VII.7 Development of the Hydrogen Station Equipment Performance (HyStEP) Device

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Subcontractor
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Project Start Date: September 2014
Project End Date: December 2015

Overall Objectives

- Accelerate commercial hydrogen station acceptance by developing and validating a prototype device to measure hydrogen dispenser performance
- Develop a device capable of testing to the Canadian Standards Association (CSA) HGV 4.3 test method to test dispensers for compliance with the table-based fueling protocol defined by SAE J2601-2014
- Make the device available for use by the state of California to commission existing and new hydrogen stations in the 2016–2017 timeframe

Fiscal Year (FY) 2015 Objectives

- Place a contract with a third party supplier through a competitive bid process for the fabrication of the HyStEP device per a detailed specification developed by the project team
- Co-develop the detailed system design with the supplier including the following
  - Final piping and instrumentation diagram (P&ID)
  - Mechanical layout
  - Electrical diagram
  - Detailed list of mechanical and electrical components
- Finalize the design through a series of reviews, including the following
  - Failure modes effects and criticality analysis (FMECA)
  - Detailed design review
  - Presentation to and review by the Hydrogen Safety Panel
  - Final review and concurrence with Fuel Cell Technologies Office (FCTO) program managers
- Development of safety systems including hardware and software safeguards
- Fabrication, assembly and integration of the HyStEP device (to be performed by the supplier)
- Validation of the HyStEP device performance at National Renewable Energy Laboratory's (NREL's) Energy Systems Integration Facility (ESIF) facility

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section of the FCTO Multi-Year Research, Development, and Demonstration (MYRDD) Plan:

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

(E) Codes and Standards

Contribution to Achievement of DOE Technology Validation Milestones

This project will contribute to achievement of the following DOE milestones from the Technology Validation section of the FCTO MYRDD Plan:

- Milestone 4.4: Complete evaluation of 700-bar fast fill fueling stations and compare to SAE J2601 specifications and DOE fueling targets. (3Q, 2016)

FY 2015 Accomplishments

- Led a team of stakeholders including NREL, Air Liquide, Boyd Hydrogen, California Air Resources Board (CARB), and Toyota, hereafter called the project team, to co-design the HyStEP device
- Developed a comprehensive specification for the device

- Through a competitive bid process, selected and placed a contract with Powertech Labs to fabricate the HyStEP device
- With Powertech, completed the detailed device design including the H_2 tank selection, P&ID, trailer selection and mechanical layout, electrical equipment selection and layout, and data acquisition, control and safety systems
- Completed a detailed FMECA that identified and analyzed 202 failure modes and effects
- Met the criteria for the first go/no-go milestone by March 31, 2015, to move forward with device fabrication; which included a briefing to and approval from the Hydrogen Safety Panel
- Completed component procurement and fabrication (Powertech)
- Completed mechanical and electrical assembly and integration (Powertech)
- Developed the LabVIEW user interface design, control screen layout, and data reporting templates with Powertech
- Completed the Rev. 1 control and data acquisition software (Powertech and contractor)
- Completed an onsite acceptance test of the device at Powertech
- Coordinated the deployment of the HyStEP device in California with CARB including drafting a contract between Sandia and CARB for the loan of the device

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INTRODUCTION

It is generally agreed that policies and technology solutions need to be developed and implemented to help reduce the time to commission a hydrogen station. The current practice of hydrogen station acceptance, which burdens vehicle original equipment manufacturers (OEMs) with serial testing of stations because each OEM conducts their own testing and evaluation, can take months. This process is not practical or sufficient to support the timely development of a hydrogen fueling station network. This is especially true in the state of California where new stations are coming online currently and as many as 35 new stations are scheduled to be commissioned soon. Ultimately, a hydrogen station test device that can be used to verify station fueling protocol, average daily and peak fueling capacity, and fuel quality would be desirable to commission new stations. In the near-term, a test device designed specifically to test station fueling protocol that is technically effective, safe, robust, and user friendly will accelerate the commissioning of hydrogen stations. This device must be safe and effective to be useful, but also simple enough to design, fabricate, assemble and implement quickly to meet the timetable of current station deployment in California. This project was carried out to develop such a device.

