# VIII.2 Component Standard Research and Development

Robert Burgess (Primary Contact), Matthew Post, Arlen Kostival, William Buttner, Carl Rivkin
National Renewable Energy Laboratory (NREL)
15013 Denver West Parkway
Golden, CO 80401-3305
Phone: (303) 275-3823
Email: robert.burgess@nrel.gov

DOE Manager
Will James
Phone: (202) 287-6223
Email: Charles.James@ee.doe.gov

Subcontractor
- Mark Mann, Spectrum Automation, Denver CO (pressure relief device test apparatus controls support)

Project Start Date: October 1, 2014
Project End Date: Project continuation and direction determined annually by DOE

## Overall Objectives

- Accelerate the development of robust codes and standards required for commercialization of hydrogen technologies
- Identify and quantify failure modes exhibited in high pressure hydrogen components by researching operational information and by conducting laboratory controlled testing
- Support the development of hydrogen components through collaborative efforts with industry stakeholders to improve hydrogen dispenser safety and reliability
- Codify standards language that is based on the latest scientific knowledge by providing analytical, technical, and contractual support
- Contribute directly to codes and standards committee efforts to identify technology gaps, then work to define research and development needs required to close those gaps
- Develop laboratory testing capability and conduct research and development aimed at providing the basis for improved code language
- Collaborate with industry, university, and government researchers to develop improved analytical and experimental capabilities

## Fiscal Year (FY) 2015 Objectives

- Complete design/build of pressure relief device test apparatus and begin cycle testing
- Plan FY 2016 activities, including hydrogen meter benchmarking project

## Technical Barriers

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

(A) Safety Data and Information: Limited Access and Availability

(C) Safety is Not Always Treated as a Continuous Process

(F) Enabling National and International Markets Requires Consistent RCS (Regulations, Codes, and Standards)

(G) Insufficient Technical Data to Revise Standards

(H) Insufficient Synchronization of National Codes and Standards

(J) Limited Participation of Business in the Code Development Process

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

## Contribution to Achievement of DOE Safety, Codes and Standards Milestones

This project will contribute to achievement of the following DOE milestones from the Safety, Codes and Standards sub-program section of the Fuel Cell Technologies Office MYRDD Plan:

- Milestone 2.19: Validate inherently safe design for hydrogen fueling infrastructure. (4Q, 2019)
- Milestone 3.1: Develop, validate, and harmonize test measurement protocols. (4Q, 2014)
- Milestone 4.3: Identify and evaluate failure modes. (Q3, 2013)
- Milestone 4.6: Completion of standards for critical infrastructure components and systems. (Q4, 2014)

## FY 2015 Accomplishments

- Designed and built test apparatus for reliability and end of life testing of high pressure hydrogen components under high pressure and cyclic temperature conditions

in the Energy Systems Integration Facility (ESIF) high pressure test laboratory currently conducting testing and generating data for pressure relief devices

- Conducted hydrogen components webinar to disseminate information about high pressure hydrogen applications and current R&D activities at NREL; webinar included open question and answer session for providing feedback on component activities from stakeholders
- Held hydrogen metrology information exchange meeting at NREL to collaborate on issues related to National Institute of Standards and Technology (NIST) Handbook 44 metrology requirements for the sale of vehicle fuel; meeting was focused on collaboration with Japanese stakeholders and included NIST Fluid Metrology Group participation
- Finalized hydrogen meter benchmarking proposal and test plan; test program is designed to measure meter performance as a function of flow, pressure, and temperature
- Developed hydrogen fueling animation as aide for customer understanding of gaseous hydrogen fueling experience
- Continued support of hydrogen standards development through participation on technical committees, including Society of Automotive Engineers (SAE) Fuel Cell Interface, SAE Fuel Cell Safety, and National Fire Protection Association (NFPA) Hydrogen Technologies; NREL hosted a joint technical committee meeting between NFPA 2 and 52 technical committees

## INTRODUCTION

Hydrogen safety, codes and standards topics have been identified in the DOE Multi-Year Program Plan as a subject area where significant barriers need to be addressed. Developing robust codes and standards helps to ensure that hydrogen systems are safe and reliable, thereby enabling the acceptance and growth of hydrogen technologies. NREL is providing research and development support to these codes and standards through validation testing, analytical modeling, and product commercialization efforts. NREL has been tasked with these responsibilities as defined in the DOE MYRDD plan.

