VI.B.2 Development of a Turnkey Hydrogen Fueling Station

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Subcontractors:
H2Gen Innovations, Inc. – Alexandria, VA
Pennsylvania State University – University Park, PA
QuestAir Technologies Inc. – Burnaby, Canada (engineering)

Start Date: January 1, 2002
Projected End Date: March 31, 2007

Objectives

To demonstrate the potential for a stand-alone, fully integrated hydrogen fueling station based upon the reforming of natural gas by striving to:

- Develop a cost-effective solution to the reforming of natural gas to produce a reformate stream.
- Build on the experience gained at the Las Vegas H2 Fueling Energy Station project.
- Develop an efficient, cost-effective means to purify the hydrogen-rich reformate to pure hydrogen employing pressure swing adsorption (PSA).
- Develop an optimum system to compress, store, meter, and dispense hydrogen into vehicles.
- Efficiently integrate the process steps mentioned above into a safe, user-friendly, cost-effective fueling station.
- Demonstrate the operation of the fueling station at Penn State University.
- Maintain safety as the top priority in the fueling station design and operation.
- Obtain adequate operational data to provide the basis for future commercial fueling stations.

Technical Barriers

This project addresses the following technical barriers from the Production section (3.1.4.2.1) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Fuel Processor Capital Costs
(C) Operation and Maintenance (O&M)
(F) Control and Safety

Technical Targets

DOE Targets (identified in the "Hydrogen, Fuel Cells and Infrastructure Technologies Multiyear Program Plan," that are addressed in this project are:

- Cost of Hydrogen when produced in quantities of 500 stations/year: $3.00/kg (pressurized to 5,000 psi and untaxed).
- Efficiency:
  - PSA: 82% by 2005
  - Overall: 65%

Accomplishments

- Progressed and completed Phase 3 work.
- Initiated Phase 3 station operation and data collection.
- Met DOE PSA efficiency target of 82% for 2005 – laboratory and field testing.
- Met DOE overall system efficiency target of 65% – start-up performance test.
- Met DOE target of $3.00/kg hydrogen dispensed – based on H2A parameters.

Introduction

The transition to hydrogen as a fuel source presents several challenges - one of the major hurdles is the cost-effective production of hydrogen in small quantities. In the early demonstration phase, hydrogen can be provided by bulk distribution of liquid or compressed gas from central production plants; however, the next phase to fostering the hydrogen economy will likely require onsite hydrogen generation to institute a pervasive infrastructure. Providing inexpensive hydrogen at a fleet operator's garage or local fueling station is a key enabling technology for direct hydrogen fuel cell vehicles (FCVs). The objective of this project is to develop a comprehensive, turnkey, stand-alone hydrogen fueling station for FCVs with state-of-the-art technology that can be cost-competitive with current hydrocarbon fuels. Such a station will help to promote the advent of the hydrogen fuel economy for buses, fleet vehicles, and ultimately personal vehicles.

Approach

The development efforts are expected to build on preliminary work accomplished by the major partners. Air Products, as the overall project manager, is responsible for the total system integration and final development of the installed equipment. As the system integrator, Air Products will ensure that the system is fully optimized and that all of the individual components are compatible to deliver the lowest cost hydrogen fuel. This project is being managed in three phases, with Stage Gate reviews between each phase.

During Phase 1 of the project, subsystem conceptual designs were formulated and costed. Options were developed and compared for the reformer system, PSA system, compression, storage, and dispenser. Air Products has worked with H2Gen and other reformer suppliers to develop and to evaluate the applicability of autothermal reforming (ATR), partial oxidation (POX), and SMR-based reforming systems. At the end of Phase 1, Air Products confirmed the team's ability to reach the cost targets via a confirmed definition of scope and execution costs and has identified the partners for further development of components in Phase 2.

In Phase 2, the most promising subsystem designs assessed and selected in Phase 1 were further developed. Laboratory and field testing of certain components was carried out. Recommendations for the optimal fueling station components were made. Air Products engineers, working with the selected reforming partner, have optimized the design of the reformer for use in the hydrogen generator system. Air Products completed the design of the hydrogen and compressed natural gas/hydrogen (CNG/H_2) blend dispensers, which were tested, installed, and commissioned on the Penn State fueling station site. Finally, Air Products served as the system integrator to pull together the various pieces into a comprehensive turnkey unit and to minimize the total cost of delivered H_2.

During Phase 3, scale-up and detailed engineering design of all equipment will be completed. The engineered system will be analyzed for Design for Manufacture and Assembly (DFMA®) and the assembled system will include instrumentation for data collection and provisions for remote monitoring of operation. Fabrication of all equipment and installation at Penn State will follow. Then, the fueling station will be started up and put into operation at Penn State University. This will include six months of operation and testing. Finally, we will validate the cost of H_2 delivered from the installed fueling station, including a study pertaining to the impact of mass-producing components.

