

## V.C Compression

### V.C.1 Hydrogen Screw Compressor

*C. David Livengood (Primary Contact) and Robert P. Larsen*

*Argonne National Laboratory*

*9700 S. Cass Avenue*

*Argonne, IL 60439*

*Phone: (630) 252-3737; Fax: (630) 252-3443; E-mail: dlivengood@anl.gov*

*DOE Technology Development Manager: Mark Paster*

*Phone: (202) 586-2821; Fax: (202) 586-9811; E-mail: Mark.Paster@ee.doe.gov*

*Start Date: October 2005*

*Projected End Date: 2008*

#### **Objectives**

- Evaluate the feasibility of adapting a novel single-screw compressor concept for hydrogen compression
- Identify key development requirements
- Optimize compressor design for hydrogen
- Design and test prototype compressor
- Demonstrate commercial-scale compressor

#### **Technical Barriers**

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

- B. Reliability and Costs of Hydrogen Compression

#### **Technical Targets**

This project is pursuing the development of a novel compression technology for hydrogen service which offers the promise of significantly improved performance and reliability at greatly reduced cost as compared to currently available technology. Identification of potential applications for the compressor technology is one of the project activities, but appropriate targets in the transmission and refueling site areas are:

- Transmission
  - Reliability: 95%
  - Hydrogen Energy Efficiency: 99%
  - Capital Cost: \$15M/compressor
- Refueling Sites
  - Reliability: 90%
  - Hydrogen Energy Efficiency: 95%
  - Cost Contribution: \$0.40/gge of H<sub>2</sub>

## Approach

- Identify potential compressor applications and establish performance criteria
- Evaluate compressor potential for identified applications and select primary target
- Identify key development issues such as materials, reduced lubrication requirements, cooling, etc.
- Develop and apply design tools for optimization of the compressor configuration for hydrogen service
- Investigate construction materials and coatings to reduce friction, minimize wear, and reduce or eliminate lubrication
- Develop a prototype compressor design and cost estimate
- Construct and test a prototype compressor
- Refine the design and demonstrate a compressor at a commercial-scale facility

## Accomplishments

- Performance model for a similar design has been identified and is being evaluated for applicability
- Preliminary analysis of design options and strategies has been carried out in collaboration with the concept developer

## Future Directions

During the balance of the initial project phase, activities will be focused on:

- Identifying compressor applications and associated performance requirements
- Modeling compressor performance for target applications to establish potential benefits
- Establishment of performance goals

In follow-on work, activities will include:

- Identification of key engineering development issues
- Optimization of the compressor configuration for hydrogen
- Investigation of materials and sealing issues
- Development of a prototype design and cost estimate
- Construction and testing of a prototype compressor
- Demonstration of a commercial-scale compressor

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## Introduction

The compression of gaseous hydrogen will be one of the most important elements in a future fueling infrastructure. Experience with compressed natural gas has shown that compressors represent the majority of the capital and maintenance costs at a fueling facility. In addition, there are opportunities for improvements in moderate-pressure, high-volume applications found in hydrogen production and transportation. The compressors that are now being used for hydrogen have been adapted from other applications and there has been little innovation or optimization. The single-screw compressor being investigated in this project has potential advantages

over those designs in a number of key areas. There are significantly fewer moving parts, which is expected to reduce costs, increase reliability, ease maintenance, and increase energy efficiency in compression. The use of all rotary motion will reduce vibration and noise, which are major customer complaints with reciprocating compressors. The design is also highly adaptable in terms of size (capacity) and configuration. A model of the key components (screw and gate rotor) is shown in Figure 1.

However, applications of the single-screw compressor have been constrained by the complex shape inherent in the original design, which has



**Figure 1.** Model of Compressor Screw and Gate Rotor

required a very time consuming production process involving dedicated machining equipment with very limited flexibility. To address these constraints, Sigma Engineering developed and patented a modified design [1] and associated manufacturing process [2] that allow the key component (the screw) to be produced rapidly on a standard computer-controlled 5-axis machine tool. This approach also facilitates investigation of a wide range of design variations in order to rapidly optimize and tailor the design. In previous work, Argonne contracted with IMPCO Technologies to conduct a proof-of-concept test to validate this new approach. A commercial compressor (intended for refrigeration service) was obtained and characterized on a dedicated test rig. Then, new components were made by the Sigma Engineering process and installed in the compressor for testing. The new components demonstrated better dimensional tolerances than the original and gave essentially identical performance figures. The successful validation of this design and manufacturing technique offers the potential for reducing compressor capital costs by 50% or more and significantly improving energy efficiency once the design is developed further for the compression of gases such as hydrogen. Key issues to be addressed in that process are being identified and evaluated in the initial phase of this project during FY 2005. Follow-on development is expected to result in the design, construction, and testing of a commercial-scale compressor.

## **Approach**

In this project, the single-screw compressor concept will be adapted to hydrogen compression requirements; engineering development issues will be identified and addressed; and a prototype compressor will be designed, constructed, and tested. This activity will be carried out in collaboration with the concept developer, Sigma Engineering of Rochester, Michigan. With the incorporation of lessons learned from that testing, a commercial-scale unit will be designed and developed in collaboration with a compressor manufacturer (to be selected).

Potential applications for the compressor technology ranging from production facilities, through hydrogen transportation, to delivery to the ultimate customer will be identified, characterized, and evaluated to determine the best development target. The flexibility inherent in the new design and manufacturing process will be exploited to optimize the design for the particular requirements of hydrogen compression in the target application. Materials of construction and advanced low-friction coatings will be investigated to achieve the required close tolerances with minimal lubrication and wear. Based on the results of this research, a prototype design will be developed that also incorporates the results of addressing engineering issues such as cooling and control under various operating conditions.

## **Results**

The initial phase of this project (FY 2005) has been limited in scope to investigation of potential applications for the single-screw compressor and preliminary evaluation of issues that could constrain the use of the concept with hydrogen. Information on desired operating parameters (pressure, volume, etc.) for compressors in various applications through the production, transmission, and delivery system is being obtained from other studies and ongoing demonstrations. Previous work that addressed modeling of a similar compressor design [3] has been identified and is being evaluated for potential application in this work. Existing applications and manufacturers of single screw compressors (of the older design) have been identified with the objective

of establishing a collaboration to provide engineering input and eventual commercialization of the concept.

### **Conclusions**

Preliminary conclusions from prior work and the initial phase of this project include:

- The new patented design for a single-screw compressor performs as anticipated and can be readily manufactured using commercial tooling.
- Modeling of a similar compressor design has been carried out and may be adaptable to evaluation of the new concept.
- Advanced post-compression gas cleanup techniques may make it possible to achieve the desired contamination-free hydrogen without totally eliminating compressor lubrication.

### **FY 2005 Presentations**

1. Livengood, C.D., and R.P. Larsen, *Novel Hydrogen Screw Compressor*, poster presentation at 2005 DOE Hydrogen Program Review, Arlington, Virginia, May 23-26, 2005.

### **References**

1. Jensen, D.L., *Fluid Compression/Expansion Machine with Fluted Main Rotor Having Ruled Surface Root*, U.S. Patent No. 5,782,624, July 21, 1998.
2. Jensen, D.L., *Method for Manufacturing Fluid Compression/Compressor Rotor*, U.S. Patent No. 6,122,824, September 26, 2000.
3. Bein, T.W., and J.F. Hamilton, *Computer Modeling of an Oil Flooded Single Screw Compressor*, Proceedings of the 1982 Purdue Compressor Technology Conference, West Lafayette, Indiana, July 21-23, 1982.