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

Microchannel High-Temperature Recuperator for Fuel Cell Systems

Developing Low-Cost, Highly Efficient Heat Recovery for Fuel Cells

Introduction

Fuel cells are electrochemical devices that produce electricity without combustion. Due to their high efficiency and minimal emissions, fuel cells are an attractive option for distributed power generation.

To further increase the efficiency of high-temperature fuel cells, it is important to develop low-cost, highly efficient heat recovery systems for the devices. If a cost-effective heat recovery system can be incorporated into the fuel cells, commercialization efforts can be advanced.

The purpose of this project was to design and fabricate an efficient recuperator that can be incorporated into a high-temperature fuel cell system. One of the primary challenges for developing such a recuperator was the need to find materials that can be used to manufacture the system. Thus, an important part of the project was to screen and select materials that perform satisfactorily within the necessary temperature range.

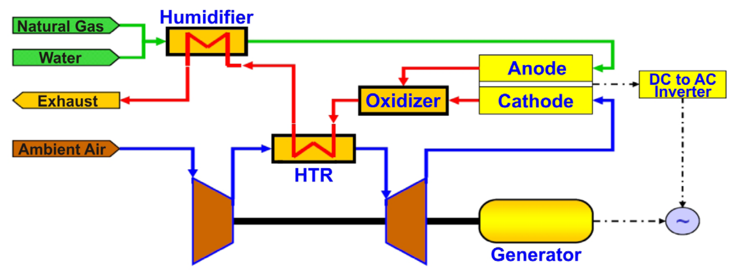
Benefits for Our Industry and Our Nation

The addition of an efficient recuperator to a high-temperature fuel cell is expected to increase the average electrical efficiency of the system from 47% to 58%. Such a hybrid fuel cell would exhibit considerably higher electrical efficiency than an average combustion engine (32%) or a microturbine (28%). As a result of this increased efficiency, a hybrid fuel cell is projected to reduce carbon dioxide (CO_2) emissions by approximately 50% compared to a simple cycle gas turbine.

Because of the electrochemical nature of fuel cells, emissions of criteria pollutants such as nitrous oxide (NO_x), sulfur oxide (SO_x), and carbon monoxide (CO) are very low. A hybrid fuel cell could potentially have NO_x emissions at levels below 0.01 lb/MWh.

Applications in Our Nation's Industry

Efficient fuel cell systems can be utilized at any industrial facility or any other facility with the need for onsite electricity generation. The high operational reliability of a fuel cell system makes it an ideal power source for industries that place a premium on the reliability of electric power, such as information technology and communications. The low emission levels of hybrid fuel cell systems also make them a suitable power source for urban and non-attainment areas.



A schematic of a high-temperature fuel cell with a high-temperature recuperator (HTR). *Illustration courtesy of FuelCell Energy, Inc.*

Project Description

The goal of this project was to build an efficient, microchannel-based waste heat recuperator for a high-temperature fuel cell system. Two pilot-scale recuperators were designed, fabricated, and tested. An important part of the project was to evaluate, screen, and select suitable materials that can be used to fabricate the recuperator.

Barriers

The project sought to overcome the following obstacles to developing a cost-effective, high-temperature recuperator:

- Identification of stainless steel and superalloy types that perform satisfactorily in 900°C temperatures
- Significant manufacturing cost reduction for successful product commercialization
- Integration of a high-temperature recuperator and an unfired gas turbine into fuel cell design
- Scale-up of system design for commercial applications

Pathways

In the first phase of the project, candidate materials for the recuperator were screened by conducting long-term, high-temperature gas exposure tests. After testing, materials were evaluated for material stability, strength, and manufacturability. Following the initial materials selection, trial components were fabricated and tested in high-temperature conditions. Components were evaluated for bond integrity, voidage, corrosion, oxidation, and other failure mechanisms.

Based on the material and component tests, a microchannel high-temperature recuperator (15 kilowatt of thermal energy, kWt) was designed, fabricated, and tested. In the next phase, an order-of-magnitude scale-up to a 150 kWt system was designed, fabricated, and tested.

Based on the 150 kWt unit tests and analysis, a design for a production-ready 1.5 MWt recuperator was developed. A detailed economic analysis of a complete, commercial-scale 3 MW high-temperature fuel cell that incorporates the recuperator design was performed.

Milestones

- Candidate material selection, testing, and analysis
- Long-term material stability testing
- Trial component fabrication and testing
- Design, fabrication, and testing of 15 kWt recuperator
- Design, fabrication, and testing of 150 kWt recuperator
- Commercial-scale recuperator design and analysis

Accomplishments

- Process information and operational data were obtained for use in the design of MW-scale high temperature recuperators. The results of the sub-scale high temperature recuperator tests indicated effective recuperation of heat and device integrity after 1,100 hours of hot-testing.
- Cost analysis activities served to establish material and fabrication costs for large-scale high temperature recuperators.

Commercialization

Toward the end of the project, the economic feasibility of a commercial-scale high-temperature recuperator was analyzed. The recuperator was considered cost-effective. It is now being incorporated into FuelCell Energy's commercial Direct FuelCell® systems, as well as the company's next-generation solid oxide fuel cells. FuelCell Energy is utilizing its current commercialization channels to market the new hybrid fuel cell technologies. Distribution partners LOGAN Energy, Pfister Energy, and PPL Energy Plus and other strategic partners, such as Caterpillar, Enbridge, and POSCO Power, are among the companies that market FuelCell Energy products.

Project Partners

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Project final report available at
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