VI.A.5 California Hydrogen Infrastructure Project*

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Working Partners/Subcontractors:
BMW
Honda
Nissan
Toyota
University of California Irvine (UCI)
National Fuel Cell Research Center (NFCRC)
South Coast Air Quality Management District (SCAQMD)

Start Date: August 1, 2005
Projected End Date: September 30, 2008

*Congressionally directed project

Objectives

- Demonstrate a cost effective infrastructure model in California for possible nationwide implementation.
  - Design, construct and operate seven hydrogen fueling stations
  - Collect and report infrastructure data
  - Document permitting requirements and experiences
  - Validate expected performance, cost, reliability, maintenance, and environmental impacts
- Implement a variety of new technologies with the objective of lowering costs of delivered H_2.
  - New Delivery Concept (NDC)
  - Hydrogen Based Unit (HBU)
  - High pressure/high purity clean up equipment

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section (3.5.4.2) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(C) Hydrogen Refueling Infrastructure

(H) Hydrogen from Renewable Resources

Accomplishments

- Enterprise remote access monitoring (eRAM) design and implementation almost complete.
- Work continued on finding a suitable location for the Torrance Pipeline Station. Equipment design work complete. Equipment in fabrication.
- Design, permitting, equipment fabrication completed for Phase I (350 bar fueling) at the NFCRC at UCI. Design and equipment fabrication started for Phase II (700 bar fueling). Early design started on Phase III (liquid H_2 fueling).
- HF-150 Hydrogen Fuelers: Three units in fabrication. Location and station operator determined for one system.
- HBU: Design complete. Equipment on order for two HBUs.
- NDC Trailer: Design complete. Equipment on order for two NDC trailers.

Introduction

Air Products and Chemicals, Inc. is leading a comprehensive, multiyear project to demonstrate a hydrogen infrastructure in California. The specific primary objective of the project is to demonstrate a model of a "real-world" retail hydrogen infrastructure and acquire sufficient data within the project to assess the feasibility of achieving the nation's hydrogen infrastructure goals. Therefore, the final infrastructure for the proposed project is expected to include many flexible modes of supply, that is, pipeline-supplied hydrogen, delivered liquid and gas, distributed hydrogen from reformed natural gas or electrolysis, processing of hydrogen-containing gas produced as an off-gas from renewable or waste energy sources, and co-production of hydrogen from high-temperature fuel cells.

The project will provide a world-class demonstration and model for the future hydrogen economy by a judicious implementation of cost-effective supply

modes with a clear path to commercial sustainability. In addition, the project will help to advance hydrogen station technology, including the vehicle-to-station fueling interface, through consumer experiences and feedback.

Air Products is leading this project in collaboration with four automakers: Toyota, Honda, and Nissan, who are providing fuel-cell vehicles, and BMW who is supplying hydrogen internal combustion engine (ICE) vehicles. By encompassing a variety of fuel cell vehicles, hydrogen ICEs, customer profiles and fueling experiences, this project is obtaining a complete portrait of *real market needs*. The project is also opening its stations to other qualified vehicle providers at the appropriate time to promote widespread use and gain even broader public understanding of a hydrogen infrastructure. The project is engaging major energy companies to provide a familiar retail fueling experience at traditional gasoline station sites to foster public acceptance of hydrogen.

Approach

Work over the past year was focused in multiple areas. With respect to the equipment needed, technical design specifications were written, reviewed, and finalized. Both safety and operational considerations were a part of this review. After finalizing individual equipment designs, complete station designs were started including process flow diagrams and systems safety reviews. Material quotes were obtained, and in some cases, depending on the project status and the lead time, equipment was placed on order and fabrication was started. Consideration was given for expected vehicle usage and station capacity, standard features needed, and the ability to upgrade the station at a later date.

In parallel with work on the equipment, discussions were started with various vehicle manufacturers to identify vehicle demand (short and long term needs). Discussions included identifying potential areas most suited for hydrogen fueling stations, with focus on safe, convenient, fast-fills. These potential areas were then compared and overlaid with suitable sites from various energy companies and other potential station operators. Work continues to match vehicle needs with suitable fueling station locations. Once a specific site has been identified, the necessary agreements can be completed with the station operator and expected station users. Detailed work can begin on the site drawings, permits, safety procedures and training needs. Once stations are brought online, infrastructure data will be collected and reported to DOE using Air Products' eRAM system. Feedback from station operators will be incorporated to improve the station user's fueling experience.

Results

The world's first fueling station supplied by a hydrogen pipeline is being developed to demonstrate a low-cost, reliable supply of hydrogen. Sites in the Torrance, CA area in proximity to an existing Air Products 800 psig hydrogen pipeline are being considered. A 4 kg/hr compressor skid and a total of 50 kg of high-pressure hydrogen storage are being provided, accommodations are provided to double storage capacity in the future. A dual dispenser for both 350 and 700 bar hydrogen is being provided, and the future upgrade to 700 bar will require a booster compressor and minimal site work. Based on a 50% compressor on-stream factor, the station will have the capacity to dispense 48 kg/day or approximately 12 cars per day. When starting with full storage, six cars can be filled in succession.

As part of this project, a novel high-pressure, high-purity hydrogen purifier has been developed, and a 4 kg/hr unit will be installed upstream of the fueling station. Hydrogen from the pipeline will be purified to ultra-high purity using a physical adsorption system. The process cycle (patents pending) utilizes a rapid regeneration cycle to yield high hydrogen recovery. There is no need for thermal regeneration, which reduces the capital, operating, and maintenance costs.

