

VIII.C.2 Novel Compression and Fueling Apparatus to Meet Hydrogen Vehicle Range Requirements

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Start Date: August 2004

Projected End Date: February 2006

Objectives

- Develop components for 700 barg hydrogen fueling
- Develop and optimize a new compression process that is lower in cost, maintenance, and power consumption
- Test the technology in a laboratory setting and potentially at a field site

Technical Barriers

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

- C. Hydrogen Refueling Infrastructure

Contribution to Achievement of DOE Technology Validation Milestones

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.

We are demonstrating a new technology compressor with lower cost, maintenance, and power usage. We expect a savings of up to 70% over existing technologies, when mass produced.

Milestone 14: Validate \$2.50/gge hydrogen cost.

We are demonstrating a new technology compressor with lower cost, maintenance, and power usage. We expect a savings of up to 70% over existing technologies, when mass produced.

Approach

- Perform Conceptual Design
- Perform Process Design
- Perform Thermodynamic Data Collection and Testing
- Perform Fluid Selection and Testing
- Perform Dynamic Modeling
- Perform Component Design, Fabrication, and Testing
- Design and Build Prototype System
- Perform Field Verification

Accomplishments

- Developed new valves and tested other components for 700 barg fueling.
- Installed three 700 barg hydrogen fueling systems (two domestic, one in Asia) using newly developed components, but conventional compression technology.
- Developed a dual-pressure dispenser with both 350 and 700 barg in a single enclosure.
- Developed a new single-stage compressor system with a $\sim 50^\circ\text{F}$ temperature rise and a compression ratio of 140:1.
- Increased compressor flow rate from 1 to 5 nm^3/hr and removed one eductor from the system, with a net reduction in system cost.

Future Directions

- Complete machining of the final compressor component.
- Assemble the prototype compressor.
- Evaluate the compressor performance.
- Analyze the hydrogen gas for signs of oil carryover.
- Install the system in a field site for long-term testing, if warranted.

Introduction

The primary goal of this project is to develop a new compression technology that will provide lower cost, maintenance, and power usage than today's compressors. We have developed a compression process that relies on a liquid compression cylinder to eliminate many of the problems associated with today's high-pressure hydrogen compressors, which require gas seals.

Approach

Our approach to design was to first determine the attributes of the compression system. These included: near isothermal operation, single stage, scalable, high purity, 14,000 psig output pressure,

low power usage, and direct compression of the hydrogen by the hydraulic fluid (no metal or elastomeric separation). We then developed a process cycle that could produce the compression ratio and temperature rise desired.

The next step was to determine which hydraulic fluid to use. The final fluid was selected through actual testing in hydrogen at the design pressure and temperature. Advanced dynamic modeling was also done to optimize the system and determine the impact of modifying various system parameters. Then we mechanically designed the compressor components, selected the pump, and optimized the process cycle to reduce the fabrication cost. The next step is to build a prototype compressor and test the performance and purity.

Results

Conceptual Design: We determined through design and modeling that our original target of 10°F temperature rise was not possible, due to the size of the compression chamber. We now expect a temperature rise of 50°F, which will have a slight impact on system efficiency, but will not limit the system operation in any way (Figures 1 and 2).

Process Design: There were a number of changes to the original process design. The original cycle time was reduced from 30 to 10 seconds, and one eductor was removed from the system. These changes were made possible by increasing the hydraulic fluid pump flow rate and horsepower, which will change the compressor’s flow rate from 1 to 5 nm³/hr. The capital cost for the compressor decreased as a result of this change.

Thermodynamic Data Collection: We were able to show that hydrogen solubility remained significantly below the acceptable level of 2% at operating pressure and temperature. The measured solubility was 0.2% (for a 30-second cycle). Our

cycle has also been reduced to 10 seconds, which will further reduce the solubility of the hydrogen. We were also able to select a hydraulic fluid (Krytox Fluorocarbon Oil) for the service based on the thermodynamic data (Figure 3).

