

## VII.10 Performance Evaluation of Delivered Hydrogen Fueling Stations

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Subcontractor  
Linde Gas, LLC (Linde), Hayward, CA

Project Start Date: March 1, 2013  
Project End Date: April 30, 2018

- (A) Lack of Fuel Cell Electric Vehicle and Fuel Cell Bus Performance and Durability Data
- (D) Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

### Contribution to Achievement of DOE Technology Validation Milestones

This project will contribute to the achievement of the following U.S. DOE milestones from the Technology Validation section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

- Milestone 3.2: Validate novel hydrogen compression technologies or systems capable of >200 kg/day that could lead to more cost-effective and scalable (up to 500 kg/day) fueling station solutions for motive applications. (4Q, 2014). The stations currently being constructed will incorporate Linde's patented ionic fluid compressor. This technology utilizes a liquid piston to compress gas rather than a diaphragm or metal piston used in conventional compressor technologies. Linde is optimistic that this technology can be cost effectively scaled to larger capacity stations in the future.
- Milestone 3.4: Validate station compression technology provided by the delivery team. (4Q, 2018). See Milestone 3.2
- Milestone 3.8: Validate reduction of cost of transporting hydrogen from central production to refueling sites to <\$0.90/GGE. (4Q, 2019). This project will yield data directly aiding to develop baseline benchmarking and measure improved cost of delivery of liquid hydrogen to fueling stations in California.
- Milestone 4.4: Complete evaluation of 700-bar fast fill fueling stations and compare to Society of Automotive Engineers (SAE) J2601 specifications and U.S. DOE fueling targets. (3Q, 2016). This project will supply data to the NCFCTEC that aid the program in the characterization of the stations' storage and delivery capacities, compression performance, fueling transactional data, operational cost, maintenance, and safety. Data supplied will provide points of direct comparison to SAE fueling standards and U.S. DOE fueling targets.

### Overall Objectives

- Integrate non-intrusive data collection systems at five 100 kg/day delivered liquid hydrogen fueling stations located in California for 24-month performance period
- Submit complete sets of the National Renewable Energy Laboratory (NREL) Hydrogen Station Data Templates to National Fuel Cell Technology Evaluation Center (NCFCTEC)
- Provide useful data to accurately benchmark and characterize station capacity, utilization, maintenance, and safety

### Fiscal Year (FY) 2015 Objectives

- Complete installation of data acquisitions systems on the two hydrogen fueling stations covered under Budget Period 1 (West Sacramento and San Juan Capistrano stations)
- Begin data collection activities at the first two hydrogen fueling stations
- Monitor progress on the other three planned hydrogen fueling stations to ensure data acquisition systems are prepared for installation

### Technical Barriers

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

### FY 2015 Accomplishments

- Completed installation of the GTI-designed data acquisition system at the newly built West Sacramento hydrogen fueling station (first of five planned stations). This station was commissioned by Linde in December 2014, and is currently open for public use.

- Data collection activities at the West Sacramento station began in January 2015. Two quarters of data have been successfully collected, organized, and reported to NREL.
- Construction of the second fueling station located in San Juan Capistrano began in early June 2015. There was a several month delay in beginning construction due to delays in the permitting process.
- Preparations are complete for the installation of the data acquisition system at San Juan Capistrano. Slight modifications were made to the design to simplify the installation and streamline the data collection process. Installation at this site will occur in 3Q 2015.
- Continuing to coordinate with Linde on the construction timing of the remaining three fueling stations. Construction is expected to begin on the remaining stations around 4Q 2015—1Q 2016.



## INTRODUCTION

The objective of this project is to collect, organize, and report on operational, transactional, safety, and reliability data for five hydrogen fueling stations located in California. Goals of the project are as follows: (1) the data collected will be statistically meaningful and the stations will have sufficient throughput and vehicle fueling frequency to minimize data aberrations; (2) the data collected will be accurate; and (3) the data collected will be comprehensive and timely.

