Dispenser Reliability

Michael Peters (Primary Contact), Josh Martin, Matt Ruple, Kevin Hartmann, Cory Kreutzer, Daniel Leighton, William Buttner
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401-3305
Phone: (303) 524-0864
Email: Michael.Peters@nrel.gov

DOE Manager: Neha Rustagi
Phone: (202) 586-8424
Email: Neha.Rustagi@EE.Doe.Gov

Project Start Date: October 1, 2016
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Explore the costs and benefits of an increase in the pre-chilled temperature during light-duty hydrogen vehicle fueling.
- Improve hydrogen dispenser reliability through accelerated life testing.
- Perform fill testing of hydrogen tanks at elevated temperature to look at pre-chilled temperature effects on final state of charge.

Fiscal Year (FY) 2018 Objectives

- Complete the commissioning of the research dispenser and recirculation loop.
- Determine the optimal hydrogen sensor placement and setpoints.
- Finish the buildout of the “device under test apparatus.”

Technical Barriers

This project addresses the following technical barriers from the Technology Validation and Safety, Codes and Standards sections of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.[1]

Technology Validation Barriers

D. Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

Safety, Codes and Standards Barriers

G. Insufficient Technical Data to Revise Standards

FY 2018 Accomplishments

- Achieved numerous flow tests on the research dispenser and recirculation loop as part of the commissioning process.
- Determined the optimal location, number, and response time for the hydrogen sensors.
- Finalized the buildout of 10 interchangeable dispenser systems.

[1] https://www.energy.gov/eere/fuelcells/downloads/fuel-cell-technologies-office-multi-year-research-development-and-22

INTRODUCTION

Hydrogen station reliability currently lags far behind consumer expectations. To support widespread fuel cell electric vehicle (FCEV) deployment, operators must improve reliability. One of the largest contributors to station reliability problems is the dispenser, in particular the components exposed to prechilled hydrogen. The National Renewable Energy Laboratory's (NREL's) 700-bar station has shown that 65% of its entire station component failures happen within the prechilled portion of the station. An improved understanding of component life cycles at low temperatures is needed so that resources can be allocated to redesign unreliable parts. If the -40°C temperature requirement could be increased to -20°C or even 0°C, station reliability could also be improved. Increasing the low temperature requirement may be possible through alternative fueling protocols, informed by validated fueling models, or through redesigned (or reassessment of the temperature limits of) vehicle tanks that can handle higher temperature excursions.

APPROACH

NREL is performing accelerated life testing of components typically found in the prechilled section of the dispenser. The objective is to measure the mean fills between failures and mean kilograms between failures of hydrogen components subjected to pressures, ramp rates, and flow rates similar to light-duty FCEV fueling at numerous temperatures: -40°C, -20°C, and 0°C. The five types of components under test include nozzles, breakaways, filters, normally closed valves, and normally open valves. Devices from two manufacturers for each component type will be tested at the three temperature levels. Therefore, the testing will yield 30 different mean fills between failures and mean kilograms between failures results by the end of the experiment.

The experiment is broken into variable and fixed factors and levels. The main variable factor that is controlled is the hydrogen temperature delivered to the components. The hydrogen temperature factor consists of three different levels: -40°C, -20°C, and 0°C. The type of component and the manufacturer part number fall within the controlled factors section. Uncontrolled variable factors include ambient temperature and ambient relative humidity. These factors will be measured, recorded, and analyzed for each fill. The fixed factors that will remain the same for each fill are the ramp rate, flow rate, and pressure range of the hydrogen delivered to the components. The expected response variables are whether the hydrogen leaks, number of fills before failure, number of kilograms before failure, and hydrogen leak rate.

The accelerated life testing will allow for eight "dispenser-like" systems to be tested simultaneously. The systems are packaged with two dispenser sets in series and four sets in parallel to complete the full system. A single test setup is shown in Figure 1. The figure shows the five components under test in addition to a pressure transducer and temperature transducer on each individual test setup; these instruments help determine the leak rate of components. The accelerated testing is achieved by putting multiple test setups into one test apparatus and testing them all simultaneously. Figure 2 shows how the individual test setups are positioned in the test apparatus to achieve accelerated life testing. Note that a controllable research dispenser and a recirculation loop were implemented into the test apparatus on the front end and back end respectively.

