Ultra Efficient Combined Heat, Hydrogen, and Power System

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

The project will utilize reducing gas from a high-temperature fuel cell to directly replace hydrogen and nitrogen used in a metal treating process, resulting in significant energy and economic benefits.

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. There are many different thermal operations that are used, including oxide reduction, annealing, brazing, sintering, and carburizing. A mixture of hydrogen and nitrogen gas is often used to provide a 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 byproducts. 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 byproduct hydrogen, reducing gas, additional power, or waste heat. 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. will utilize reducing gas produced by a high-temperature fuel cell to directly replace hydrogen and nitrogen used in a bright annealing process. To utilize excess reducing gas, the CHHP system will incorporate a low-temperature bottoming cycle fuel cell to increase overall system efficiency.

Benefits for Our Industry and Our Nation

The CHHP system under development is expected to yield 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 nitrogen and hydrogen
- Reduction in total utility costs by 25% for the host site

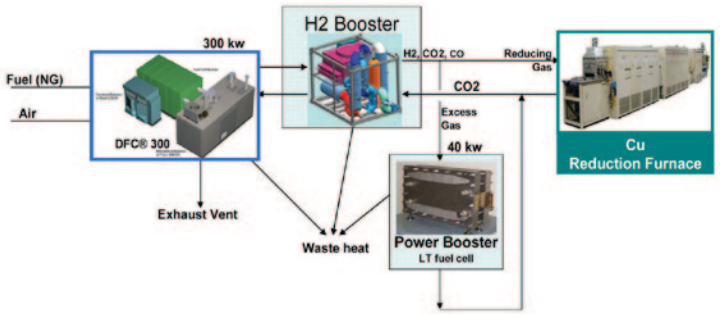

Figure 1. Major components of the combined heat, hydrogen, and power system include a 300 kilowatt fuel cell, hydrogen booster, bottoming cycle fuel cell, and copper reduction furnace.

Illustration courtesy of FuelCell Energy, Inc.

- Eliminating need for additional hydrogen and nitrogen in copper treatment expected to more than double net revenue stream compared to power-only fuel cell application
- Low pollutant emissions from fuel cells compared to current air quality standards and average fossil fuel power plants
  - Reduction in annual carbon dioxide emissions by 2,000 tons
  - Reduction in annual nitrogen oxide emissions by 7 tons
  - Reduction in annual sulfur oxide emissions by 15 tons

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 a wide range of metals. The system can also be used by other industries that use hydrogen gas in their processes.

The low-temperature bottoming fuel cell technology incorporated into the CHHP system will make the technology suitable for other applications besides industrial gas users. 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 being developed by FuelCell Energy, Inc. will be based on a modified version of the company's commercial 300 kilowatt (kW) high-temperature fuel cell. The system will utilize reducing gas produced by the fuel cell to directly replace hydrogen and nitrogen used in a bright annealing process at a copper production facility. The reducing gas will completely eliminate the hydrogen and nitrogen gas mix used in the copper reduction furnace. Because not all reducing gas will be needed in the annealing process, the CHHP system will incorporate a low-temperature, bottoming cycle fuel cell to increase overall system efficiency.

Barriers

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

- Proving feasibility of using fuel cell reducing gas in the copper annealing process
- Maintaining a high quality of copper product
- Exporting reducing gas from a fuel cell
- Scaling up of a low-temperature bottoming cycle fuel cell
- Keeping capital and maintenance costs for the system low

Pathways

The project builds on FuelCell Energy's previous research on production of reducing gas. The developed CHHP system will be based on the company's commercially available DFC® 300 high-temperature fuel cell. Other key components that will be incorporated into the CHHP system are a hydrogen booster, which increases the hydrogen content of the reducing gas, and a low-temperature bottoming cycle fuel cell. Waste heat from the system will be used for space heating.

In the first phase of the project, FuelCell Energy will validate the overall technology concept and address major technical risks. Controlled tests will be conducted to confirm that fuel cell reducing gas can be used to produce high-quality annealed copper products. Additional testing and analysis will be conducted to confirm that new technologies required by the system, such as the low-temperature bottoming cycle fuel cell and exportation of reducing gas from the fuel cell, can be made to operate as expected.

If results from phase one testing and analysis are positive, a demonstration CHHP system will be constructed and installed at an ACuPowder International manufacturing facility. The performance, reliability, and economics of the system will be evaluated during its operation for a minimum of six months.

Milestones

The project started in fall 2010.

Phase one milestones include:

- Confirming viability of system concept
- Testing key components
- Finalizing system design
- Performing preliminary economic feasibility analysis

Phase two milestones include:

- Construction, installation, and optimization of a system
- Operation of the system for a minimum of six months
- Evaluation of system performance, reliability, and economics

Commercialization

The expected energy and economic benefits of the developed CHHP system are significant and will be crucial for commercialization success. Eliminating the need for any additional hydrogen and nitrogen in the copper annealing process is expected to more than double the net revenue stream compared to power-only production for a typical fuel cell. It is estimated that there are over 500 commercial potential 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.

Two key commercialization partners for FuelCell Energy, Inc. are ACuPowder, which will host the demonstration of the first unit, and Abbott Furnace Company, which supplies annealing furnaces to metal industry. The project partners and other consultants involved in the project regularly present at various industry conferences, which will help in the commercialization efforts.

Project Partners

FuelCell Energy, Inc.
Danbury, Connecticut
Principal Investigator: Pinakin Patel
E-mail: ppatel@fce.com

ACuPowder International, LLC
Union, New Jersey

Abbott Furnace Company
St. Marys, Pennsylvania

For additional information, please contact

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

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

EERE Information Center
1-877-EERE-INFO (1-877-337-3463)
eere.energy.gov/informationcenter

DOE/EE-0452 • August 2011
Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.