## APPROACH

Hydrogen safety is being addressed by first identifying safety concerns, then developing appropriate test and analysis tasks that provide a technical basis for improved engineering best practices. Safety concerns are being compiled by direct discussion with key stakeholders, by leveraging existing data available through NREL's Technology Validation Program and by utilizing public outreach activities such as workshops and webinars. Identified safety concerns are prioritized, and then research and development tasks are aligned with the highest risk safety concerns. In general, the risk is defined by the combination of the severity and the likelihood of occurrence. Research and development results are then published for general use by stakeholders. Information is further disseminated through NREL outreach activities. Published results are also being used as a basis for improved hydrogen codes and standards.

NREL is participating on relevant codes and standards committees to help identify gaps and define research and development needs to close those gaps. Working at the committee level allows us to quickly identify areas that need R&D support and to work directly with the technical experts in planning a path forward. This process is instrumental in avoiding delays and setbacks in the development of new codes and standards and in the revision of existing codes and standards. Research and development support is being used to establish codes and standards language with solid technical basis.

## RESULTS

NREL has been working toward identifying safety gaps and supporting R&D efforts for developing new and improved hydrogen codes and standards. Results reported here are for efforts specifically directed at component level standards and identified hydrogen safety concerns.

**Codes and Standards Technical Committee Support**—NREL participated on SAE safety and interface technical committees working on documents under revision including J2601, J2600, and J2579. NREL also supported NFPA 2 Hydrogen Technologies Code by hosting the joint meeting with NFPA 55, July 14–18, 2014. These two standards are on a synchronized revision schedule to simplify hydrogen content improvements.

**NREL Hydrogen Component Webinar**—NREL held a component webinar on February 4, 2015, to disseminate information on component gaps and R&D programs. Presentation material summarized NREL hydrogen component activities taking place in the Energy Systems Integration Facility (ESIF) laboratory. The webinar provides valuable input for component suppliers and system developers while providing opportunity for feedback to NREL.

**Hydrogen Vehicle Fueling Animation** – At the request of the SAE J2601 sponsor, NREL prepared a fueling animation that depicts the ramp rates, pressure holds and target conditions required under the SAE J2601 protocol. The animation will help fuel cell electric vehicles (FCEV) users understand the behavior of gaseous motor vehicle fueling.

The animation can be viewed at the following link.
http://widgets-stage.nrel.gov/afdc/hydrogen-animation/

**Pressure Relief Valve Failure Mode Demonstration**—NREL is conducting qualitative reliability testing of hydrogen relief valves to better understand a known failure mode in high pressure hydrogen. This study is focused on determining the necessary and sufficient conditions needed to reproduce the known failure under laboratory controlled conditions. This data will be used as input for developing better performance-based standards. Performance-based standards need to be capable of failing product with known failure modes. This investigation is utilizing the high pressure test cell capability at NREL. Testing has been ongoing since Q2 FY 2015 and is planned to continue into FY 2016. Cycle testing temperature profiles are shown in Figure 1. The thermal transient required to heat and cool the relief valves is a limiting factor for the test design. Convective heat transfer is used in the thermal control box to optimize the number of cycles in a 24-hour period. At this point one valve failure has been detected as shown in Figure 2. During the start of a heating cycle a slow leak was detected, resulting in a system shutdown. Investigation of the leak identified the leak path was through the valve seat. The identified root cause is a valve nozzle–seat interface that was not able to follow the thermal expansion during the start of the heating cycle. Depressurizing and subsequent repressurization resulted in the valve reseating. Pressure relief device seating is a reliability concern and this failure is valuable data for capturing pressure relief device operational issues.

**Component Crosscutting Accomplishments**—NREL is conducting DOE funded component tasks under other subprograms. This includes a hydrogen meter benchmarking project aimed at quantifying the performance of flow meters and comparing results to NIST Handbook 44 requirements. These efforts have provided an opportunity to leverage safety, codes and standards objectives through crosscutting activities. These activities include regulations, codes, and standards (RCS) guidance for defining test protocols and design requirements for improved code requirements. Crosscutting metrology activities in FY 2015 also included an information exchange meeting with Japanese stakeholders on January 14, 2015. NIST Fluid Metrology Group was also represented at the meetings.

**Research and Development Outreach Activities**—Numerous outreach activities were conducted in conjunction with the DOE/NREL safety, codes and standards program. Outreach activities are used as a resource in soliciting industry feedback and identifying priorities for research and development tasks. Outreach tasks include contribution to key technical committees and working groups at H2USA, H2FIRST, the California Fuel Cell Partnership, and work with other key stakeholders. Other outreach activities in FY 2015 include participation on the UL Renewable Energy Council meetings being held April 27–29, 2015, and discussions about component testing activities with CSA at their high pressure hydrogen test laboratory in Langley, British Columbia.

