VII.C.5 Hydrogen Meter Benchmark Testing

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Project Start Date: September 1, 2015
Project End Date: September 30, 2016

Overall Objectives

- Design and build a laboratory-grade gravimetric standard for measurement of hydrogen flow. The gravimetric standard will be capable of verifying compliance with National Institute of Standards and Technology (NIST) Handbook 44 requirements for ±1.5% accuracy for the dispensing of motor vehicle fuel (gravimetric standard capability of 1/3 the required level or ±0.5%).
- Measure flow meter performance of three commercially available meters using the gravimetric standard. Testing will be conducted with high-pressure hydrogen under flow conditions simulating the range of dispenser operation.
- Disseminate results through communications and reporting to provide data on current flow meter performance, identifying the shortfalls to meeting regulations.

Fiscal Year (FY) 2016 Objectives

This project is scheduled to be completed by the end of FY 2016. The overall objectives of designing, building, and conducting flow meter performance testing will be completed.

Technical Barriers

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

Technology Validation Barriers

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

Hydrogen Safety, Codes and Standards Barriers

(F) Enabling National and International Markets Requires Consistent RCS

(G) Insufficient Technical Data to Revise Standards

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

Contribution to Achievement of DOE Milestones

This project contributes to achievement of the following DOE milestones from the Technology Validation and Hydrogen Safety, Codes and Standards sections of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan.

- Technology Validation Milestone 4.5: Based on field validation data, publish assessment of remaining fuel cell technology gaps requiring additional RD&D to satisfy residential/commercial fuel cell CHP markets. (4Q, 2016)
- Hydrogen Safety, Codes and Standards Milestone 3.1: Develop, validate, and harmonize test measurement protocols. (4Q, 2014)

FY 2016 Accomplishments

- Finalized the design and build of a gravimetric flow standard. The design includes two composite overwrapped Type III cylinders mounted on a common scale.
- Completed market survey of existing flow meter technologies. Results presented to DOE and at the stakeholder project review to down-select three meters for testing. Final selection includes two coriolis meters and one turbine meter.
- Conducted gravimetric standard design review with NIST Fluid Metrology Group in Gaithersburg, Maryland. This review provided feedback from the NIST experts in fluid metrology on important aspect of the gravimetric standard design and operation.
- Performed project review with industry stakeholder group to ensure that the project plan meets the needs of the fuel cell vehicle market. Data from this project will be utilized to address the gap in meter performance

relative the motor vehicle fueling requirements in NIST Handbook 44.

- Verified system performance by conducting pre-test system level testing. This testing includes system integrity leak checking, structural interaction measurements, dynamic flow effects testing and quantification of PVT (pressure, volume, and temperature) system corrections.

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INTRODUCTION

The hydrogen meter benchmarking project is being supported under the DOE Technology Validation program and is part of the DOE/NREL/Sandia H2FIRST (Hydrogen Fueling Infrastructure Research and Station Technology) project. The H2FIRST objective is to ensure that fuel cell electric vehicle customers have a positive fueling experience similar to conventional gasoline and diesel stations as vehicles are introduced (2015–2017) and transition to advanced fueling technology beyond 2017. The H2FIRST activities are expected to positively impact the cost, reliability, safety, and consumer experience of fuel cell electric vehicle stations.

APPROACH

Background: The hydrogen flow meter benchmarking study will provide data for state weights and measures groups that are working toward station certification. All 50 state agencies have adopted NIST Handbook 44 in whole or in part for their state motor vehicle fuel metrology requirements. As a result, flow meter manufacturers are working toward developing a product capable of meeting NIST Handbook 44 requirements as specified in section 3.39 Hydrogen Gas-Measuring Devices. The acceptance criterion for flow measurement accuracy is defined as ±1.5% acceptance tolerance and ±2.0% maintenance tolerance. California Code of Regulation has adopted amendments to the Handbook 44 requirements, adding accuracy classes of 3%, 5%, and 10% as a temporary allowance for hydrogen dispensers. This action is a result of known limitations in flow meter accuracy for high-pressure hydrogen.

Experience: NREL's experience with hydrogen metrology includes a project with the California Department of Food and Agriculture Division of Measurement Standards. NREL was contracted to design and build the Hydrogen Field Test Standard employing gravimetric, volumetric, and master meter capability. The gravimetric method was shown to be capable of ±0.5% accuracy, or three times the accuracy requirement in NIST Handbook 44. This accuracy level is required for use as a standard for certification of motor vehicle fuel dispensing and was used as a basis for the gravimetric design of the meter benchmarking apparatus.

Technical Description: Flow meter testing was conducted to quantify meter accuracy over a range of environmental conditions (input variables: flow, pressure, temperature, and transient time). Testing was conducted on representative meters that are production models or are prototype models with potential for near-term production. Test priority was given to commercially available devices. The hydrogen metering benchmarking apparatus consists of a stationary hydrogen flow loop capable of controlling input variables of temperature, pressure and flow as it passes through a flow measuring device. The minimum and maximum input conditions were per the SAE J2601 fueling protocol. The flow loop is able to measure the flow rate by gravimetric methods. A future work task being considered is the addition of a critical flow venturi as a secondary master meter concept. Both these methods will incorporate traceability to NIST standards.

Gravimetric Method: The NREL-designed apparatus incorporates two Type III composite overwrapped pressure vessels (COPVs) mounted on a NIST traceable scale to measure the mass of dispensed hydrogen vs. time. The COPVs are lightweight cylinders that minimize scale tare weight. A high accuracy stationary Sartorius scale was used for the gravimetric measurement.