To meet this goal, the project team, along with contractor Powertech Labs, has developed the HyStEP device. The device includes three Type IV 70 MPa tanks capable of storing a total of 9 kg hydrogen that are instrumented with pressure and temperature sensors. The tanks are connected to a 70 MPa receptacle equipped with pressure and temperature sensors as well as Infrared Data Association (IrDA) communications integrated with a data acquisition, analysis, and control system. A valve near the receptacle attached to a vent manifold can be used to both simulate a leak for fault detection tests and for controlled defueling. A nitrogen purge system is also included. Additional temperature sensors will record ambient temperature near the receptacle and various external system temperatures. The HyStEP device is capable of performing key tests defined in CSA HGV 4.3. These include IrDA communication tests, fault detection tests, and communication and non-communication fills.

APPROACH

The project team will select the device supplier through a competitive bid process and collaborate with the supplier on the design and acceptance testing of the HyStEP device. In order to prepare the device for real-world deployment, the device will undergo extensive validation testing at NREL's ESIF facility. This testing will include using the device to carry out many, if not all of the tests defined in CSA HGV 4.3 to ensure safe and reliable operation. The method for data reporting will also be refined during testing and proved out for a real-time report of the results that would be available at a commercial station. Following validation testing at NREL, the device will be shipped to California for pre-deployment testing at two commercial hydrogen stations. The device will then be put into service by the state through a contract between Sandia National Laboratories and CARB.

The device supplier will provide the project team with a comprehensive set of documentation covering device design, operation, maintenance and safety. The required documents will be published by Sandia to a publicly accessible website.

RESULTS

Upon placing the contract, the project team worked closely with Powertech to determine the mobile platform for the device and develop the detailed final P&ID shown in Figure 1. A trailer-based design was chosen and the P&ID was used to develop the list of components for the HyStEP device including valves, tubing and fittings, filter, thermally-activated pressure relief device, hydrogen sensor,

