Research and Development of a PEM Fuel Cell, Hydrogen Reformer, and Vehicle Refueling Facility

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Abstract

Air Products and Chemicals, Inc. has teamed with Plug Power Inc., of Latham, NY, and the City of Las Vegas, Nevada, to develop, design, procure, install, and operate an on-site hydrogen generation system, an alternative vehicle refueling station, and a stationary hydrogen fuel cell power plant, to be located in Las Vegas, Nevada.

This proposed facility will become the benchmark for validating new natural gas based hydrogen production systems, PEM fuel cell power generation systems, and numerous new technologies for the safe and reliable delivery of hydrogen as a fuel to vehicles. Most importantly, this facility will serve as a commercial demonstration of hydrogen as a safe and clean energy alternative.

In the current year fabrication and laboratory testing of all the key equipment for the project were completed including the H_2 generator, fuel station, and stationary fuel cell. Field construction was initiated at the Las Vegas site for installation of the equipment in the summer of 2002. The following sections report on this progress and the future plans and milestones in the next year.

Project Overview

A team of three organizations, Air Products and Chemicals Inc., Plug Power Inc., and the City of Las Vegas, has come together to develop, design, procure, install, and operate an alternative vehicle refueling station, and a stationary hydrogen fuel cell power plant, to be located in Las Vegas, Nevada. The objective of this project is to advance the technology and validate the commercial viability of an alternative refueling station for dispensing blends of hydrogen and compressed natural gas (CNG) and pure hydrogen to vehicles, and the co-production of electricity from a stationary fuel cell. This co-production of hydrogen fuel and electric power is referred to, as an "Energy Station". Air Products is the prime contractor to DOE for this technology validation project. Figure 1 is a block diagram of the proposed refueling facility. This refueling station will include onsite hydrogen generation equipment supplied by Air Products and a stationary fuel cell powered electric generator, to be supplied by Plug Power under a subcontract. The City of Las Vegas (CLV) is also a team member, providing the site location and the operating and maintenance staffing for the refueling station. The DOE cooperative agreement covers a five-year nominal period (1999-2004) for development, design, installation, startup, and operation of the refueling station.

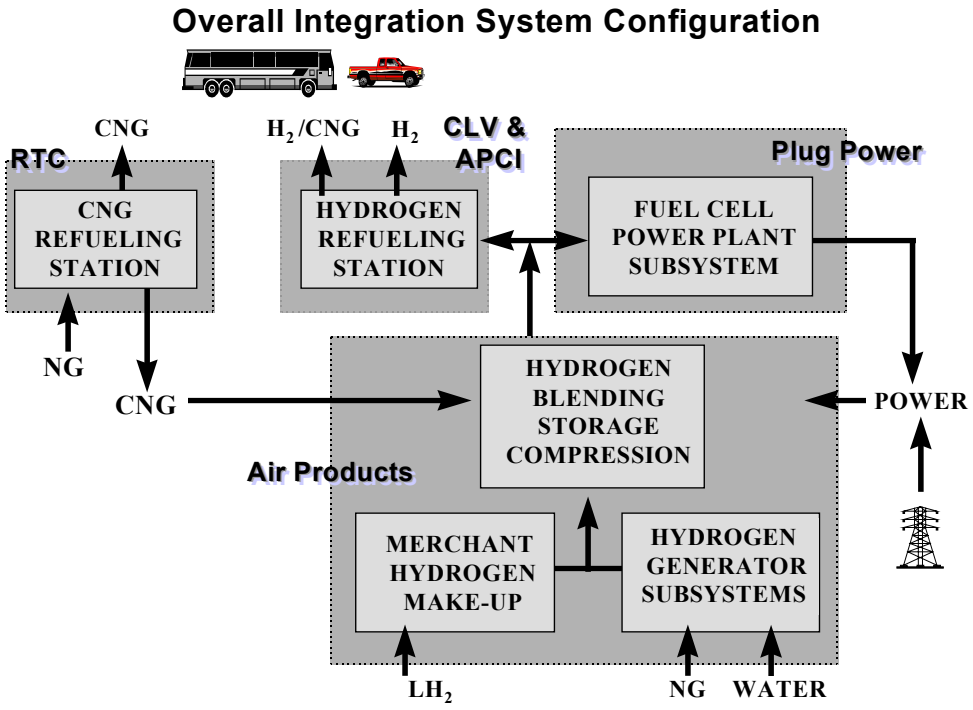

Figure 1: Overall Integration System Configuration

A standard merchant liquid hydrogen supply system (liquid hydrogen storage tank and vaporizers) will be installed to satisfy initial demand for hydrogen at the refueling station. A blending system will be installed which will mix hydrogen with compressed natural gas (CNG) in a pre-determined blend to be dispensed to the alternative fuel vehicles. The station will also be able to dispense pure hydrogen to vehicles. The hydrogen compression, storage, blending and dispensing systems will be installed in July 2002 to make the station operational to meet initial refueling requirements. It is expected that there will initially be 2 Light Duty Vehicles (LDVs) and