This project will directly assist DOE in assessing the readiness level of current infrastructure and state-of-the-art technologies utilized to support planned fuel cell vehicle deployment within the next five years. The data and observations collected during the performance period of this project will provide NREL with information detailing the operational costs, efficiencies, and reliability of the delivered hydrogen fueling station design. Furthermore, the Linde design utilizes the patented IC90 ionic fluid compressor package; through this project GTI will provide the performance data which will enable DOE and original equipment manufacturers (OEMs) to evaluate real-world efficiencies, further gauging the technology's adequacy in this application. This system is a first of its kind utilized for hydrogen fueling applications in the United States.

## APPROACH

Hydrogen station data will be submitted quarterly to the NFCTEC at NREL using the appropriate Hydrogen Station Data Templates. GTI's project partner, Linde, is currently developing delivered hydrogen fueling stations

under programs sponsored by the California Energy Commission (CEC). The sites will be accessible to the public for fueling consumer fuel cell vehicles, commercial vehicles, or government-owned vehicles. All five of the sites will be developed at existing or at new sites along with conventional gasoline stations operated by major-branded fuel providers. This provides the project with vehicle fueling data from a broad, cross-section of real-world vehicle applications. The station sites were selected to provide convenient, consumer-friendly vehicle fueling for drivers of fuel cell vehicles. Development of each of these stations has the support of vehicle OEMs and each site has passed stringent location selection requirements of the CEC to ensure the stations will be utilized by a high volume of fuel cell vehicle operators.

The data collection system will utilize a variety of methods in order to provide the entire data requirements set forth by NREL. This system will utilize the existing control architecture of the compressor and dispenser equipment as well as monitor and record signals from a set of installed instrumentation that will supplement information required that is not already captured inherently by the stations' operating system. There are multiple descriptive (as opposed to measured data) deliverables that will be taken manually and submitted to GTI for processing and formatting prior to delivery to NREL. Manually collected data templates include the following:

- NREL Site Log: recording safety drills, training, or public meetings
- Storage & Delivery: compiling liquid hydrogen supplies, delivery quantities, and cost
- Fuel Log: transferring transactional data from monthly reports emanating from fuel management system
- Maintenance: station maintenance and operations reporting
- Hydrogen Cost: collection of utility bills
- Safety: station environmental, health, and safety reporting
- Hydrogen Quality: SAE quality analysis completed annually and submitted

GTI will collaborate with Linde and create a reporting/submittal process to collect this type of data required to populate the NREL templates.

## RESULTS

The past year has shown substantial progress including installing the data acquisition system, retrieving data from the first hydrogen station, and making progress toward installing the system at the second station. Figure 1 shows the monthly dispensed hydrogen data collected from the first hydrogen station in West Sacramento. This data shows a

large variability in the station usage for the first half of 2015. This is just a small subset of the large amount of data that is being reported to NREL each quarter. Other data collected includes the energy used in compression and precooling of the hydrogen, maintenance and safety logs, and hydrogen control quality results.

Great progress was made toward construction and commissioning of the second hydrogen station, to be located in San Juan Capistrano. Station construction was started in early June and commissioning activities are planned for late 3Q 2015. With this second installation of the data acquisition system, a review of the performance of the currently installed system was completed to determine if any changes should be made prior to the second installation. During this review, we found the data from two temperature transmitters installed at the West Sacramento station are not being used as inputs to any calculations or data reporting and were therefore removed from the design for subsequent stations (TE-3 and TE-4 in Figure 2). These temperature transmitters are between the compressor, storage, and the dispenser. The TE-4 transmitter was meant to measure storage temperature, but this was found to be more accurate if ambient temperature is used. The TE-3 transmitter was meant to read the 350 bar gas delivery temperature, but modifications made to the pre-cooling system meant this temperature is an intermediate temperature between two coolers, and therefore not useful for data gathering. The delivery temperature will be read from the dispenser instead.