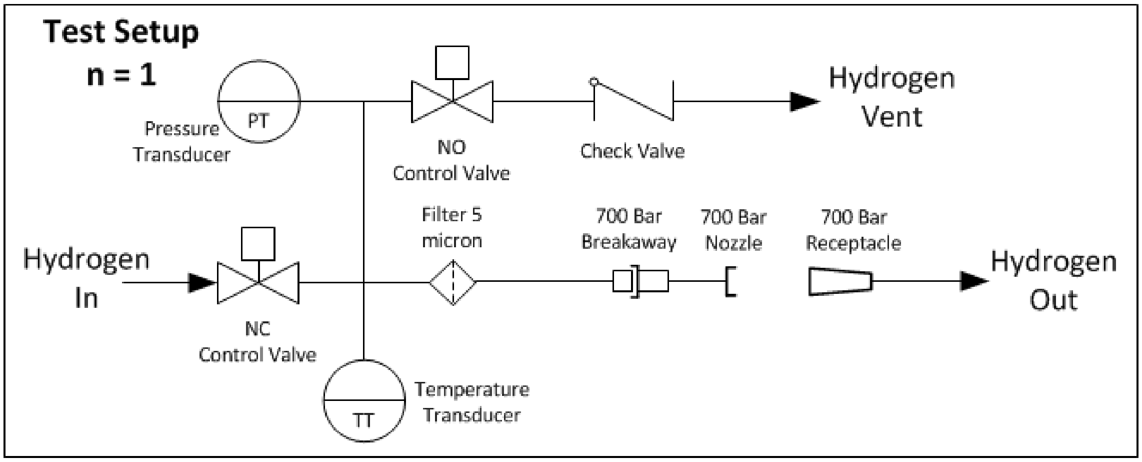

Figure 1. Overview of one test setup

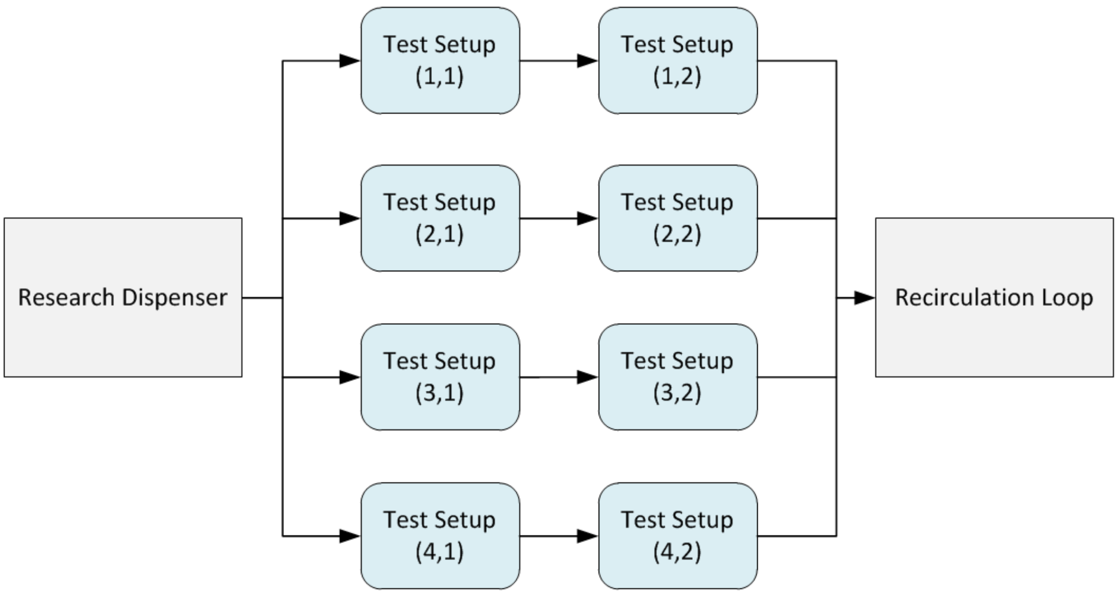

Figure 2. Complete system with eight dispenser test setups

RESULTS

Leak Testing

It is important for the test apparatus to identify any leaks from the components as quickly as possible to determine the true lifetime of the components. There are two different ways the system checks for leaks: hydrogen sensors and a mass calculation using the pressure, temperature, and volume of a given section.

For the sensor approach NREL used its Hydrogen Wide Area Monitoring (HyWAM) apparatus to determine the optimal sensor placement, response time, and warning/fault set points. The testing concluded that two hydrogen sensors were needed per compartment. The test apparatus is broken up into four compartments, each with two dispenser systems, so there is a total of eight hydrogen sensors in use for this experiment. Figure 3 shows the test setup used for determining the optimal sensor placement and response time.