one para-transit bus fueled with the CNG/H_2 blend. There will also be one H_2 Hybrid Electric bus (operating at low pressure with metal hydride storage) fueled with the pure hydrogen. A natural gas-based onsite hydrogen generator will also be installed and operated at the refueling station. In addition, a Fuel Cell Power Plant, operating on pure hydrogen to generate electric power for the refueling station, will also be installed at the refueling station. The fuel cell will be operated to balance the hydrogen demand on the hydrogen generator for vehicle refueling. For system reliability, the onsite hydrogen generation system will continue to be backed up or supplemented by the liquid hydrogen supply system.

Upon successful testing/operation of the first CNG/H_2 fueled para-transit bus, CLV will proceed to convert six new CNG fueled buses, to CNG/H_2 blended fuel operation. They expect to have all six buses converted over a six-month period, nominally one bus per month through December 2002. H_2 demand growth is expected to continue as additional buses and light duty vehicles are converted to the alternative fuels over the remaining two years of the demonstration project.

Should the alternative vehicle refueling demonstration station prove to be successful, it is anticipated that vehicle fleets would continue to grow.

Process Description of the Facility

The overall integrated system configuration and the general areas of responsibility of each member are illustrated in Figure 1. The following section is a general description of the scope of the facility to be installed.

A Hydrogen Supply system with capacity to meet the nominal projected hydrogen requirements and provide additional capacity to allow growth of the station to serve fleets of commercial vehicles in the future. This hydrogen supply system will consist of natural gas-based hydrogen generation subsystem and a liquid hydrogen make-up backup supply subsystem.

A Compressed Natural Gas (CNG) system, which will be installed at the proposed CLV site, as part of a separate program, would be used to supply the CNG. Tie-ins for the CNG supply would be made on the outlet of the CLV fueling station storage tubes and routed to the hydrogen/CNG blend fuel station that will be designed and constructed by Air Products. This system includes hydrogen compression, storage and blending subsystems, which will supply the H_2 and CNG/H_2, blended fuels to the metering and dispensing units.

A Fuel Cell Power Plant being supplied by Plug Power will help to test, and demonstrate the technical, and economic viability of integrating baseload fuel cell power generation with on-site hydrogen production for vehicle refueling. The fuel cell power plant will be connected to the fuel station, and to the local power grid.

Project Objectives

The technical objectives of the project include the following:

- Resolve design issues and demonstrate small, on-site H_2 production for fuel cells and H_2 fuel stations
- Design, construct, and operate a multipurpose refueling station
- Dispense CNG, H_2/CNG blends, and pure H_2 to up to 27 vehicles

- Design, construct, and operate a 50kW fuel cell on pure H_2
- Evaluate operability, reliability, and economic feasibility, of integrated power generation and vehicle refueling designs.
- Maintain safety as a top priority in the refueling station and fuel cell design and operation.
- Obtain adequate operational data on fuel station to provide basis of future commercial fueling station designs. Develop appropriate "standard" designs for commercial applications
- Expand the current facility to serve as the first commercial facility when sufficient hydrogen demand develops. Ultimately serve as a link in a national H_2 corridor.

Project Status

Significant progress was made in the development of this project in the current year as described below:

H_2 Generator

A fully integrated auto thermal (ATR)-based prototype H_2 generator that was completed last year, and successfully tested at the Air Products laboratories in Allentown, PA, experienced ongoing operational issues requiring several changes. Major changes included replacement of the air blower to obtain capacity, steam generation coil and waste gas combustion chamber modifications due to failures, change of recycle water system to once-through due to solids build up, and pressure swing adsorption (PSA) adsorbent change out. Following these changes, a full characterization of the ATR was completed at the Air Products laboratories. However, based on an economic analysis that concluded that steam methane reformer (SMR) technology was more economical than ATR technology to generate pure H_2, at this size range (50-100kW), and the recurring maintenance issues, it was decided not to install it in Las Vegas in FY 02.