A second fueling station is under development at the NFCRC at UCI. Hydrogen supply will be from a 1,500 gallon horizontal liquid hydrogen storage tank. This work is being undertaken in three phases:

- **Phase I**: Installation of a 2 kg/hr compressor skid, storage for 50 kg of hydrogen, and a dual dispenser for both 350 and 700 bar hydrogen
- **Phase II**: Installation of a booster compressor for the 700 bar dispenser
- **Phase III**: Installation of a liquid hydrogen dispenser

Based on a 50% compressor on-stream factor, the station will have the capacity to dispense 24 kg/day or approximately six cars per day. When starting with full storage, four to five cars can be filled in succession. Equipment design and procurement for Phases I and II have been completed, and design work for Phase III is underway.

Two new technologies are being deployed under this project. The New Delivery Concept (NDC) trailer (patents pending) is a new method of hydrogen distribution capable of supplying low, medium, and high pressure systems using a single liquid hydrogen trailer (Figure 1). The NDC trailer provides a tenfold increase in the amount of transported hydrogen compared with traditional tube trailers. This delivery system can be utilized to supply existing merchant bulk hydrogen and liquid hydrogen supply chains as well as hydrogen fueling stations, resulting in greater equipment

utilization. Delivery pressures as high as 8,000 psig are achieved, and no utilities are required from the receiving stations. Equipment is on order for two NDC trailers.

The Hydrogen Based Unit (HBU) (patents pending) is a new approach to reduce costs associated with stationary fueling stations. As shown in Figure 2, this product can be deployed at customer sites in conjunction with the NDC trailer. The HBU requires minimal space and can be located remotely from storage (including underground). No compression is required, as the NDC trailer delivers the hydrogen at the desired pressure (up to 7,000 psig). The design capacity of the HBU is 150 to 200 kg of hydrogen. Equipment for two HBUs is on order, and HBU stations are planned in the Los Angeles area and in northern California.

During the performance period, the economics of the NDC trailer and HBU were presented in a confidential report to the DOE. In many geographical locations, the total evaluated cost of hydrogen from the NDC-HBU system is less than other near-term supply alternatives; these results will be validated during this project. Early stage investment in hydrogen infrastructure development can be minimized and can be focused towards developing more hydrogen fueling stations. In the long term, other means of hydrogen supply (for example, large-scale hydrogen production with better proximity to the fueling station) may ultimately provide a more economical solution to the NDC-HBU combination.

The project also plans to use an NDC trailer to fill a number of mobile Hydrogen Fueler (HF) systems. The HF-150 (shown in Figure 3) is ideal for small fleet fueling and offers the advantages of being a highly reliable, cost-effective, and automated fueling system that can be easily installed. The HF-150 maintains about 150 kg of gaseous hydrogen at 6,600 psig. It can dispense

FIGURE 1. Air Products New Delivery Concept (NDC) Trailer

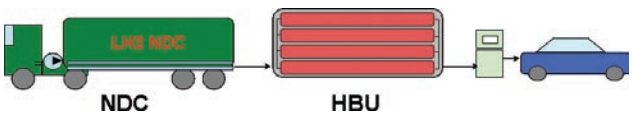

FIGURE 2. Air Products Hydrogen Based Unit (HBU)

FIGURE 3. Air Products HF-150 Hydrogen Fueler

approximately 80 to 90 kg before needing to be refilled. An NDC trailer will be sited at an optimal location to fill multiple HF-150 trailers and reduce the transportation distance between the fill location and the various dispensers. Three HF-150s are in fabrication, and sites in the Los Angeles area and in South Lake Tahoe are under consideration.

Software and hardware support for eRAM is almost complete. This will allow for automatic data collection from the gaseous H_2 dispensers at the hydrogen fueling stations. We have successfully completed the software setup for the first hydrogen dispenser and have tested the data flow from the test programmable logic controller, through a wireless modem, to the Air Products website. This was performed on a dry run in order to commission a dispenser into the eRAM system. The first real dispenser was successfully commissioned into the production version of eRAM. Infrastructure data automatically collected from eRAM along with additional data manually collected at the site will be reported to NREL when the first station goes online.

Conclusions and Future Directions

Since the start of the project, equipment design has been completed in most cases and major equipment with long lead times has been ordered. Fabrication has also been started for most stations in advance of site selection in many cases.

Planned future work includes:

- Demonstrate a variety of technologies in the deployment of the Hydrogen Infrastructure.
  - Perform an infrastructure study with the NFCRC at UCI
  - Determine potential station operators and locations for:
    - Torrance Pipeline Station
    - HF-150s in Los Angeles area and in South Lake Tahoe
    - HBUs in Los Angeles area and in northern Califonia

- Begin infrastructure data reporting
- Complete site selection and design work for northern California fill station
- Begin work on in-depth study on cryogenic compressed hydrogen
- Following approval by DOE, initiate work on the direct production of hydrogen from non-hydrocarbon sources using anaerobic digestion

Special Recognitions & Awards/Patents Issued

1. "Production of Carbon Monoxide-Free Hydrogen and Helium from a High-Purity Source," U.S. Patent Application, assigned U.S. Serial No. 11/365,780, application date February 2006.

2. "Cryogenic Fluid Supply Method and Apparatus," U.S. Patent Application, assigned U.S. Serial No. 11/039,264, application date January 2005.

3. "Optimized Cryogenic Fluid Supply Method," U.S. Patent Application, assigned U.S. Serial No. 11/264,058, application date October 2005.

FY 2006 Publications/Presentations

1. M. Pedersen, "California Hydrogen Infrastructure Project," Poster Display at National Hydrogen Association Conference, Long Beach, CA (March 2006).

2. A presentation regarding the overall project status was given at the DOE Annual Merit Review Meeting (May 2006).