Results

During the past year, the project team completed Phase 2: Subsystem R&D and completed the first part of Phase 3: System Deployment. Phase 2 was managed as a comprehensive development program, wherein work was organized by process sub-system (reformer, PSA, compression, storage, and dispensing). A combination of simulation, laboratory R&D, real-world component testing, collaboration with vendors, and engineering design work was integrated to enable significant progress towards the DOE Targets and Barriers. The R&D, laboratory testing, and field testing culminated in a final engineering design for an integrated H_2 and H_2/CNG blend refueling station. An overall process flow diagram for the integrated refueling station is shown in Figure 1.

All equipment was purchased, fabricated, and installed at the Penn State site during the past winter and spring, culminating in the integrated station being declared "on-stream" on April 1, 2006. Figure 2 shows the installed refueling station at Penn State.

Finally, the H2A model was run to show both the current cost of H_2 from the station and the future potential cost of H_2 from a larger station based upon the installed technology. Table 1 shows that the station is currently operating at an overall efficiency of 65.1%, which slightly exceeds the DOE Target of 65%. This efficiency will be monitored carefully during the station

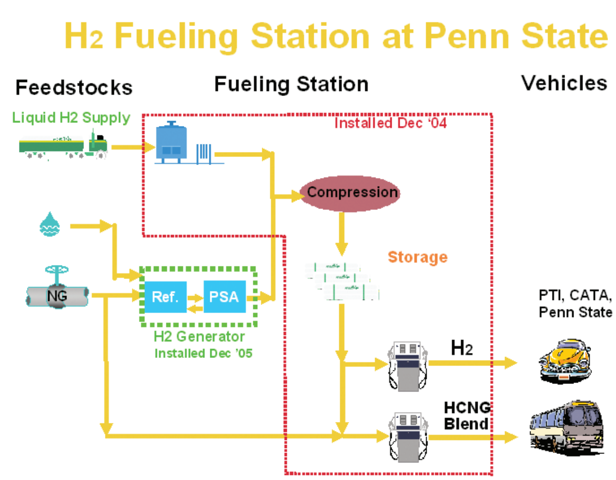

FIGURE 1. Fueling Station Process Flow Diagram

FIGURE 2. Equipment Installed at the Penn State H2 Refueling Station

TABLE 1. H2A Model Results

	Base	Large Scale, H2A Inputs	
H2 Production, kg/d	108	1,500	
Utilization, %	70	70	
Overall Efficiency, %	65.1	65.1	Target 65%
Units Produced per Year	5	500	
IRR, %	10	10	
Power Cost ($/kwh)	0.08	0.08	
NG Cost ($/nm^3)	0.175	0.175	
Calc'd H2 Cost ($/gge)	13.98	3.03	Target $3.00

operating period to determine stability of efficiency and operation. Also shown in Table 1 is the current cost of H_2, of about $13.98/kg, fully burdened with engineering and development costs, at the installed production volume of 108 kg/day H_2. Note that when this technology is scaled up to 1,500 kg/day H_2, the cost of H_2 decreases significantly. When stations of this larger size are deployed at volumes of 500 installations per year, the cost of H_2 is calculated by the H2A model to be $3.05/kg H_2 dispensed at 5,000 psi, very close to the DOE Target of $3.00/kg.

Conclusions and Future Directions

Work was completed on the system design, equipment installation, and start-up of the H2 Fueling Station during Phase 3 of this aggressive project to determine the viability of a commercial turnkey H_2 fueling station. Over the past year, the team completed its Phase 2 goals, completed Phase 3, kicked-off the operation and data collection phase, and achieved several significant milestones:

- A cost-effective route for production and delivery of H_2 from a commercial fueling station was identified.
- The cost of H_2 from stations improves with mass production and with scaling to larger station sizes.
- The H_2 PSA system efficiency has been demonstrated through operation and testing to be >82%, meeting the DOE Target.
- The H_2 generator produced nameplate capacity (50 nm^3/hr pure H_2).
- The overall system efficiency was measured during a start-up performance test to achieve the 65% DOE Target.
- The H2A model was run under scenarios defined within the model. For a 1,500 kg/day H_2 fueling station, when deployed in volumes of 500 per year, the H2A modeling support that the $3.00/kg H_2 DOE 2005 Target is achievable.

Future Direction

The future direction of this H2 Refueling Station is to run the system at maximum rates for a period of six months. During this time, system optimization and data collection will continue. A full performance test is planned for Fall 2006. Finally, Penn State's Transportation Institute plans to ramp-up vehicle driving at the university, which is expected to increase demand for H_2 at the station.

FY2006 Publications/Presentations

1. Quarterly and Annual Reports to U.S. DOE, as required per the Cooperative Agreement, were submitted by Air Products.

2. Annual Program Merit Review presentation was made by David Guro of Air Products at the DOE meeting held in Washington, D.C., in May 2006.

3. A Production and Delivery Tech Team "Deep Dive" Program Review meeting was held at Penn State in February 2006. Attendees included DOE HQ program management team, the DOE Technical Advisory Team, and APCI team.