V.L.4 Low-Cost Manufacturable Microchannel Systems for Passive PEM Water Management

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Objectives

- Create a low-cost, passive technology for water management in proton exchange membrane (PEM) systems.
- Establish technical feasibility and characterize performance in a single channel device.
- Scale-up device and demonstrate performance in a 10 kW PEM fuel cell system.
- Develop and validate a manufacturing process that can hit 7% of the $30/kW$_e$ cost target at the 80 kW$_e$ scale

Technical Barriers

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

(B) Cost

(E) System Thermal and Water Management

Technical Targets

This project is developing a low-cost, compact water management technology that will contribute to reducing size and weight of integrated fuel cell power systems operating on direct hydrogen. Project success will help meet system targets for power density, specific power, and cost. Focusing on automotive scale 80 kW$_e$ integrated fuel cell power systems, targets for the technology as a percentage of total system metrics are:

- Cost: less than 7% of system or $170 for an 80 kW$_e$-scale device
- Specific power: less than 9% of system or 11 kg for an 80 kW$_e$-scale device
- Energy density: less than 7% of system or 9 L for an 80 kW$_e$-scale device

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Approach

The device under development uses the cathode exhaust stream to simultaneously heat and humidify the cathode inlet in a single passive step as shown in the schematic in Figure 1. In the device, condensation and evaporation occur simultaneously, and wicks are used to convey water between the streams. Using wicks to hydraulically conduct water not only allows passive operation but also facilitates distribution of water within a channel and between channels as well as managing liquid water inventory in the device to prevent flooding and dry-out. Because the device works passively and with low pressure drop, parasitic power demand is minimized.

The technical approach is based on a unique, patented family of technologies for two-phase processing in microchannels [1-3]. The technology relies on capillary forces that allow passive operation in a highly efficient architecture. The microchannel architecture offers straightforward scale-up through increasing the number of parallel channels. Cost targets are achieved through a design-for-manufacturing strategy that incorporates low-cost materials and high-volume, automated manufacturing processes, such as progressive die stamping and automated assembly.

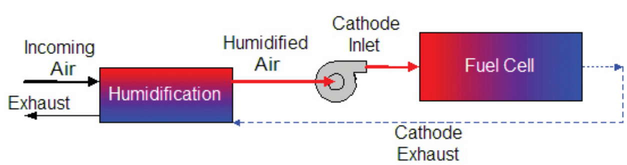

FIGURE 1. Process Schematic for Cathode Air Humidification Using Cathode Exhaust

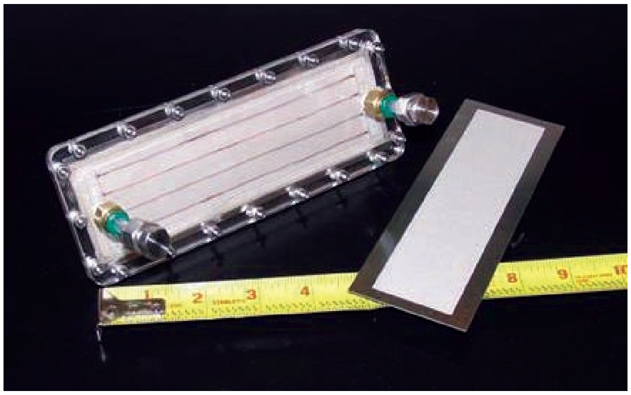

FIGURE 2. Single-Channel Proof-Of-Concept Microchannel Humidifier

Accomplishments

- The single-channel device shown in Figure 2 was fabricated. The device can be disassembled to change wick structures for comparative testing and is transparent to facilitate visual observation of 2-phase flow and liquid build-up within the device. Characteristic performance data generated with this device will be used for scale-up to 1 kW_e and 10 kW_e scale devices for demonstration with a fuel cell system.
- A test stand was constructed for single-channel testing. The dry air stream is metered into microchannels on one side of the wick material while heated, humidified air is metered to the channels on the opposite side. Water content of both exit streams is determined by on-line humidity probes and by chilling the streams and continuous weighing of condensate that is collected. Water balance, heat transfer effectiveness, and overall heat and mass transfer coefficients are calculated at each test condition.
- The single-channel device was successfully operated in counter-flow, transferring water and heat from a 100% relative humidity (RH) hot air stream to a cold dry air stream. In one example from initial testing, 2 SLPM of humid air at 78°C was cooled to 41°C while heating 2 SLPM of dry air from 24°C to 72°C and saturating to nearly 100% RH. The approach temperature at the hot end of 6°C is only half of the 12°C objective, but the flow rates are only 23% of that required to hit size and weight targets. Therefore, scale-up of this performance to an 80 kW_e device is estimated at 48 kg and 39 L. Future testing at higher flow rates is expected to dramatically reduce size estimates.

FY 2007 Publications/Presentations

1. TeGrotenhuis, W.E., C.A. Lavender, V.S. Stenkamp, K.S. Weil, B.Q. Roberts. 2007. "Passive Microchannel Humidifier for PEM Fuel Cell Water Management", Preprint Paper-Am. Chem. Soc., Div. Fuel Chem. ***2007***, 52 (2).

References

1. TeGrotenhuis, W.E., and V.S. Stenkamp, Improved Conditions for Fluid Separations in Microchannels, Capillary-Driven Fluid Separations, and Laminated Devices Capable of Separating Fluids, U.S. Patent 6,875,247, April 2005.

2. TeGrotenhuis, W.E., R.S. Wegeng, G.A. Whyatt, V.S. Stenkamp, P.A. Gauglitz, Microsystem Capillary Separations, U.S. Patent 6,666,909, December 2003.

3. TeGrotenhuis, W.E. and V.S. Stenkamp, "Gas-Liquid Processing in Microchannels." In Microreactor Technology and Process Intensification, eds. Y. Wang and J.D. Holladay, **ACS Symposium Series 914**, ACS, Washington, DC, 2005, pp. 360-377.