VI.E.1 Research and Development of a PEM Fuel Cell, Hydrogen Reformer, and Vehicle Refueling Facility

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Subcontractors:
Plug Power Inc., Latham, NY
City of Las Vegas, Las Vegas, NV

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Projected End Date: June 30, 2006

Objectives

Design, develop, and demonstrate small on-site H_2 production system for stationary fuel cells and H_2 fuel stations.

- Design, construct, and operate a multipurpose refueling station to dispense hydrogen-compressed natural gas (HCNG) blends, and pure H_2.
- Design, construct, install and operate a H_2-fueled stationary 50 kW fuel cell.
- Maintain safety as a top priority for the fueling station and fuel cell.
- Evaluate operability, reliability, and economic feasibility of integrated power-generation and vehicle-fueling system.
- Obtain adequate operational data to provide basis of future commercial fueling station designs.

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:

(B) Storage
(C) Hydrogen Refueling Infrastructure
(D) Maintenance and Training Facilities
(E) Codes and Standards
(I) Hydrogen and Electricity Coproduction

Technical Targets

This project will contribute to achievement of the following DOE technology validation milestones from the Technology Validation section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

Milestone 11: Validate cost of producing hydrogen in quantity of \$3.00/gge untaxed. Results achieved and lessons learned in this project were applied to the Penn State Fueling Station, assisting in the progress on this milestone under that project.

Milestone 15: Validate co-production system using 50 kW fuel cell, hydrogen produced at \$3.60/gge and electricity at 8 cents/kW hr. This report covers the conclusion of demonstration testing of the distributed production of hydrogen for this project. The results validate the capability to achieve this milestone as defined by the HFCIT Multi-Year RD&D Plan.

Accomplishments

- Achieved satisfactory process operation and product-purity capability with the hydrogen generator, with one-button start and load-following capability.
- Achieved aggregate hydrogen generator operation of over 4,800 hours.
- Achieved lower heating value (LHV) efficiency of 68%, with hydrogen purity at <1 ppm CO.
- Identified and implemented system improvements under real-world performance and durability testing experience.
- Successfully performed over 200 HCNG blend and hydrogen vehicle fuelings.
- Achieved safe operation during operating period to date; safe operation was provided by the safe engineering, design, fabrication and utilization of the station.

- Updated economic models to incorporate latest fuel cell data and reformer efficiencies. H_2 pricing of $3.54/kg and electricity pricing of $0.08/kWh are possible with a 1,500 kg/day plant using H2A modeling.

Introduction

Small-scale, on-site hydrogen production technology that can operate on available fuels such as natural gas will be required to provide hydrogen for fueling stations where delivered hydrogen is not readily available. Small-scale, natural gas-based hydrogen reformers are not fully developed, and will suffer from poor economics due to their small scale and poor utilization rates in the early years of hydrogen vehicle development. One approach to achieving high utilization rates on the reformer is to baseload it with a stationary fuel cell that produces electric power while the intermittent vehicle-fueling load, and resulting demand shortfall, is handled by diverting a portion of the hydrogen from the fuel cell to the fuel station. This co-production of hydrogen fuel and electric power is referred to as an "Energy Station." A team of three organizations, Air Products and Chemicals Inc., Plug Power Inc., and the City of Las Vegas (CLV), under the leadership of Air Products, has contributed to this Energy Station demonstration in Las Vegas, Nevada.

Figure 1 is a block diagram of the refueling facility. In addition to the on-site hydrogen generation, a liquid hydrogen supply system was installed to satisfy initial demand for hydrogen at the refueling station, and to provide backup supply for additional system reliability. The hydrogen compression, storage, blending and dispensing system is capable of supplying pre-determined blends of H_2 and compressed natural gas

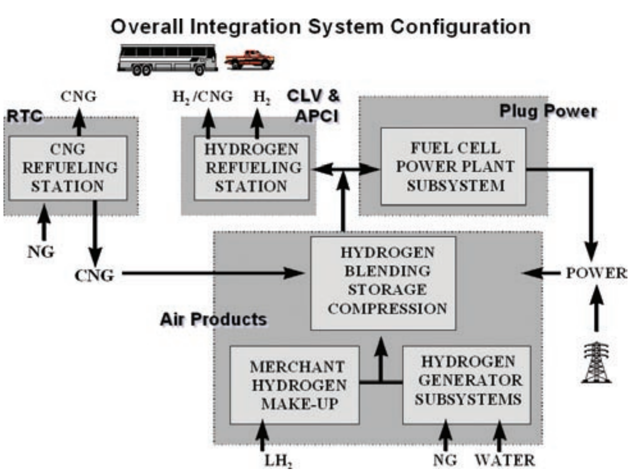

FIGURE 1. Overall Integration System Configuration

(CNG) to be dispensed to trucks and buses with internal combustion engines (ICEs) that have been converted to run on HCNG mixtures. The station is also able to dispense pure hydrogen to vehicles. Currently four light duty vehicles (LDVs) and one para-transit bus are being fueled with the HCNG blend.