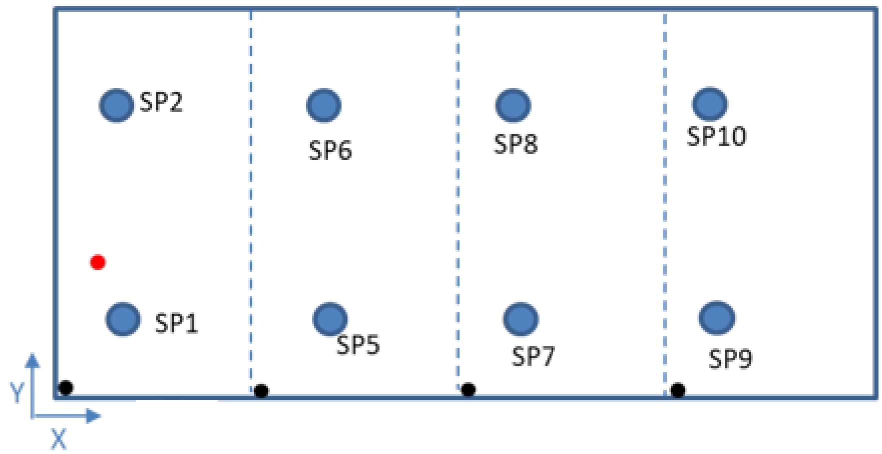

Figure 3. HyWAM sensor placement

In addition to using sensors, a leak rate can be determined by calculating the mass in each section with the corresponding pressure and temperature transducers. The system performs four different leak checks during a fill and it uses that time to determine if there is a small leak that the sensors are not picking up. This leak check method is standard to SAE J2601 fills and is a redundancy to the sensor method that has been implemented.

Research Dispenser and Recirculation Loop Commissioning

NREL designed, built, and commissioned a research dispenser and recirculation loop to support the flow rates, ramp rates, and temperatures required for this testing. The research dispenser supplies high-pressure hydrogen to the system, controls pressure ramp rate, and is used to dial in the hydrogen temperature to the device under test. The recirculation loop acts as a high pressure to low pressure crossover to make a closed system for testing that allows for no consumption of hydrogen. The recirculation loop also controls the flow rate of the test. Figure 4 shows a commissioning fill that was exploring the interaction between the research dispenser and the recirculation loop. The desired ramp rate corridor is represented on the primary y-axis in red and the test pressure ramp rate is in blue. This test showed good agreement between the desired ramp rate and the actual rate. On the secondary y-axis is the gas temperature leaving the system. The black dotted lines show the J2601 requirement window of -33°C to -40°C and the orange line is the actual temperature. The fill reached the required temperature in enough time and the temperature hovered around the warmest part of the temperature corridor.

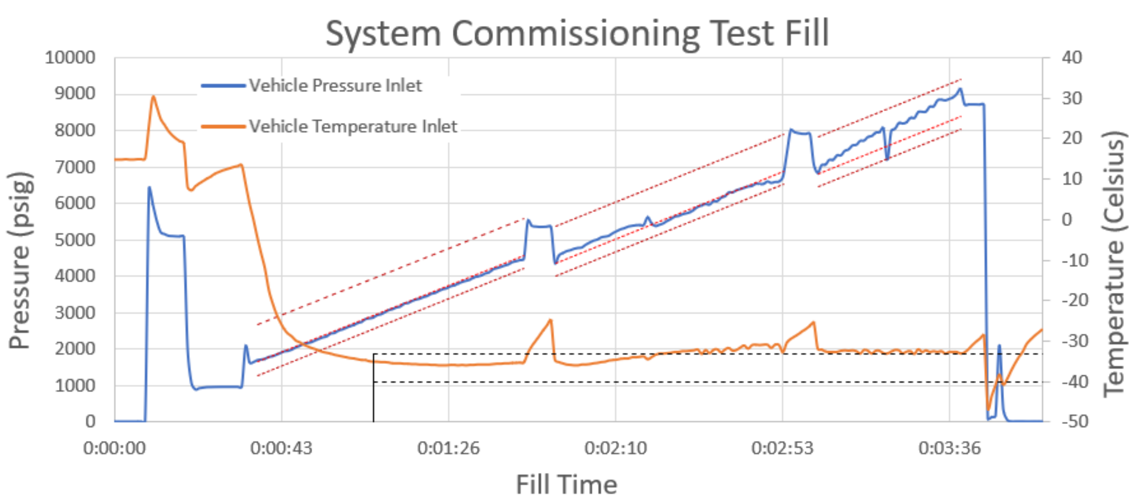

Figure 4. System commissioning test

Device Under Test Buildout

NREL was able to obtain components from two different manufacturers for each device under test. The device under test appartus was built to accommodate eight dispenser-like systems at once with two dispenser systems going into a single compartment. The apparatus was modeled after an electrical rack where components can easily be slid in or out based on the need to replace a component. Spare parts are on hand to ensure the quick transition of the apparatus when parts fail; this allows for continued testing while the failure analysis is being conducted. Figure 5 shows the device under test apparatus after buildout was complete.

Figure 5. Device under test apparatus

CONCLUSIONS AND UPCOMING ACTIVITIES

NREL will complete the accelerated life testing on the components at -40°C, -20°C, and 0°C.

FY 2018 PUBLICATIONS/PRESENTATIONS

1. M. Peters, N. Menon, K. Hartmann, and J. Martin, "Dispenser Reliability," presentation at the DOE Hydrogen and Fuel Cells Program 2018 Annual Merit Review and Peer Evaluation Meeting, June 2018, Washington, DC.