A steam-methane reformer (100 kW, 3000 SCFH H_2) based on technology from Harvest Energy Technologies was developed and tested at the Harvest facilities in California. Lessons learned in the previous ATR development were incorporated in the SMR development including: one button start capability, improved PSA recovery, and recycle of off-gas. The unit is ready to be moved to Las Vegas site.

Fuel Station

As reported last year, Air Products completed the fuel station design, and fabrication of all the equipment components such as the compressor, storage tubes, blender, and dispenser in November 2000.

The integration of a metal hydride "thermal" compressor to compress hydrogen for the fuel station was evaluated but dropped from project since it was determined that there was insufficient waste heat from the reformer to provide the thermal energy required by the metal hydride compressor.

Installation of the fueling equipment at the project site was delayed by one year awaiting completion of the CLV CNG station, which was completed in March 2002. The required permits for installation of the hydrogen station were issued and site work initiated in late March 2002.

Fuel Cell

The 50 kW fuel cell stack system comprised of eight 7.5 kW stack modules was fully assembled and tested at Plug Power's Latham, NY facility. This is Plug Power's first large scale stationary system. Initial startup and qualification testing yielded a number of design changes related to component selection, control and electronic equipment, software algorithms, and gas delivery systems. Plug Power first qualified individual subsystems followed by final system configuration testing. Test data provided an operational baseline and validation of the interface conditions to support integration into the refueling station.

The 50 kW fuel cell system was shipped to the Las Vegas site in October 2001.

Future Work and Milestones

The planned work and milestones for the upcoming year are as follows:

H_2 Generator

The Harvest SMR unit will be installed at the Las Vegas site and integrated with the fuel station in August 2002.

A test program will be conducted at the CLV site and include:

- Verify the design performance of the hydrogen generator. Demonstrate hydrogen production capability and natural gas consumption as required by the product line. The 100% rate test will be conducted at the design conditions and data will be collected continuously over a minimum period after steady state operation has been established.
- Close heat and material balances, calculate plant efficiency, and document performance at 75%, 50%, and 25% rates. Test data will be collected over a minimum time period after steady-state operation has been established.
- Address any outstanding step out new technology issues and verify that these technologies have performed at least as well as design.
- Determine the plants maximum production rates and system bottlenecks.
- Demonstrate automated "warm" and "cold" start-ups.
- Determine ongoing operating costs.

The test period onsite will vary to determine reliability and maintainability. Longer periods of testing will be used on site, including ongoing monitoring and data analysis. Operating modes for the integrated system will be developed for testing various operational scenarios of the overall system.

Fuel Station

The multi purpose fuel station is expected to be operational in August 2002 starting with a fuel source of delivered liquid hydrogen. The fuel station will then be tied-in to the on-site H_2 generator with the installation, commissioning and start-up of the Harvest SMR in July and August 2002.

Vehicle fleet buildup will add 6 CLV H_2/CNG buses, UNLV H_2 bus and various light duty vehicles between September and December 2002.

Fuel Cell

The Fuel Cell Power Generator will be installed, started up and integrated with the hydrogen generator and the fuel station in August 2002.

A photo of the assembled 50kW fuel cell power plant is shown in Figure 2.

Figure 2: Plug Power Fuel Cell Power Plant

The testing of the fuel cell at the CLV site will include:

- Evaluation of design improvements resulting from product testing and field operations of hydrogen and natural gas fuel cell systems on an ongoing basis for possible incorporation into the system.
- Development of operating modes for the integrated system.
- Ongoing collection of data to assess overall operation of the system.

Leadership-Cooperative Efforts

Presentations on the “Energy Station” concept and the Las Vegas project have been given to various audiences separately or in conjunction with a discussion of developing hydrogen infrastructure, including:

- Merrill-Lynch Global Energy Technology Conference – New York City, May 2001
- California Fuel Cell Partnership Steering Team – Diamond Bar, CA, October 2001
- The EVAA Electric Transportation Industry Conference & Exposition – Sacramento, CA, December 2001 NRC Hydrogen Study Team Meeting - Washington D.C. CHALLENGES FOR THE CHEMICAL SCIENCES IN THE 21ST CENTURY – January 2002

- Globe 2002 – Vancouver, Canada, March 2002
- H_2 Investor Forum – Washington, D.C., Apr 2002

Outreach efforts have been made to auto participants of the California Fuel Cell Partnership with a view to promote the Las Vegas site as a link in a California-Nevada H_2 corridor.

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