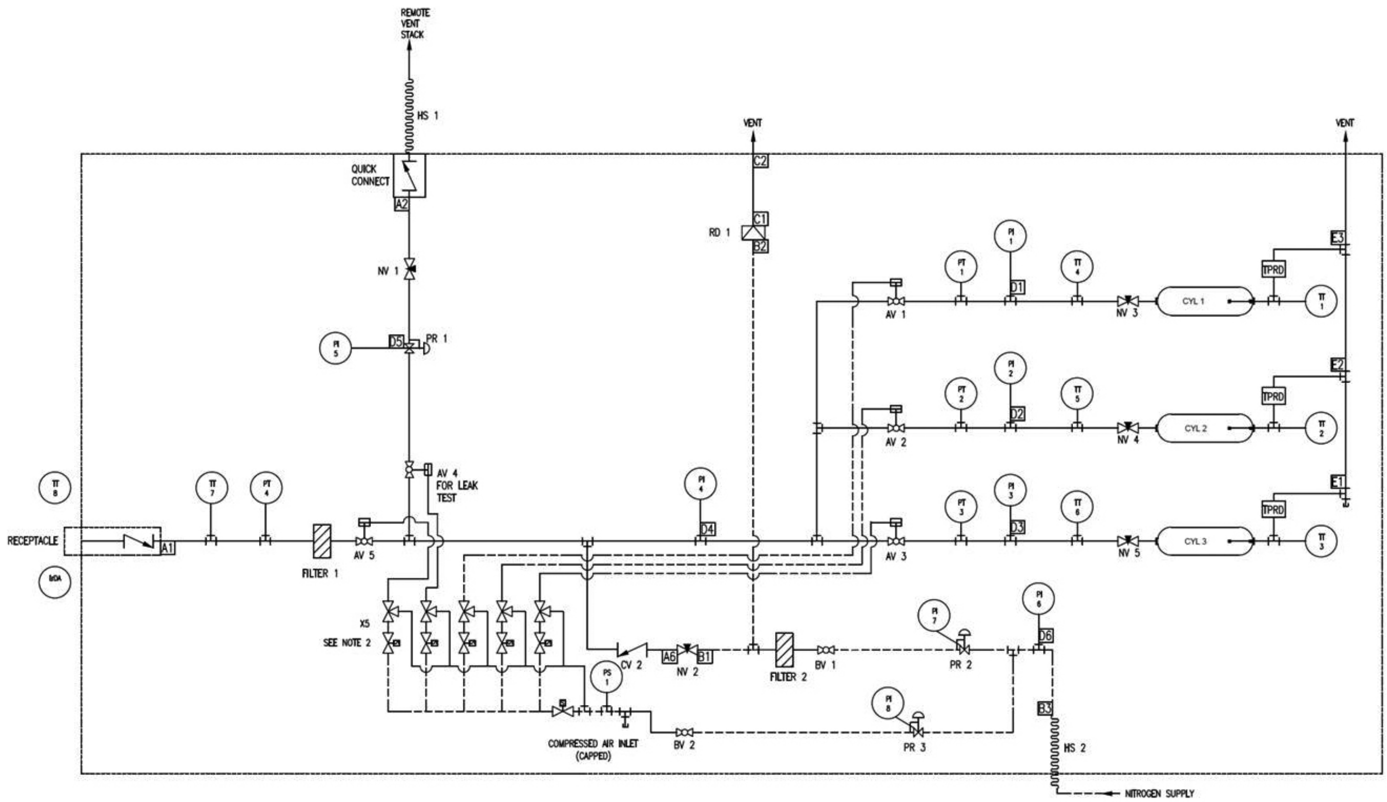

FIGURE 1. HyStEP device piping and instrumentation diagram

tank mounting hardware, IrDA system, receptacle, and instrumentation including pressure transducers, temperature sensors and feedthroughs. The outcome was a comprehensive list of all of the system components, specifications, suppliers and part numbers.

The overall HyStEP device design, including the P&ID, electrical diagrams and component lists, was then reviewed in several ways. Firstly, Powertech and the project team completed a detailed FMECA on the HyStEP design facilitated by Intertek Consulting. The results of the FMECA are summarized as follows:

- 7 functional blocks were analyzed
- 44 functions were defined
- 202 failure modes and effects were identified
- Each effect was assigned severity, occurrence, and detection/prevention ratings
- 47 failure mode effects had severity of 9 or 10 indicating a safety hazard
- 20 failure mode effects had a risk priority number (RPN = severity*occurrence*detection) greater than 100

Following the completion of the FMECA, Powertech and the project team addressed all failure mode effects with RPN values >100 and severity of 9 or 10. Actions were taken to mitigate these risks through design changes, safeguards, and/or operating procedures.

Secondly, a final design review for the HyStEP device was carried out that included a majority of the project team and three engineers from Powertech. Every component on the P&ID was reviewed along with the electrical layout and design as well as the trailer and frame layout and design. Several design changes were made and implemented by Powertech based on this review.

Thirdly, the project team briefed the Hydrogen Safety Panel on the HyStEP device and the results of the FMECA. The team provided the latest design documents at that time. Selected panel members then carried out a more detailed review of these documents. The panel's compiled comments were provided to the project team and Powertech. The project team determined that the panel's comments and recommendations were satisfied by the HyStEP design and prepared a response to the panel, which was accepted.

Based on the FMECA, the project Design Review and the independent review by the Hydrogen Safety Panel, the DOE program management team agreed to move forward with fabrication of the HyStEP device.

With DOE approval, Powertech began the process of procurement and fabrication of the mechanical and electrical hardware for the device. In parallel, Powertech hired a

National Instruments certified LabVIEW programmer to develop the control and data acquisition software and user interface. The project team worked with Powertech to define the requirements for this software including a comprehensive alarm matrix and list of software safeguards based on the FMECA results.

As the major components arrived, Powertech began the mechanical assembly and integration of the system. This included fabricating a custom frame to mount the tanks and hydrogen manifold. A structural finite element analysis was performed on the frame to ensure mechanical stability under shock and vibration. The three hydrogen storage tanks were then mounted to the frame and the tubing manifold was bent and assembled with fittings, valves, and instruments. Instruments and wiring followed. In parallel, a benchtop test apparatus was used to test out the LabVIEW software including the interface to the IRDI Systems infrared communications hardware. Figure 2 shows the nearly complete layout of the interior of the HyStEP trailer with all major systems identified.

At this stage, initial tests in the Powertech lab were carried out including control and data acquisition communications, IrDA operation, leak checks and proof test of the pressure components, and automated procedures. The system was verified to be mechanically sound and leak free and all control and data acquisition functionality was verified using the operator panel shown in Figure 3. These tests were performed at reduced pressure and with nitrogen.