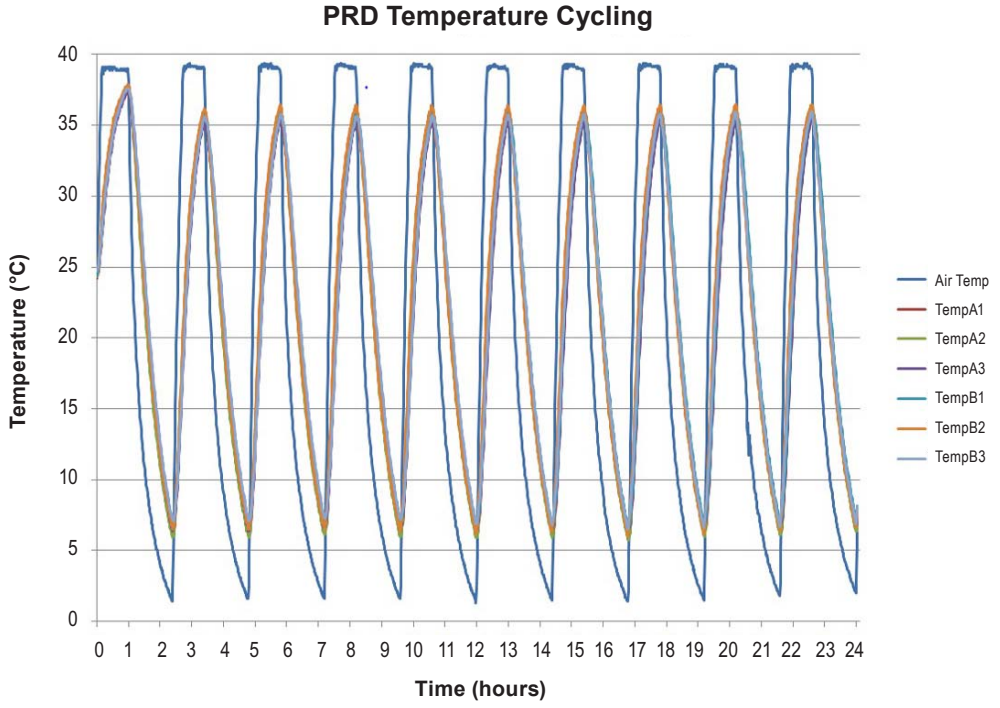


**FIGURE 1.** Pressure relief device thermal cycles

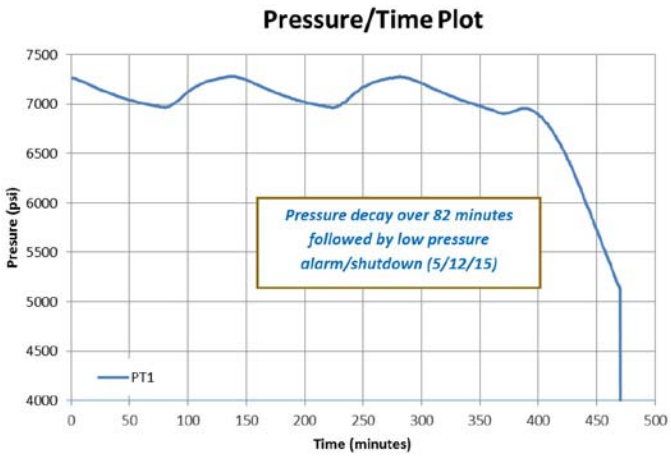


**FIGURE 2.** Pressure relief device seat failure

## CONCLUSIONS AND FUTURE DIRECTIONS

NREL has identified numerous opportunities to further improve the inherent safety of high pressure hydrogen systems that are designed to serve FCEV markets. These opportunities must be pursued through a variety of means, including failure mode testing investigations, root cause analysis and codes and standards development. Future direction will include R&D programs that utilize existing ESIF laboratory facilities for component and system level testing.

## FY 2015 PUBLICATIONS/PRESENTATIONS

**1.** "Component Standard Research and Development," DOE Annual Merit Review, June 9, 2015.

**2.** NREL Components Open House Presentation, 'Pressure Relief Device Testing R&D," May 28, 2015.

**3.** NREL Component Webinar Presentation, "Pressure Relief Device Testing R&D", February 4, 2015.

**4.** "Hydrogen Fueling Station Metrology," Metrology Information Exchange, NREL January 14, 2015.

**5.** "NREL Component R&D," CSA Langley, B.C. Test Laboratory meetings, January 29, 2015.

**6.** Hydrogen Fueling Station Animation, http://widgets-stage.nrel.gov/afdc/hydrogen-animation/, Q1 FY 2015.