A High-Temperature Fuel Cell to Provide On-Site Process Reducing Gas, Clean Power, and Heat

Introduction

In order for metal products to have desired properties, most metal is thermally processed at a high temperature one or more times under a controlled atmosphere. Many different thermal operations are used including oxide reduction, annealing, brazing, sintering, and carburizing. A mixture of hydrogen and nitrogen gas often provides the reducing atmosphere for these processes.

High-temperature fuel cells directly convert the chemical energy in its fuel to electricity, with water, carbon dioxide, and heat as by-products. High-temperature fuel cells typically consume only 70%-80% of their fuel. The unconsumed hydrogen is essentially a waste stream that can be utilized for the production of by-product hydrogen, reducing gas, additional power, or heat. For example, the ratio of hydrogen and carbon dioxide in the dried reducing gas of a fuel cell is similar to the ratio of hydrogen/nitrogen gas mix commonly used in the annealing process for copper.

The combined heat, hydrogen, and power (CHHP) system being developed by FuelCell Energy, Inc. captures the reducing gas produced by a high-temperature fuel cell, and that gas can be used to replace hydrogen in various industrial processes. In addition, excess reducing gas can be utilized in a low-temperature bottoming cycle fuel cell incorporated into the CHHP system to increase overall process efficiency.

Benefits for Our Industry and Our Nation

The developed CHHP system provides the following energy, economic, and environmental benefits:

- Overall system efficiency of more than 75%
- Significant additional energy savings due to avoided energy that is needed for liquefying and transportation of hydrogen
- Reduction in total utility costs by 25% for the host site
- Exporting hydrogen for use in industrial processes can significantly increase net revenue stream compared to a power-only fuel cell application

The combined heat, hydrogen, and power system, which includes a 300 kilowatt fuel cell and an electrochemical hydrogen separation system, was installed at a manufacturing facility in Torrington, Connecticut. *Photo credit FuelCell Energy, Inc.*

- Pollutant emissions from the fuel cell are less than 10% of California's stringent air quality standards, making permitting easy

Applications in Our Nation's Industry

It is expected that the CHHP system can be utilized by a large number of plants that use thermal processes to treat various metals. The system can also be used by other industries that consume hydrogen gas in their processes. A low-temperature bottoming fuel cell technology can be incorporated into the CHHP system to make the technology suitable for uses beyond industrial gas applications.

Fuel cell systems are an ideal power source for industries where a high premium is placed on the reliability of electric power, in regions where low emission levels are required (such as urban and non-attainment areas), and in grid constrained areas.

Project Description

The CHHP system developed by FuelCell Energy, Inc. is based on a modified version of the company's commercial 300 kW high-temperature fuel cell. Reducing gas produced by the fuel cell can be used as a direct replacement for hydrogen in metal treatment and other industrial processes. If all reducing gas is not needed in the industrial process, the CHHP system can incorporate a low-temperature, bottoming cycle fuel cell to increase the overall system efficiency.

Barriers

The project sought to overcome the following barriers to successful implementation of the CHHP concept:

- Proving feasibility of using fuel cell reducing gas in metal industry processes
- Maintaining a high quality of metal products
- Exporting reducing gas from a fuel cell
- Keeping capital and maintenance costs for the system low

Pathways

The project expanded on FuelCell Energy's previous research on production of reducing gas. The developed CHHP system is based on the company's commercially available DFC® 300 high-temperature fuel cell. Another key component that was incorporated into the CHHP system is an electrochemical hydrogen separation system, which is used to purify the generated hydrogen. Waste heat from the system is used for space heating.

In the first phase of the project, FuelCell Energy validated the overall technology concept and addressed major technical risks. Controlled tests were conducted to confirm that fuel cell reducing gas can be used to produce high-quality metal products. Additional testing and analysis was conducted to confirm that new technologies required by the system, such as exportation of reducing gas from the fuel cell, can be made to operate as expected.

Results from phase one testing and analysis were positive, and a demonstration CHHP system was constructed and installed at a FuelCell Energy manufacturing facility in Torrington, Connecticut. The performance, reliability, and economics of the system were evaluated during its operation.

Milestones

The project started in 2010 and concluded in 2015.

- Confirming viability of system concept
- Testing key components
- Finalizing system design
- Performing preliminary economic feasibility analysis
- Construction, installation, optimization, and operation of the system
- Evaluation of system performance, reliability, and economics

Accomplishments

- The project proved the feasibility of exporting reducing gas from a fuel cell and that the reducing gas can be successfully used in copper annealing and nickel reduction processes.
- The demonstration CHHP unit confirmed that the export of reducing gas can be done reliably with minimal impact on the fuel cell's availability.
- As a result of this project, FuelCell Energy is now marketing an on-site reducing gas system.

Commercialization

The energy and economic benefits of the developed CHHP system are significant and will be crucial for commercialization success. Exporting hydrogen—which can eliminate the need to purchase hydrogen, and in some applications nitrogen, for metal treatment and other industrial processes—significantly increases the net revenue stream compared to power-only production for a typical fuel cell.

It is estimated that there are over 500 potential commercial users for the technology in 25 states. For power-only system designs that utilize all reduction gas for greater electricity production in the low-temperature, bottoming-cycle fuel cell, the potential market is even larger.

A key commercialization partner for FuelCell Energy is Abbott Furnace Company, which supplies annealing furnaces to the metal industry.

Project Partners

FuelCell Energy, Inc.
Danbury, CT
Principal Investigator: Fred Jahnke
E-mail: fjahnke@fce.com

Abbott Furnace Company
St. Marys, PA

For additional information, please contact

Bob Gemmer
Technology Manager
U.S. Department of Energy
Advanced Manufacturing Office
Phone: (202) 586-5885
E-mail: Bob.Gemmer@ee.doe.gov

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