Following the integration and initial checkout and testing by Powertech, Terry Johnson (SNL) and Danny Terlip (NREL) visited Powertech's facility on July 22–23, 2015, to verify the initial checkout. Over the two days, they reviewed the design with the Powertech team and carried out communications and venting tests using the Powertech's commercial hydrogen dispenser (see Figure 4). Fueling tests were not carried out at this time because the system had not been fully pressure tested with hydrogen. A few modifications to the LabVIEW software were identified through this testing that will be completed prior to the device shipping to NREL for validation testing. In addition, a full system leak check at 87.5 MPa hydrogen pressure will be completed before the device ships.

FIGURE 3. HyStEP device operator panel including receptacle, system pressure indicators, touchscreen panel, electro-static discharge, and vent controls

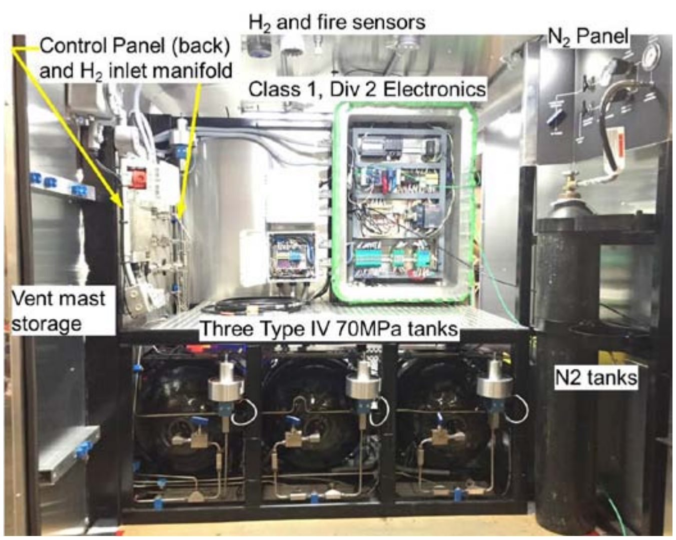

FIGURE 2. Layout of the interior of the HyStEP device trailer showing the major subsystems

FIGURE 4. HyStEP device sited at Powertech's H_2 dispenser with the remote vent stack

CONCLUSIONS AND FUTURE DIRECTIONS

- Final fabrication and assembly—Powertech—through August 7, 2015
- Ship the device to NREL—Powertech—arrival week of August 10, 2015
- Post-shipment leak and functionality checks and communication tests—NREL—week of August 17, 2015
- Onsite training carried out by Powertech; trainees will include NREL staff as well as operators from CARB and California Department of Food and Agriculture Division of Measurement Standards (DMS)—week of August 24, 2015
- Final checkout and verification—NREL/Powertech/SNL—August/September 2015
  - Go/No-Go 15.1: Results of the NREL testing will be reviewed by the project team, DOE HQ, and communicated to H2USA members and additional DOE-approved stakeholders
- Publication of documentation—Powertech/SNL—August 2015
- Pre-deployment test #1—SNL/project team—October 2015
  - Milestone 17.1: Testing has been completed at the first California station
- Pre-deployment test #2—SNL/project team—November 2015
- Performance analysis and report—NREL—November 2015
- Initiate loan to State of California agency (CARB/DMS)—SNL—November 2015

FY 2015 PUBLICATIONS/PRESENTATIONS

1. Johnson, T. "Station Acceptance Project Team," California Fuel Cell Partnership meeting, October 2014. (presentation)

2. Ainscough, C; Pratt, J.; Kurtz, J.; Someday, B.; Terlip, D.; and Johnson, T. "Hydrogen Fueling Infrastructure Research and Station Technology," DOE Webinar, November 2014. (presentation)

3. Johnson, T. "HyStEP Device Update," Combined Codes and Standards and Hydrogen Delivery Tech Team meeting, January 2015. (presentation)

4. Johnson, T. "HyStEP Device Design and Safety Analysis," 21st Hydrogen Safety Panel meeting, March 2015. (presentation)

5. Johnson, T. "HyStEP Device Update," H2FIRST Coordination Panel Meeting, March 2015. (presentation)

6. Johnson, T. "Development of the Hydrogen Station Equipment Performance (HyStEP) Device," 2015 DOE Hydrogen and Fuel Cells Program and Vehicle Technologies Office Annual Merit Review and Peer Evaluation Meeting, June 2015.