scoping risk assessment for accident mitigation features for refueling stations and indoor refueling applications including development of any required data and new methodologies.

This project addresses the following technical barriers from the Safety Codes and Standards section (3.8) of the 2011 Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Safety Data and Information: Limited Access and Availability
(F) Enabling National and International Markets Requires Consistent Regulations, Codes and Standards
(G) Insufficient Technical Data to Revise Standards
(L) Usage and Access Restrictions – parking structures, tunnels and other usage areas

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 Program Multi-Year Research, Development and Demonstration Plan:

- Milestone 2.4: Publish national indoor hydrogen fueling standard. (4Q, 2015)
- Milestone 2.5: Develop holistic design strategies. (4Q, 2017)
- Milestone 2.6: Validate inherently safe design for hydrogen fueling infrastructure. (4Q 2019)
- Milestone 2.9: Publish protocols for identifying potential failure modes (2Q, 2013)
- Milestone 2.10: Publish risk mitigation approaches (2Q, 2014)
- Milestone 2.11: Publish draft protocol for identifying potential failure modes and risk mitigation (4Q, 2014)
- Milestone 2.12: Publish a system for classifying accident types (2Q, 2013)
- Milestone 2.13: Publish a methodology for estimating accident likelihood (2Q, 2013)
- Milestone 2.14: Release a report of the most common accident scenarios (4Q, 2013)

FY 2012 Accomplishments

- Presented results of risk assessment for indoor fueling to NFPA 2 Fueling Working Group. While code development is an iterative discussion among the committee members, this accomplishment is in direct support of milestone 2.4 and continues progress toward milestones 2.5, 2.6, 2.9, 2.10, 2.11, 2.12, 2.13 and 2.14.
- Provided leadership for code development activities associated with indoor hydrogen fueling, NFPA 2 Fueling Working Group. Leadership in code development activities signifies a commitment to a continuous improvement process for the risk assessment methods developed under this project. This directly supports the achievement of milestone 2.10 and ensures that the publication of this approach leverages industry and peer research input. All other milestones (2.4, 2.5, 2.6, 2.9, 2.11, 2.10, 2.12, 2.13, 2.14) benefit from a continuous feedback loop rather than uni-directional communication.
  - Facilitated discussion with industry and research collaborators to identify safety data, specifically

necessary data information for improved quantitative risk assessment (QRA) fidelity.

– Developed generic hydrogen fueling system plumbing and instrumentation drawings to facilitate the discussion surrounding NFPA 2 chapter 10 for both indoor and outdoor refueling. This holistic approach to refueling leverages information from indoor fueling experience to inform the revision of codes for outdoor systems.

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Introduction

Safety is critical to enabling the hydrogen as an energy carrier. While hydrogen has been used for industrial purposes for many years, bringing industrial technology to a retail setting such as a refueling station involves many unknowns with regard to safety. QRA has been used in several high-consequence industries in recent years including nuclear power and oil/gas production. QRA utilizes data from previous failure events to model postulated accidents and estimate the associated risk from operation of a facility. Risk considerations are incorporated in to the development of model codes and standards to appropriately regulate the retail/commercial use of hydrogen.

The overarching goal of applying QRA to the hydrogen industry is to ensure that the use of hydrogen is 'as safe or safer' than existing fuel technologies. The quantitative approach allows engineers to identify the main risk contributors and develop targeted improvements that have the greatest potential to reduce risk.

Approach

Sandia National Laboratories uses QRA to establish a common understanding of the safety level of the hydrogen industry. This process provides a basis for risk-informed decision-making with regard to implementing hydrogen systems in a variety of applications. Application of the risk-informed approach began with establishing separation distances for stationary bulk hydrogen storage as covered in NFPA 55 and adopted into NFPA 2. The work continues by addressing the indoor refueling requirements in chapter 10 of NFPA 2.

The goal of QRA is to establish that the risk is "As Low As Reasonably Practicable" or ALARP. Embedded in the ALARP approach is the understanding that there is no zero risk situation, but that there is an unacceptably high level of risk. This unacceptable risk threshold varies based on activity—the approach balances the fatality risk with the personal or societal benefit of the technology. For hydrogen applications, the unacceptable level of risk was determined to be a fatality rate greater than 1 e^{-4}/year for an individual worker or a fatality rate greater than 1 e^{-5}/yr for a member of the public. Once it is determined that a risk is below the unacceptable threshold, the best practice is to continue to allocate reasonable resources to further reduce the risk (i.e., continuously target improvements to the major remaining risk drivers in a cost-effective manner).

Results

Preliminary results from the risk assessment of indoor hydrogen fueling indicate that the risk of fatalities from indoor refueling in a generic, representative warehouse is not unacceptable. Based on the available information, the risk of fatality for any given individual, called the average individual risk (AIR) is 4.0 e^{-6} fatalities/exposed worker or 1 in 24,900. Note that this value is below the unacceptable threshold of 1 e^{-4}/year for workers identified previously. The result is also lower than the AIR for freight, stock and material movers, which is 7.0 e^{-5} fatalities/person (Bureau of Labor Statistics, 2007).

A 'generic' plumbing and instrumentation diagram was created to facilitate discussion and represent the hardware requirements of NFPA 2 for indoor refueling activities; shown in Figure 1. This activity also uncovered gaps in current code language.

Conclusions and Future Directions

Based on the current analysis, the risk of fatality resulting from indoor hydrogen refueling is less than the activities that it supports (operating forklifts in a warehouse).