Lastly, progress continues to be made on the installation of the remaining three stations. These installations have progressed slowly due to permitting issues. Components from

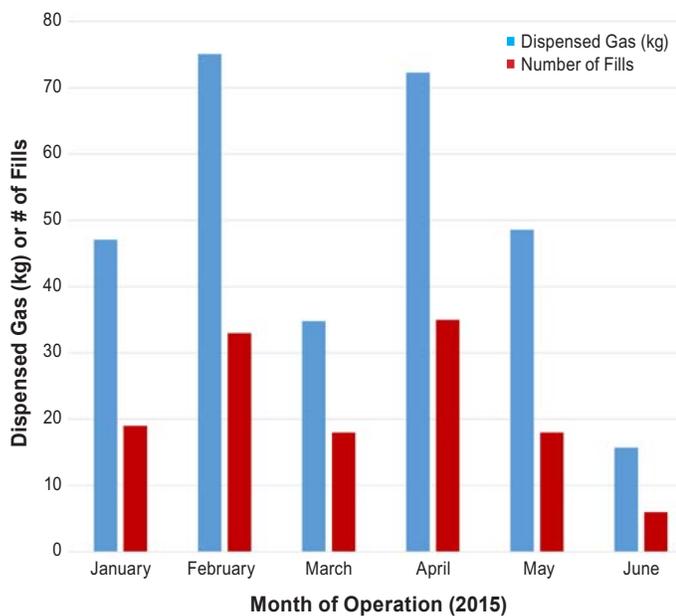


FIGURE 1. Usage data collected from West Sacramento station in first half of 2015

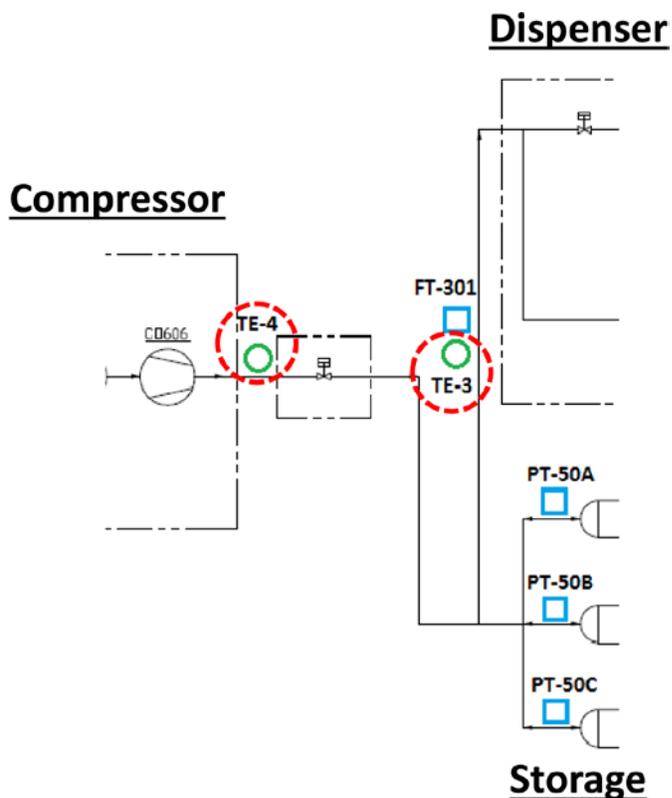


FIGURE 2. Portion of data acquisition system schematic showing thermocouples to be removed (circled in red)

these remaining stations have begun assembly in preparation for installation, which is targeted to start in 4Q 2015. Geographic diversity and multiple locations should provide an aggregate representation of the stations’ performance and operational characteristics. The additional funding allocated to Budget Period 2 will enable the installation of data acquisition systems on these remaining three stations as well as the data collection from all five stations for a two year period. This information will supply the NREL database with accurate representation and characterization of the readiness of delivered hydrogen as a vehicular fuel supply.

**CONCLUSIONS AND FUTURE DIRECTIONS**

- Install and commission the second system in Q3 of 2015 at San Juan Capistrano, California, site location
- Produce the complete sets of data for the first two project sites at the end of each quarter after startup and commissioning is completed
- Obtain approval to continue project efforts into Budget Period 2 (Q4 2015)

**FY 2015 PUBLICATIONS/PRESENTATIONS**

1. tv025\_barnes\_2015\_o.pptx – Oral Presentation 2015 AMR.