Early in the project, Air Products evaluated various small-scale developmental natural gas reformation technologies via extensive laboratory and field testing. These technologies included partial oxidation, auto thermal reforming and steam methane reforming. The test results were the basis for technology selection for the steam methane reformer (SMR) fuel processor. The fuel processor was integrated with a pressure swing adsorber (PSA) system supplied by QuestAir to develop the on-site system capable of generating pure hydrogen from natural gas.

Plug Power developed and provided a 50 kW fuel cell for the project. This fuel cell was built by assembling eight 7.5 kW residential fuel cell stacks that were being developed by Plug Power for the residential power market. The residential system was designed to operate on reformate, and thus modifications were required for the pure hydrogen service in this project. Extensive testing of the fully assembled module at Plug Power's Latham, N.Y. facility was conducted to qualify individual systems and the final system configuration.

This report covers the conclusion of the Hydrogen Generator distributed generation test period. Previous results achieved by Plug Power's 50 kW fuel cell power generation system were considered in evaluating and validating the co-production capabilities of the Energy Station.

Approach

- Several small-scale, natural gas–based, fuel-processing technologies under development by others were tested. These included partial oxidation (POX), auto thermal reforming (ATR), and SMR technologies. Based on the experience from the testing and the results of an economic analysis, the final technology selected for use was SMR.
- The 50 kW fuel cell stack design was based on existing 7.5 kW reformate-based stack modules developed for residential power generation. Modifications were made to allow operation on pure hydrogen.
- The fuel station design was based on previous H_2 and HCNG fueling station experience.
- Extended duration operation of the fully integrated hydrogen-generation, fuel-cell, fuel station system was conducted to address robustness, performance, and economic feasibility of this "Energy Station" concept.

Results

Hydrogen Generator

The hydrogen generator was installed, commissioned and placed into operation in the summer of 2002 (Figure 2). On-spec hydrogen production, with purity in excess of 99.95%, was established in August 2002. Successful process operation of the hydrogen generator was achieved without process modification to the system after delivery of the unit to the site for operation. Since the initial establishment of hydrogen production, the unit has achieved an aggregate run-time of over 4,800 hours. The integrated hydrogen generator system controls achieved the full range of expected operability control.

During this period, we continued to test the operation of the hydrogen generator. An efficiency (LHV) of 68% was achieved, with hydrogen produced at purities of less than 1 ppm CO.

Further economic analysis of the technology was performed during this period. Based on the economic assumptions provided by the DOE HFCIT MYPP, the test results from Las Vegas confirm the technology's ability to achieve an integrated, co-production result of less than $3.60/kg (GGE) cost of hydrogen and $0.08/kWh cost of electrical power.

Las Vegas provides an excellent real-world performance and durability testing environment. Several improvement opportunities were identified as a result of the operating conditions provided by this Nevada site.

Fueling Station

The Fueling Station segment of the Energy Station (Figure 3) consists of liquid hydrogen storage, gaseous hydrogen storage, product compression, HCNG fuel blending, and HCNG and hydrogen fuel dispensing. Since operation of the Fueling Station was established, satisfactory vehicle fueling functionality has been demonstrated. Fueling operations have been performed for both hydrogen fuel cell vehicles and blend HCNG internal combustion engine vehicles. To date over 200 fuelings have been safely performed.

FIGURE 2. View of the Hydrogen Generator (Left) and Fuel Cell (Right)

FIGURE 3. View of the Fuel Station

In April 2005, the hydrogen fueling pressure was upgraded from 250 bar (3,600 psig) to 350 bar (5,000 psig). This upgrade to the hydrogen fueling continues to operate reliably.

The DOE Safety Panel reviewed the project and the site in March 2004. A better than satisfactory assessment was achieved from this review.

Conclusions

- The Energy Station is a viable operational concept. The fuel cell provided a demand for hydrogen during low levels of vehicle fueling demand.
- DOE HFCIT MYPP targets are obtainable with the technologies used for this demonstration when adopted in sufficient numbers to achieve manufacturing economies of scale.
- The project has provided a significant source of development opportunities, given the applied technology demonstration in a real-world environment.

Future Directions

- Continue to provide the CLV fleet fueling and testing through conclusion of current project period. Support CLV fleet expansion as applicable. Lessons learned have been incorporated into the Penn State Hydrogen Fueling Station.