

## DEVELOPMENT OF A TURNKEY COMMERCIAL HYDROGEN FUELING STATION

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### 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 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 demonstrate the economic and technical viability of a comprehensive, turnkey, stand-alone hydrogen Fueling Station for FCVs with state-of-the-art technology that is cost-competitive with current hydrocarbon fuels. Such a station will promote the advent of the hydrogen fuel economy for buses, fleet vehicles, and ultimately personal vehicles.

In order to demonstrate the potential for an economically viable stand-alone, fully integrated H<sub>2</sub> Fueling Station based upon the reforming of natural gas, the development team will be striving to:

- Develop a cost effective solution to the reforming of natural gas to produce a reformat stream;
- Develop an efficient, cost-effective means to purify the hydrogen-rich reformat to pure hydrogen employing Pressure Swing Adsorption technology;
- 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; and
- Obtain adequate operational data to provide the basis for future commercial Fueling Stations.

## Approach

Within this program, 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 H<sub>2</sub> fuel.

This nine-quarter project is being managed in three phases, with Stage Gate reviews between each phase. These phases overlap in time in order to make efficient use of resources and minimize costs. 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. Also, the technical viability and Fueling Station costs will be validated. Phase 3 will include fabrication, installation, and testing of the full-scale H<sub>2</sub> generator and dispenser at Penn State University. This H<sub>2</sub> Fueling Station will be designed to deliver 50 nm<sup>3</sup>/hr H<sub>2</sub>. A brief description of the approach to be taken in each Phase of the program is included below.

During Phase 1 of the program, subsystem conceptual designs will be formulated and costed. Options will be developed and compared for the reformer system, PSA system, compression, storage, and dispenser. Air Products will work with H2Gen to develop and to evaluate the applicability of a novel convective SMR-based reforming system. At the end of Phase 1, we will confirm the preliminary feasibility of cost targets via an initial, pre-developmental definition of scope and execution costs and will identify the partners for further development of components in Phase 2.

In Phase 2, 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 PSA systems, and build and test components of the systems in laboratories. Air Products will be directly responsible for the design of the dispenser, which will be tested in a shop prior to installation on site. 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 H<sub>2</sub>.

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 will follow. Then, the Fueling Station will be started up and put into operation, including 6 months of operation and testing. Finally, we will validate the cost of H<sub>2</sub> delivered from the installed Fueling Station, including a study pertaining to the impact of mass-producing components.

## Status of Progress

Although the cooperative agreement was not signed until 29 March 2002, the 1 January 2002 start date of the Project Period allowed the development team to begin pre-award work addressing the technical challenges in October 2001. Below is a summary of progress to date:

#### Agreements and Contracts:

- Cooperative Agreement between DOE and APCI signed on 29 March 2002.
- Subcontract with H2Gen signed for development of reformer.
- Subcontract with QuestAir in review for supply of competitive improved H<sub>2</sub> PSA purifier design.
- Subcontract with Penn State University completed for siting of Fueling Station

#### Reformer:

- Kicked-off development work on the novel reforming system. Began the process and cost study of the various reforming options available.
- H2Gen development work kicked-off in October 2001. Catalyst characterization work has begun and the first prototype reformer is being built. Components have been tested. Burners have been sized and tested in the lab.
- APCI began engineering study in April 2002 to update the comparison of ATR, POX, and SMR technologies to determine the optimum route to small-scale H<sub>2</sub> production. This kicked-off the "Phase 1" portion of the development program and will last 1 quarter.
- Prepared and sent out a Request For Quotation for the reforming system to several reformer vendors. Included in the RFQ were companies offering SMR, ATR, and catalyst systems.

#### H<sub>2</sub> PSA Purifier:

- APCI H<sub>2</sub> PSA development work began in October 2001. Adsorbent development has commenced and step-out approaches to achieving compact PSA designs have been identified. PSA cycle development work is underway to fully utilize the adsorbents' capabilities. Laboratory experiments are underway. Additionally, development of new PSA valve, vessels, and other mechanical components has been initiated - testing plans have been formulated and laboratories are being equipped for component testing.
- APCI completed detailed design of a prototype H<sub>2</sub> PSA unit to be evaluated at one of Air Products' H<sub>2</sub> production facilities. The data collected on this PSA unit will serve to verify several of the significant technical "step-outs" being taken in the new PSA design being developed by the APCI team. Fabrication of the PSA skid was completed in early June and the system is being installed on site.
- In anticipation of an engineering services sub-contract, QuestAir began work to improve their HyQuestor H<sub>2</sub> purifier in October 2001. Preliminary design and cost summaries are nearing completion.

#### H<sub>2</sub> Compression, Storage, and Dispensing:

- APCI compression, storage, and dispensing development work began in October 2001. To date, Air Products has completed the preliminary engineering work to determine the optimum configuration and selection of components for the H<sub>2</sub> dispenser.
- Laboratory equipment to test H<sub>2</sub> flow meters for use in the dispenser has been purchased and is being installed.

#### General:

- Air Products set up its engineering team, computer storage system, and held its internal kick-off meeting.
- Completed Public Abstract, Statement of Work, Cooperative Agreement, Patent Waiver application, 2-Page Abstract for Peer Review Meeting, Presented a Report at the Peer Review Meeting, and Submitted the Project Management Plan
- Updated budget and schedule to match Cooperative Agreement signing date.

- Completed initial conceptual PFD for integrated fueling station. This will serve as the basis for engineering discussions related to the Penn State Fueling Station.
- Issued process specifications for all major components in the Fueling Station.
- Defined a natural gas specification based on North American averages. Also defined a potable water specification. Identified Penn State specific natural gas and potable water specifications.

**Future Directions**

The expected schedule for these Phases is outlined in the table below:

<b>Task</b>	<b>Date</b>
Phase 1 Pre-Contract Technical Development	Oct 2001 – March 2002
Cooperative Agreement Award	29 March 2002
Phase 1 Conceptual Design and Economic Evaluation	April 2002 – June 2002
Phase 2 Subsystem Development	July 2002 – March 2003
Phase 3 System Deployment	April 2003 – December 2003
Phase 3 System Deployment – Operation & Testing	January 2004 – June 2004

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