V.D Refueling Technology Development and Demonstration

V.D.1 Development of a Turnkey Hydrogen Fueling Station

David E. Guro
Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, PA 18195
Phone: (610) 481-4625; Fax: (610) 481-4260; E-mail: gurode@apci.com

DOE Technology Development Manager: Sig Gronich
Phone: (202) 586-1623; Fax: (202) 586-9811; E-mail: Sigmund.Gronich@ee.doe.gov

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

Objectives

To demonstrate the potential for an economically viable 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 H_2 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 Technology Validation section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- B. Storage
- C. Hydrogen Refueling Infrastructure
- D. Maintenance and Training Facilities
- E. Codes and Standards

Approach

This project is being managed in three phases, with Stage Gate reviews between each phase.

- In Phase 1, conceptual design and preliminary cost evaluations for each major sub-system in the fueling station will be completed.
- In Phase 2, sub-system R&D will be performed to test the concepts put forth in Phase 1. Technical viability and fueling station costs will be validated.
- Phase 3 will include fabrication, installation, and testing of the full-scale hydrogen generator and dispenser at Penn State. This hydrogen fueling station will be designed to deliver 50 nm^3/hr hydrogen.

During the past year, the project progressed within Phase 2: Subsystem R&D. Phase 2 is being managed as a comprehensive development program, wherein work has been 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 is being integrated to allow significant progress towards the DOE targets and barriers.

Accomplishments

- Initiated Phase 2 development work, as outlined below.
- Re-worked project cost and schedule, to match with reduced FY 2004 funds available.
- Met DOE PSA efficiency target for 2005.
- Met DOE overall system efficiency target for 2005.
- Met DOE 2005 target of $3.00/kg hydrogen dispensed.

Future Directions

- Phase 2 – Subsystem Development: Lab testing of certain components will be carried out. Recommendations for the optimal fueling station components will be made.
- Phase 3 – System Deployment: Scale-up and detailed engineering design of all equipment will be completed. Fabrication of all equipment and installation at Penn State will follow. Finally, the fueling station will be started up and put into operation at Penn State University. This will include 6 months of operation and testing.

Table 1. The schedule for completed and remaining work is outlined in the table below

Task	Date
Phase 1 Pre-Contract Technical Development	Oct 2001 – March 2002 (Complete)
Cooperative Agreement Award	29 March 2002 (Complete)
Phase 1 Conceptual Design and Economic Evaluation	April 2002 – June 2002 (Complete)
Phase 2 Subsystem Development	July 2002 – September 2004
Phase 3 System Deployment – Station without SMR/PSA	October 2003 – October 2004
Phase 3 System Deployment – SMR + PSA	October 2004 – June 2005
Phase 3 System Deployment – Operation & Testing	July 2005 Start-Up of Reformer August 2005– January 2006 Operation and Testing

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 steam methane reformer (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, currently underway, the most promising subsystem designs assessed and selected in Phase 1 will be further developed. Lab testing of certain components will be carried out. Recommendations for the optimal fueling station components will be made. Air Products engineers, working with the selected reforming partner, will optimize the design of the reformer, and build and test components of this reactor in a laboratory. Air Products will be directly responsible for the design of the dispenser, which will be tested in a shop prior to installation on site. Because of the partners' relationships with the automotive manufacturers, we will solicit their assistance for inclusion of commercial features such as vehicle communication. Finally, Air Products will act as the system integrator to pull together the various pieces into a comprehensive turnkey unit and to minimize the total cost of delivered hydrogen.

During Phase 3, scale-up and detailed engineering design of all equipment will be completed. The engineered system will be analyzed for DFMA (Design for Manufacture and Assembly) 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 University (PSU) will follow. Then, the fueling station will be started up and put into operation at PSU. This will include 6 months of operation and testing. Finally, we will validate the cost of hydrogen delivered from the installed fueling station, including a study pertaining to the impact of mass-producing components.

Results

General:

- Phase 2 kicked-off.
- The DOE funding for this project in FY 2004 was reduced. Thus, the team agreed to a creative alternative plan that achieves several objectives:
  - Allows the opening of a hydrogen fueling station at PSU in October 2004, in support of PSU's planned vehicle availability.
  - Completes development of the PSA in FY 2004, and includes the deployment of the hydrogen compressor, storage module, and

hydrogen and hydrogen/CNG dispensers in FY 2004.

