# VII.C.1 Hydrogen Component Validation

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

## Overall Objectives

- Reduce fuel contamination introduced by forecourt station components.
- Improve station reliability and uptime.
- Increase the publicly available energy and performance data of major station components.

## Fiscal Year (FY) 2016 Objectives

- Develop a contaminant library through H2Tools.org.
- Improve maintenance and reliability data collection and analysis at NREL Hydrogen Infrastructure Testing and Research Facility (HITRF).
- Collect and analyze power and energy consumption data for major hydrogen station components.

## Technical Barriers

This project addresses the following technical barrier from the Technology Validation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

(D) Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

## FY 2016 Accomplishments

- Nine forecourt hydrogen stations are participating in a contaminant collection program.
- Began discussions with H2Tools.org for a section on the contaminant library.
- Installed three power and energy meters on major station equipment at HITRF and automated the data collection; analyzed data used by other DOE researchers for station energy and cost analysis.
- Discussions with compressor manufacturers resulted in changing the lubricant used for components in hydrogen service from a substance harmful to fuel cells to a known safe substance.
- Installed and commissioned a 900 bar, 140 SCFM linear piston compressor at HITRF.
- Generated first maintenance graphic for comparison to composite data product (CDP) INFR 21 showing the contribution of HITRF station components to overall maintenance events.

## INTRODUCTION

The Hydrogen Component Validation task is focused on addressing three challenges currently facing forecourt hydrogen stations today that were prioritized from an H2USA Fueling Stations Working Group brainstorming session: fuel contamination introduced by forecourt station components; station reliability and uptime; and lack of publicly available energy and performance data of major station components. Improvement in each one of these topic areas is critical for successful station operation, positive fuel cell driver experience, and a robust hydrogen economy.

## APPROACH

NREL is working to better understand particulate contamination in the hydrogen process stream by distributing contaminant collection packets to forecourt station operators. When a maintenance event occurs, the participating station operators will collect any particulate matter found in the hydrogen tubing or components and send the samples to NREL, where they will be analyzed, anonymized, and published to the Hydrogen Station Contaminant Research Library for the larger community to reference for root cause analysis of contamination events.

Station reliability and uptime are being studied in depth at the HITRF station, where detailed logs of planned and unplanned maintenance events are kept. The process media, component materials of construction, failure mechanism, and station downtime are all recorded. Data are aggregated monthly and compared with data collected by National Fuel Cell Technology Evaluation Center on forecourt hydrogen stations. The major contributors to downtime are identified and studied.

NREL installed power meters on two hydrogen compressors and the hydrogen pre-cooling system at HITRF. The HITRF Supervisory Control and Data Acquisition (SCADA) system is collecting power and energy data as each of these components operates to support the HITRF. NREL engineers are analyzing the data and collaborating with other DOE researchers to better understand operating costs of forecourt hydrogen stations and possible precursors to equipment failures that can be used to indicate the need for preemptive maintenance.

## RESULTS

NREL has provided sample kits including swabs, vials, baggies, and an information form to nine forecourt hydrogen stations. Multiple samples have been collected, typically from failed parts. Contaminants found range from metal shards—likely from tubing cutting—to elastomer material —likely from failed seals. Figure 1 shows two examples of particulate contaminants that were collected. The image on the left shows metal shards embedded in a valve seat. The image on the right shows elastomer material collected in a filter just upstream of the dispenser.

It is clear from other samples collected that lubricant, normally used on elastomer seals, is collecting at certain areas in the process stream. This reinforces the need for lubricants that do not adversely affect fuel cell operation, such as Krytox. Often the lubricant acts as an aggregator for particulates and is commonly found discolored. NREL has advised three major compressor manufacturers on the composition and application of appropriate lubricant on process stream components.

NREL has collected maintenance data on the HITRF since it began operating in February 2015. This data includes component failures and routine maintenance on all major system components. NREL compiles the maintenance data collected at HITRF in a similar manner to data collected from CDPs to promote a direct comparison, as shown in Figure 2. Like at retail stations, the dispenser and compressor are large contributors to downtime and system maintenance.