Future efforts will leverage the methods refined in this analysis to develop a hydrogen specific quantitative risk assessment tool kit for use in a variety of applications by a variety of users. The planned efforts will:

- Incorporate data from industry collaborators into the next iteration of risk assessments.
- Continue facilitating discussion and eliminating discussion barriers through working group leadership.
- Develop academic and research partnerships to improve broad focus feedback loop:
  – Incorporate National Renewable Energy Laboratory composite data product outputs into hydrogen-specific QRA toolkit.
  – Incorporate hydrogen-specific QRA toolkit results into infrastructure analysis tools such as Spatially & Temporally Resolved Energy & Environment Tool.
- Host workshop of QRA practitioners and potential end-users to identify hydrogen specific QRA toolkit needs.
- Scope the activity to produce and disseminate a hydrogen specific QRA toolkit.

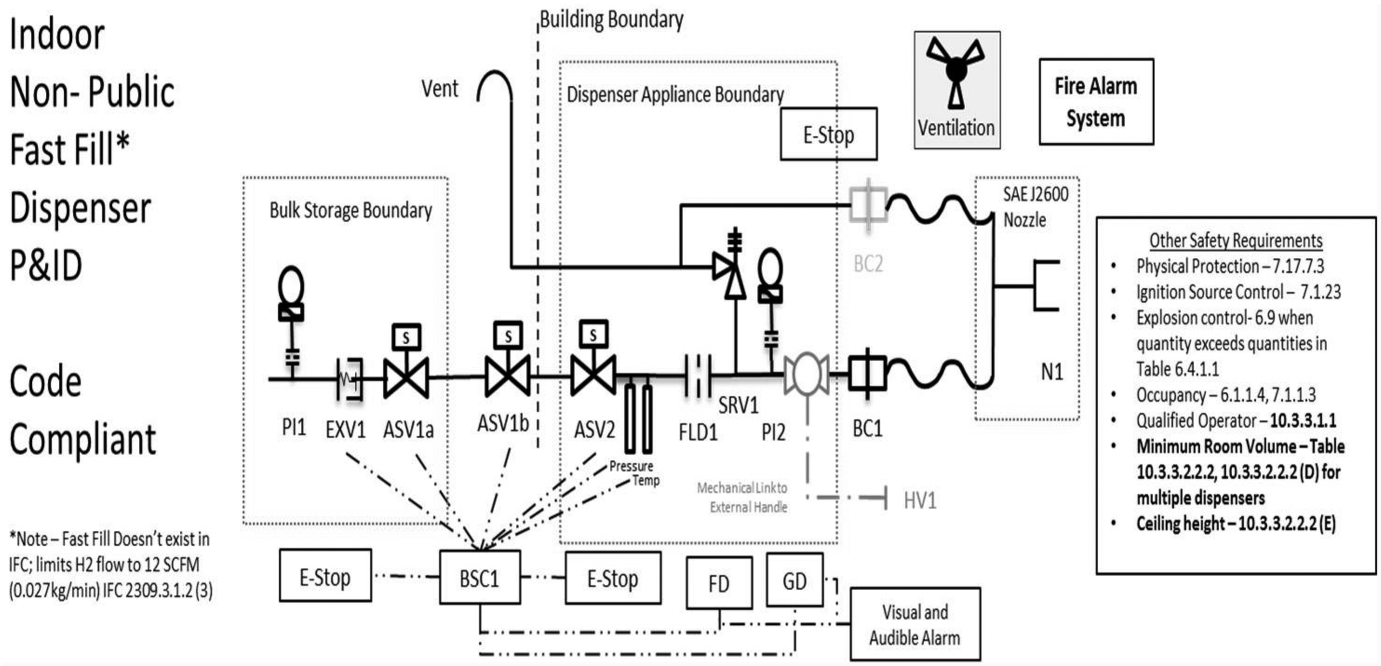

FIGURE 1. Plumbing and Instrumentation Diagram for Generic Code-Compliant Indoor Non-Public Fast-Fill Dispenser with references to NFPA 2

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FY 2012 Publications/Presentations

1. J. LaChance, A. Tchouvelev, Angunn Engebo, "Development of Uniform Harm Criteria for Use in Quantitative Risk Analysis of the Hydrogen Infrastructure," International Journal of Hydrogen Energy 36 (2011) pgs. 2381-2388.

2. Groth, K. M. & LaChance, J. L. "Risks associated with hydrogen indoor refueling." World Hydrogen Energy Conference, 2012.

3. J. LaChance, "Progress in the Use of Quantitative Risk Assessment in Hydrogen Safety," H2Can 3rd AGM and Annual conference, Niagara Falls Ontario, June 9, 2012.

4. J. LaChance, "QRA Data Analysis," IEA Task 31 hydrogen safety meeting in Paris (March 16–18, 2012) on US progress in Activities C1, C2, and C.

5. J. LaChance and K. Groth."Progress in QRA for Indoor Refueling of Forklifts," IEA Task 31 hydrogen safety meeting in Paris (March 16–18, 2012) on US progress in Activities C1, C2, and C.

6. J. LaChance "QRA Quality," IEA Task 31 hydrogen safety meeting in Paris (March 16–18, 2012) on US progress in Activities C1, C2, and C.

7. LaChance, J.L.; Middleton, B. & Groth, K.M. "Comparison of NFPA and ISO approaches for evaluating separation distances." International Journal of Hydrogen Energy, In Press. Corrected Proof published 29 June 2012. Doi: 10.1016/j.ijhydene.2012.05.144.