– Enables continued progress on the reforming and integrated hydrogen generator (reformer + syngas compressor + PSA), albeit at a slower pace to keep within the budget constraints of FY 2004.

Of critical importance to the success of this project is the availability of vehicles at the PSU site to validate the performance of the installed fueling station. It is recognized by PSU, Air Products, and its partners, that fuel cell buses will not be available by January 2004. Since this was the targeted commissioning date for the hydrogen fueling station, a team was established to synthesize a plan for the station and for making vehicles available. The team meets regularly and consists of representatives from Air Products, the PSU Hydrogen Institute, DOE (Philadelphia Regional Office), State of Pennsylvania Department of Environmental Protection, Centre Area Transit Authority (CATA), Penn State University, Pennsylvania Transportation Institute (PSU PTI), and Penn State University, Office of Physical Plant (PSU OPP). The PSU Hydrogen Institute has taken the lead in developing a follow-on project to: (1) convert several CATA CNG buses to run on a H_2/CNG blend, (2) convert several PSU OPP utility vans to use a H_2/CNG blend, (3) purchase for PSU OPP one hydrogen utility van (with internal combustion engine), (4) upgrade the CATA and PSU facilities for operation with a H_2/CNG blend, including required training, and (5) operate and maintain the fueling station for a period of 3 years. Penn State PTI has secured funding from two Pennsylvania State agencies for the first year of its project.

Reformer:

- Process engineering development work continues on optimization of the reformer system, including desulfurization, shift, steam generation, heat exchange, and valving.
- Lessons learned from the operation and maintenance of the Las Vegas H_2 Refueling Station DOE-sponsored project are being fed directly into the design and development work on this project.
- Process Flow Diagram (PFD) issued. Preliminary Process and Instrumentation Diagrams P&IDs have been developed. Engineering reviews ongoing.

PSA:

- APCI's adsorbent development complete. Novel structured adsorbents and advanced beaded adsorbents show significant improvement in bed size and hydrogen recovery. PSA cycle development work concluded – it was used to fully utilize the advanced adsorbents' capabilities. Laboratory experiments completed.
- Rotary valve testing continues at Air Products' and its supplier's labs.
- APCI fabricated its "beta" PSA test unit. The unit was then sent to a commercial Air Products hydrogen production facility and run. Data has been collected. Tests continue on the operation of the unit. The PSA unit has provided data for use in the comparison with the QuestAir PSA unit.
- After careful review of both companies' reports, the Air Products PSA system has been chosen for deployment in Phase 3. This is due primarily to advantages in cost, efficiency, and anticipated maintenance with the Air Products system.

H_2 Compression, Storage, and Dispensing:

- Air Products has continued engineering work to determine the optimum configuration and selection of components for the hydrogen dispenser.
- Laboratory equipment to test hydrogen flow meters for use in the dispenser has been commissioned. Testing is underway and is expected to continue through Summer 2004.

Conclusions

Work progresses on Phase 2 of this aggressive project to determine the viability of a commercial turnkey hydrogen fueling station. Over the past year, the team progressed significantly towards its Phase 2 goals and achieved several significant milestones:

- A cost-effective route to production and delivery of hydrogen from a commercial fueling station was identified.

- The cost of hydrogen from stations improves with mass production and with scaling to larger station sizes.
- The PSA system efficiency has been demonstrated through operation and testing to be >82%, meeting the DOE 2005 target.
- The overall system efficiency is estimated to achieve the 68% DOE 2005 target.
- The $3.00/kg hydrogen DOE 2005 target is achievable.

FY 2004 Publications/Presentations

1. Annual Program Merit Review presentation was made by David Guro of Air Products at the DOE meeting held in Philadelphia, PA, in May 2004.

Special Awards

1. David Guro of Air Products received an R&D Award from Steve Chalk of DOE at the Annual Review meeting in Philadelphia, PA, in May 2004. The award was for achieving the DOE 2005 target for H_2 Purification/Separation efficiency of 82%.