There are some notable differences in maintenance events for the HITRF station and aggregated industry data. The reason for these differences is that the HITRF data was collected during the commissioning and initial phases of station operation. Additionally, the HITRF is a research station that, while similar to a retail station, is not operated in the same manner. For instance, the electrolyzer system at HITRF is a bespoke system designed by NREL engineers and has multiple research projects associated with it. This results in maintenance events that would not normally occur with retail hydrogen stations. Despite these differences, the data collected is still informative for deep dive failure analysis and improving station uptime.

NREL engineers installed power meters on two hydrogen compressors and the pre-cooling system. The HITRF SCADA system is collecting data on the amount of power and energy consumed by each component at one-second intervals. NREL engineers perform detailed analysis on the data, resulting in quantitative performance information.

For instance, the 400 bar compressor, with a constant suction pressure (6.89 bar), was found to consume 3.53 kWh/kg[1] at a flow rate of 2.78 kg/hr. The 20 hp motor consumed a peak power of 11.5 kW when compressing from 350 bar to 400 bar. This type of data is important when budgeting for the operation of a hydrogen station. For example, a 100 kg/d station would require a station operator

[1] Compressor motor consumption only. Balance-of-plant components, such as jacketed cooling and control system, have been found to consume 1.5 kW to 2 kW.


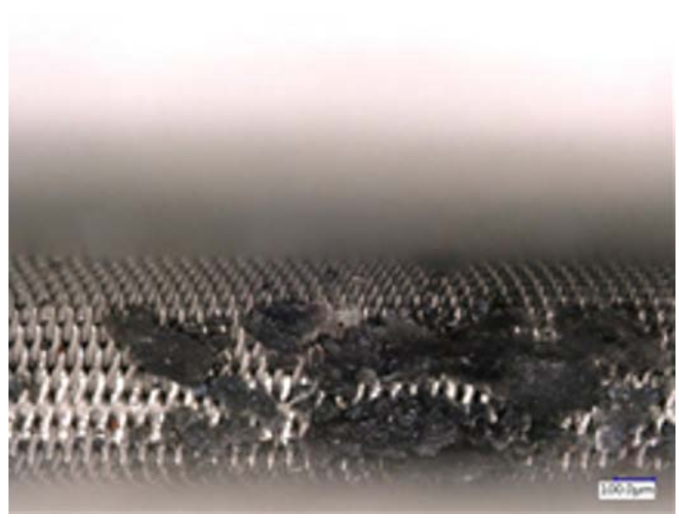

**FIGURE 1.** Two contaminant samples collected as part of the Hydrogen Station Contaminant Research Library task

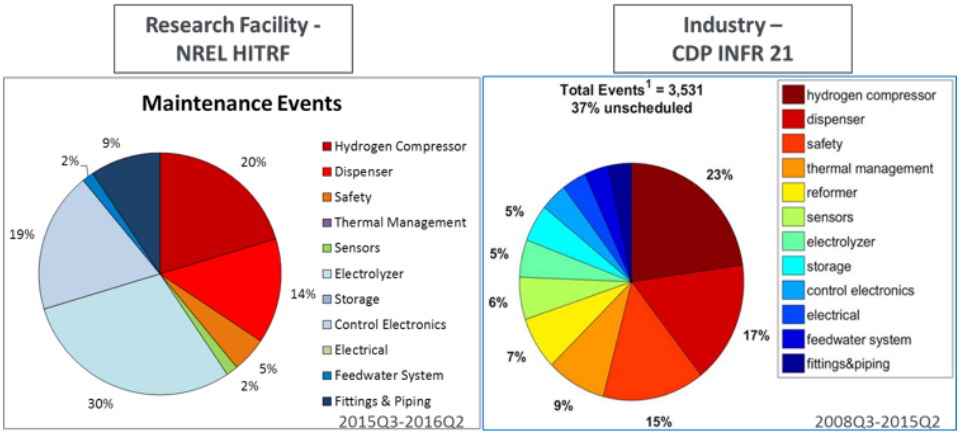


**FIGURE 2.** NREL HITRF (left) and aggregated industry (right) maintenance events for hydrogen stations

to purchase 353 kWh of electricity to compress 7 bar gas to 400 bar.