Dynamic Modeling: The system surge vessels, heat exchanger, hydraulic manifold, eductor, compression chamber, and hydraulic pump process designs were all finalized through the use of ASPEN™ Dynamics modeling software. The hydraulic pump pressure and flow rate were optimized using this model.

Component Design, Fabrication, and Testing: The compressor components were machined in-house due to the inability of machine shops to cost-effectively produce a single unit. If the compressor were built in quantities of at least 10 units per order, the machining costs would be significantly lower than for the single prototype unit that was built. Even so, the prototype compressor cost is 50% of the cost of a traditional hydrogen compressor with the same flow rate and compression ratio. Many of the hydraulic components were designed from scratch to serve dual purposes. One example is the solenoid valve, which also acts like a check valve, when de-energized, reducing the number of components required. The system control issues were also solved using custom-built solutions. One example is the compressor discharge check valve, which combines the check valve with the cycle completion sensor.

Prototype: We are machining the final components of the compressor and expect to finish in July 2005 (Figure 4). Two weeks will be required to

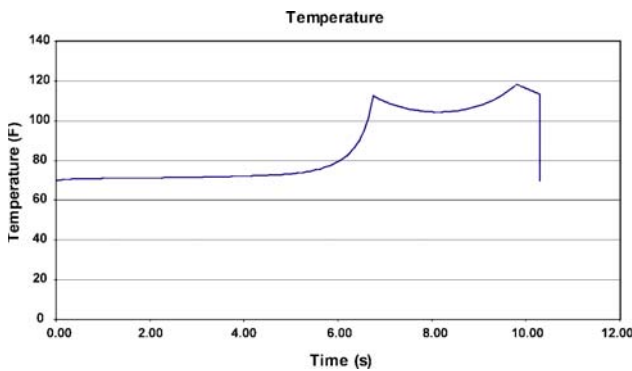


Figure 1. Novel Compressor Temperature vs. Time

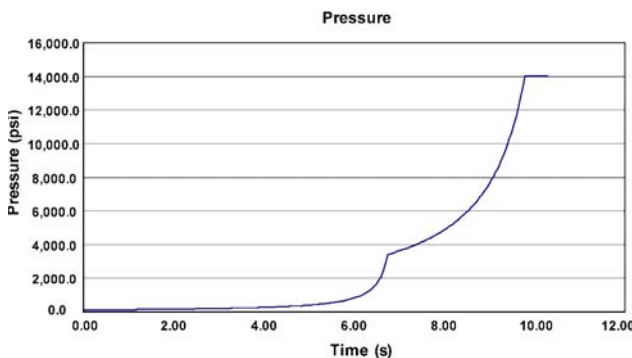


Figure 2. Novel Compressor Pressure vs. Time

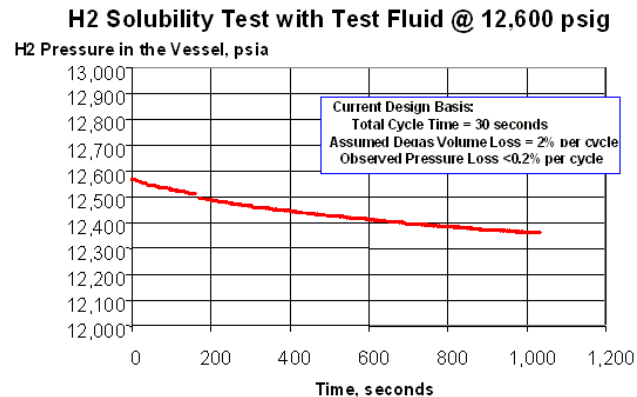


Figure 3. Hydrogen Solubility in Krytox Fluorocarbon Oil

assemble and pressure-test the compressor. The compressor will be capable of compressing from below 100 psig up to 14,000 psig. We have also designed a small test skid that will allow us to run the compressor and test performance. Testing will begin on helium in August, followed by hydrogen testing. Analytical sampling will be used to verify that the level of hydraulic oil carryover is acceptable.

