V.D.3 Novel Compression and Fueling Apparatus to Meet Hydrogen Vehicle Range Requirements

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Objectives

- Evaluate and develop new components for hydrogen fueling at 700 bar gauge (barg) pressure, including an isothermal compressor, packless valves, and dispenser.
- Install the isothermal compressor into a fueling station for testing.

Technical Barriers

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

- B. High Cost of Hydrogen Compression (Hydrogen Delivery)
- C. Hydrogen Refueling Infrastructure (Technology Validation)

Approach

- Complete a conceptual process design for an isothermal compressor.
- Develop a compressor process simulation to size components and evaluate upset conditions.
- Test compressor fluids and pressure transmitters for service in high-pressure hydrogen service.
- Develop and test high-pressure actuated valves with vendors.
- Develop a next-generation dispenser capable of 700 barg fueling.
- Design, build, and test the isothermal compressor in fueling service.

Accomplishments

- Developed a compressor conceptual design.
- Developed a dynamic simulation of the compressor.
- Selected a suitable fluid for the isothermal compressor.
- Started testing of a number of fluid-filled pressure transducers for suitability in hydrogen high-pressure service.
- Sized and designed all mechanical components of the isothermal compressor.
- Developed unique compressor controls.
- Selected a high-accuracy pressure transmitter for testing.
- Completed a new dispenser design for service to 700 barg.
- Control panel design in progress.

- Developed and tested a second-generation automated valve for fueling service to 1050 barg in all ambient conditions.
- Developed fueling test skid flowsheet.

Future Directions

- Build and test the isothermal compressor.
- Install the compressor at Air Products for hydrogen fuel station testing.
- Install the compressor at an existing fueling station for extended testing.

Introduction

One of the challenges facing automakers is providing a hydrogen-fueled vehicle with a range of 300 miles. This has led all major automotive manufacturers to pursue 700 barg (nominally 10,000 psi gauge [psig]) onboard storage systems. These vehicles will require fueling stations with storage at 972 barg (14,100 psig) to achieve fast-fills (3 minutes).

Using today's compression technology, increasing from 438 barg (6250 psig) to 972 barg (14,100 psig) discharge pressure requires an additional stage of compression, which results in a 70-80% increase in cost. This project aims to develop a new compression technology that will be more efficient and have much lower cost having a single compression chamber.

All other components in the fueling station must also be upgraded to handle the increase in pressure. New components were either developed or selected from existing commercial products.

Approach

A new process cycle was developed to accomplish hydrogen compression from 7 barg (100 psig) to 972 barg (14,100 psig) by Air Products. This compression range will accommodate all sources of hydrogen fuel, including reforming, electrolysis, liquid tank, pipeline, and tube trailer gaseous delivery. This cycle uses a low-cost, commercially available liquid pump to generate pressure. A process working fluid was selected and tested to collect the needed thermodynamic data. The process cycle was checked for feasibility by dynamic modeling. The system is designed to be near isothermal.

Next, a control strategy was devised and compressor components were designed. The designs completed include the compression chamber, heat transfer system, fluid pump, inlet and outlet valves, accumulator, shuttle valves, fluid manifold, drain, flowsheet, and physical layout. A control panel and test skid will be designed to collect data and allow the compressor to operate under typical fueling station conditions. The compressor components are being fabricated to allow compressor testing in 2005.

The other components required for 700 barg fueling have also been developed or selected for testing. These components include storage vessels, valves, instruments, hoses, and tubing.

A design has been completed for a standalone hydrogen dispenser that will be rated to 15,000 psig. Our existing 7,000-psig dispenser has been updated and improved to allow compliance with upcoming codes and standards and higher-pressure fueling.

Results

Initial cost estimates show the potential to reduce the cost of compression to one-third of today's cost. The power requirement will also be reduced by 20%. Simple mechanical controls are used as opposed to pressure and level transducers, where possible.

The compressor design has been completed (Figure 1), and the unit will be packaged to fit into existing fuel station designs. This will allow for retrofit in the future when 700 barg vehicles are available.

Extensive testing of automated valves and solenoids has been completed satisfactorily.

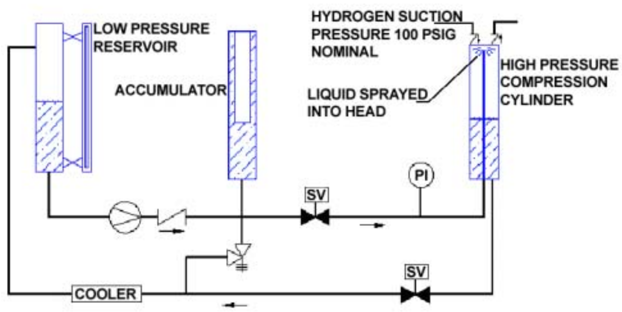

Figure 1. Compression System Process Flow Diagram

A new standalone dispenser has also been designed using our fueling experience and continuous improvement work process. The first new standalone dispenser will be finished in October for incorporation into another DOE project at Penn State University.

Conclusions

The work completed over the past year has shown that hydrogen fueling at 700 barg can be accomplished in a cost-effective manner.

The compression process appears to be feasible with simple off-the-shelf and fabricated components. The major challenges that remain include maintaining fluid levels, cycle timing, fluid carryover into the hydrogen, and heat transfer. Testing will begin in 2005.

There have been announcements that fueling nozzles, vehicle receptacles, and fuel hose breakaways will soon be commercially available for 700 barg service. Air Products will obtain and test these components when available. Materials testing may be required, as hydrogen embrittlement can affect the high-strength materials that are typically used.

High-pressure storage is one area that requires additional study and industry cooperation. There are no viable, mass-produced storage vessels available at these pressures. The most likely solution will be composite vessels, but these are currently not allowed by ASME pressure vessel codes. For the test system, we will procure two custom one cubic foot stainless steel vessels ASME-rated to 15,500 psig maximum allowable working pressure.