The energy and power requirements for recovery of the pre-cooling system after a vehicle fill is another example of impactful performance analysis. As a fuel cell electric vehicle is filled, heat from the hydrogen flowing from the station is added to the heat exchanger. The chiller then needs to run a compressor to cool the block back down. Figure 3 shows one-second data collected from the power meter on the chiller and other sensors in the heat exchanger.

Analysis from this data capture shows that full cooling block recovery takes 6 kWh and 58.9 min. Reaching the allowable fill temperature only takes 3.7 kWh and 35.4 min. This information is critical to a hydrogen station operator that will likely have more than one customer every 35.4 min and thus will consider sizing of the pre-cooling system. In addition to the energy cost of recovering from a fill, the station operator must consider the energy cost to maintain the block temperature during non-filling periods, which is data that NREL collects.

## CONCLUSIONS AND FUTURE DIRECTIONS

The Hydrogen Component Validation project addresses three major challenges facing forecourt hydrogen stations today: fuel contamination, reliability, and energy consumption related to major station components. The Hydrogen Station Contaminant Research Library was developed to collect field samples of particulate matter, determine the origin, and publish the results to identify major issues impacting a high percentage of stations. Currently nine stations are participating, and NREL is reaching out to more as stations become operational.

NREL has implemented a detailed maintenance log at the HITRF station in Golden, Colorado. This database allows NREL to not only document failures on station components,

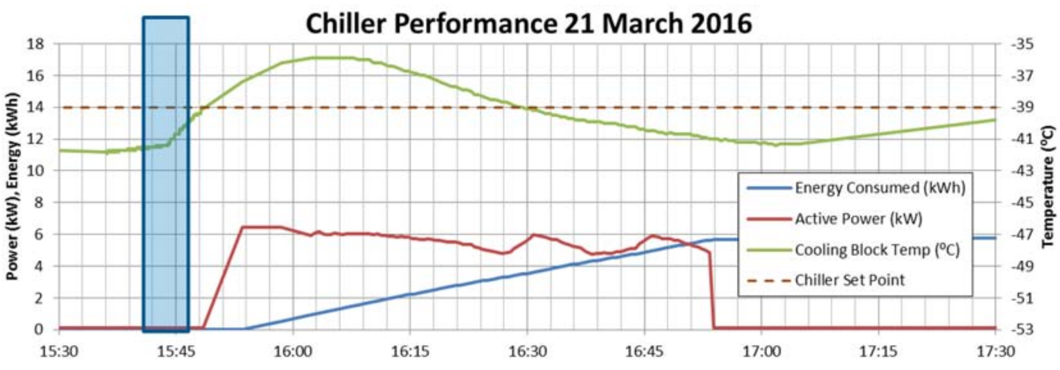


**FIGURE 3.** Chiller performance data showing the power (red line) and energy (blue line) requirements to recover the heat exchanger block temperature (green line) from a fill (indicated by the blue shaded rectangle). The system is unable to perform a fill when the cooling block temperature is above the set point (orange dotted line).

but also perform analysis on the causes of the failures. The data collected is compared to retail hydrogen stations to help identify the most common failures at forecourt hydrogen stations that impact station uptime and their causes. The HITRF will continue to be a test bed for new components and designs for hydrogen service as they are made available.

Power and energy consumption of major station components impacts operating costs at hydrogen stations. NREL has installed power meters on two hydrogen compressors and the hydrogen pre-cooling system. The HITRF SCADA system continually records data during operation, and NREL engineers analyze the data. The analysis is used to inform modeling efforts of hydrogen stations. Future work will involve analyzing the data for possible precursors to failure and impacts for reducing operating costs at hydrogen stations.

## FY 2016 PUBLICATIONS/PRESENTATIONS

**1.** "Hydrogen Component Validation," Terlip, Danny. U.S. Department of Energy Hydrogen and Fuel Cells Program Annual Merit Review 2016. Washington D.C., 7 June 2016.