RESULTS

Flow Meter Survey and Selection: Coriolis meters are typically used for compressed natural gas dispensing where the dispensed pressure is much lower than 70 MPa. When designing for high-pressure hydrogen, thicker walls are needed for pressure containment. The thicker wall reduces the deflections required for coriolis meter operation. Thicker walls are also a challenge for an ultrasonic meter, reducing the signal to noise ratio. Material selection is also dependent on the effects of hydrogen mechanical properties. Project scope for this effort included testing of three commercially available meters.

The final selection process included two coriolis meters and one turbine meter. The two coriolis meters are being used in 70 MPa stations. Data provides a benchmark for future development. The turbine meter is a product that is used extensively in industry but is new for 70 MPa hydrogen applications. The turbine meter drawback is that it is a volumetric device so the output will require conversion to gravimetric units. This data provides valuable information on the applicability of a turbine meter and also shows the incremental inaccuracies of a gravimetric conversion.

Gravimetric Standard Design/Build: The test hardware shown in the isometric view was mounted on an 80/20 frame with protection from wind. The location of the two COPV cylinders can be seen in Figure 1. The inner frame is positioned on the Sartorius scale. The entire inner frame can be lifted off the scale for scale maintenance and calibration.

FIGURE 1. Flow meter test apparatus

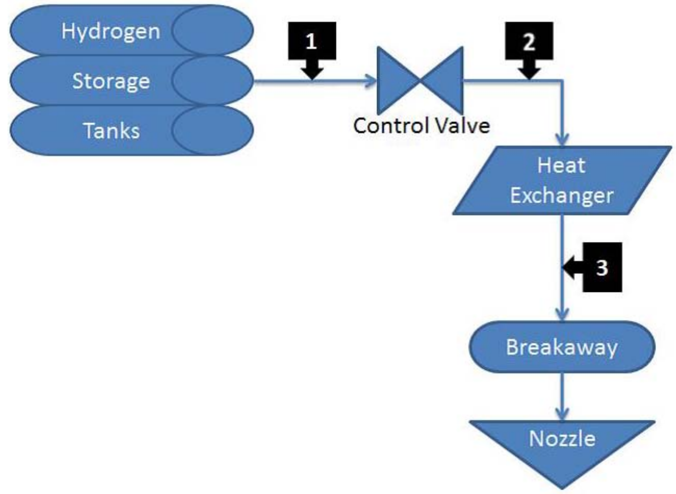

FIGURE 2. Meter location determination

The device under test is mounted upstream of the tank/scale, employing a gravimetric method for validation of flow measurements. The apparatus was designed with the following design considerations.

- Wind protection
- Removable scale
- Device leveling
- Two 40-L COPVs
- Program logic controls
- 80/20 aluminum

System Design Meter Location: Three potential meter locations are depicted in Figure 2. Stations in operation today have the meter upstream of the hydrogen chiller due to the meter being a heat sink if placed downstream of the chiller (compromising the ability to meet SAE J2601 cool down times). As a result, during this testing, meter performance was explored under conditions simulating positions 1 and 2.

System Pretesting: System pretesting is required to quantify both static and dynamic effects that would otherwise adversely affect the accuracy of the gravimetric measurement. Interactions between the gas lines and the scale were quantified by conducting four system level pretests.

- Inner and outer structure interaction – Confirmation tests were conducted to verify separation between the outer and inner structure by pressurizing lines up to isolation valve separating inner and outer structure and confirming zero readout on the scale when pressurized.
- Slow and fast step up of hydrogen – This test was performed by stepping up the pressure in hydrogen lines connected to the vessels and comparing static scale reading to PVT estimates. These data were used to establish a correlation between PVT calculations and scale readings under static conditions.
- Flow momentum effects – Dynamic effects caused by the momentum of turning flow can offset scale readings. This test was conducted by flowing nitrogen (for safety) through the lines with the vessel isolation valve closed. A correlation was determined between flow and scale reading.
- Pressure step down effects – Scale reaction to fill line depressurization was quantified and if greater than zero a correlation was used for scale correction.

CONCLUSIONS AND FUTURE DIRECTIONS

The DOE funded Hydrogen Meter Benchmarking project is scheduled to be completed by the end of FY 2016. The data generated characterize three high-pressure hydrogen flow meters and will be used to support further development of flow meters. The sale of dispensed hydrogen is governed by state regulations that reference NIST Handbook 44 requirements. Currently NIST Handbook 44 requires ±1.5% accuracy when dispensing motor vehicle fuels; however these requirements are being reviewed by NIST based on the experience with California Code of Regulation and the reduced accuracy classes that have been instituted for early market adoption of fuel cell vehicles.

Results from this project will be compiled into a composite data product that will show the current capability of the flow meter market without identifying performance of specific meters. NREL will work closely with meter manufacturers, station providers, and other key stakeholders to disseminate results of the benchmarking study. These test results are aimed at enabling the development of commercially available hydrogen flow meters for 70 MPa dispensing stations.

FY 2016 PUBLICATIONS/PRESENTATIONS

1. "Meter Benchmarking Stakeholder Project Review," Burgess, R., Peters, M., Post, M., National Renewable Energy Laboratory, January 19, 2016. (presentation)

2. "Hydrogen Meter Benchmarking Interim Report," Burgess, R., Peters, M., Post, M., Ainscough, C., National Renewable Energy Laboratory, January 2016. (report)

3. "Meter Benchmarking Project Review," Joint Tech Team Meetings, Sandia National Laboratories, Livermore, CA, April 5, 2016. (presentation)

4. "Hydrogen Meter Benchmark Testing," 2016 DOE Hydrogen and Fuel Cells Program, Annual Merit Review, June 9, 2016. (presentation)