Field Testing: We have two operating 700 barg stations (one domestic, the other in Asia). There is

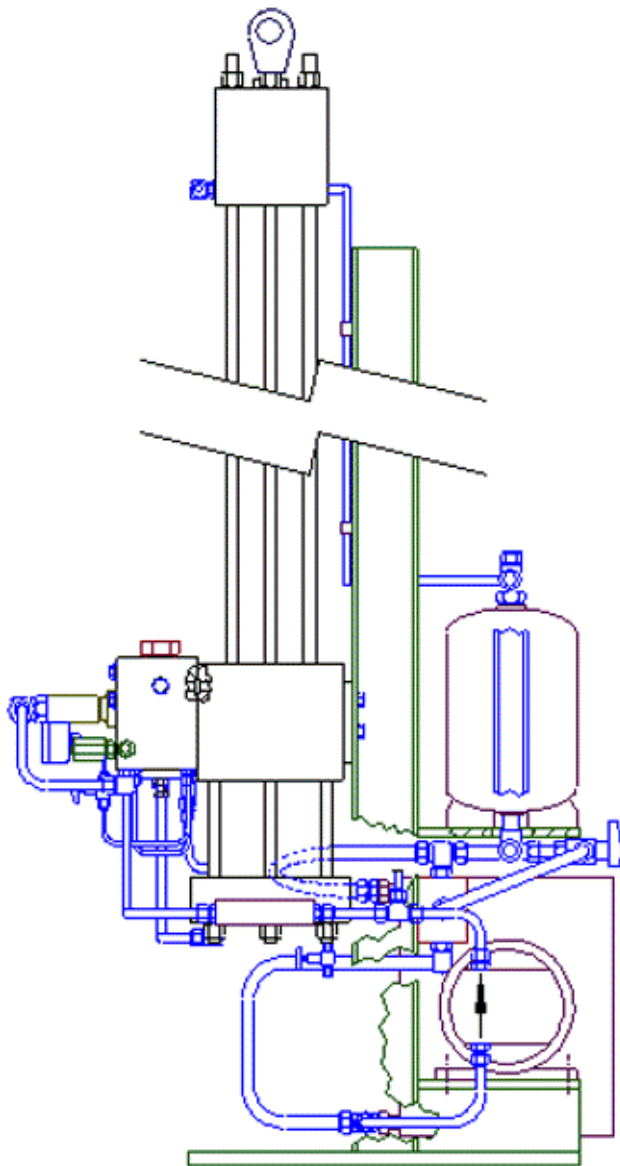


Figure 4. Novel Compressor

also a third 700 barg station installed domestically that is awaiting an operating permit. We have begun the field testing of the 700 barg components. These include relief valves, air-operated valves, pressure transmitters, pressure switches, hoses, breakaways, and nozzles.

Conclusions

- Isothermal compressors have significant cost advantages over traditional compressors.
- Isothermal compressors have significant maintenance benefits over traditional compressors, with no wear items within the compression chamber.
- Isothermal compressors have significant efficiency gains over traditional compressors.
- Hydraulic compression with no gas separation eliminates the issues of gas sealing and temperature rise typical of traditional compressors.
- Isothermal compression technology is technically feasible.
- Automotive OEMs are moving towards 700 barg vehicles to meet the range requirements, necessitating storage and a compressor system at 14,000 psig to enable fast cascade fueling.
- Acceptable production options are available for all fueling components except the cascade storage vessels.
- The major barrier to cost-effective, 700 barg hydrogen fueling is the cascade storage vessels. Steel cylinders are too costly to be used. Composite cylinders, when approved by ASME, are the likely solution.

Special Recognitions & Awards/Patents Issued

1. Patent Pending

FY 2005 Publications/Presentations

1. May 2005 Annual Peer Review
2. June 2005 Technical Team Review