V.K.1 Development of Thermal and Water Management System for PEM Fuel Cells

Zia Mirza
Honeywell Engineering & Technology
2525 W. 190th Street, MS-36-0-55000
Torrance, CA 90504
Phone: (310) 512-3374; Fax: (310) 512-3020
E-mail: zia.mirza@honeywell.com

DOE Technology Development Manager:
Jason Marcinkoski
Phone: (202) 586-7466; Fax: (202) 586-9811
E-mail: Jason.Marcinkoski@ee.doe.gov

DOE Project Officer: Reg Tyler
Phone: (303) 275-4929; Fax: (303) 275-4753
E-mail: Reginald.Tyler@go.doe.gov

Technical Advisor: Walt Podolski
Phone: (630) 252-7558; Fax: (630) 972-4430
E-mail: podolski@anl.gov

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Objectives

- Develop advanced heat exchanger (radiator) that can efficiently reject heat with a relatively small difference between fuel cell stack operating temperature and ambient air temperature.
- Develop advanced humidification system to meet fuel cell inlet air humidity requirements.

Technical Barriers

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

(E) System Thermal and Water Management

Technical Targets

The inlet air to the proton exchange membrane (PEM) fuel cell stack should have a minimum humidity of 60 percent (at 80°C) to achieve fuel cell stack required performance and to increase the life of the stack. Accomplishments to date:

- Humidity of 60 percent at 80°C achieved in subscale units.
- Testing of the full-scale unit underway.

The heat load requirements for the fuel cell stack heat exchanger is 50 kW, with 85°C coolant (50/50 ethylene glycol) supply temperature to the radiator at a flow rate of 2.5 kg/sec. Radiator frontal area 0.32 sq. (0.71 m width and 0.45 m height) and depth, not to exceed 71 mm.

Total parasitic (air fan and coolant pump) power not to exceed 2.4 kW with reliability of 5,000 hr and minimum weight and cost. Accomplishments to date:

- The radiator design with advanced fins will meet cooling requirements within specified envelope constraints based on preliminary design.
- The value function being used for evaluation of various radiator configurations takes into account parasitic power, unit weight and cost.

Accomplishments

- The humidity system test stand checked out and operational.
- Full-scale humidity units received.
- Enthalpy wheel leakage test completed. Enthalpy wheel will be modified by supplier.
- Requirements for fuel cell heat exchanger defined.
- Value function defined and being used to compare various advanced heat exchanger configurations.
- Four sub-scale radiators fabricated and testing underway.

Future Directions

- Complete performance testing of the two selected full-scale humidification systems.
- Conduct sub-scale radiator testing to validate design parameters.
- Build full-scale radiator with select advanced fin configurations and test to validate performance.
- Complete final technical report.

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Introduction

The objective of this work is to develop an air humidification device and an advanced radiator system for fuel cell water and thermal management. The air supplied to the PEM fuel cell stack is required to have a certain amount of humidity. Two humidification devices have been down-selected and are being evaluated to validate their performance.

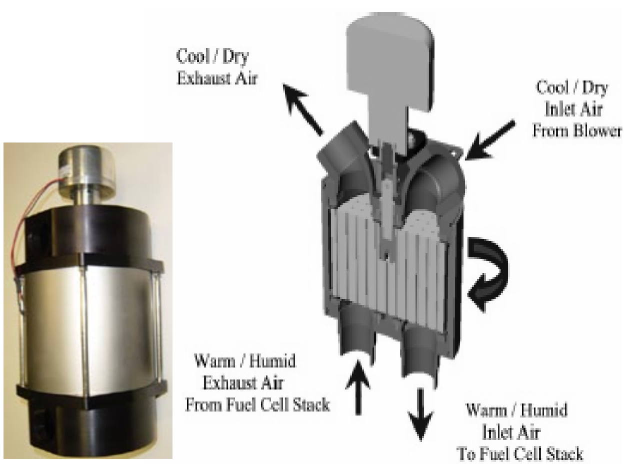
The heat generated in the fuel cell stack is a low-quality heat that needs to be dissipated to the ambient air. To minimize the size and weight of the radiator, advanced fin configurations are being evaluated for this application. Micro-channel and advance louver fins have been identified.

Approach

Water Management

The inlet air to the PEM fuel cell stack should have a minimum humidity of 60 percent (at 80°C) for enhancing the performance and increasing the life of the PEM fuel cell stack. Two humidification systems were down-selected for the fuel cells application.

- Enthalpy wheel (ceramic honeycomb) rotates while adsorbing moisture from fuel cell outlet air and transferring (desorbing) it to the inlet air. Details of the wheel are provided in Figure 1.
- The Nafion® membrane transfers moisture from one side of the air stream to the other side. Membrane has upper temperature limit that requires precooler in the inlet air stream. Module details are presented in Figure 2.



- Water adsorbed and desorbed in a rotating wheel
- Power: <100 W
- Leakage <1% process flow
- 8" Ø, 6" length wheel
- Vol: 17l cu in.; Wt: 17 kg
- Anodized Al construction
- Seal tension controlled with tie rods

FIGURE 1. Enthalpy Wheel by Emprise, Showing Unit Cut-Out with Flow Path Shown

Small-scale enthalpy wheel and membrane modules met the humidity requirements during testing at the supplier. Full-scale system testing is being conducted at Honeywell.

Enthalpy wheel seal leakage of up to 18 percent was observed at high operating pressures. The manufacturer of the wheel is making some design changes to reduce seal leakage at the high operating pressure conditions.

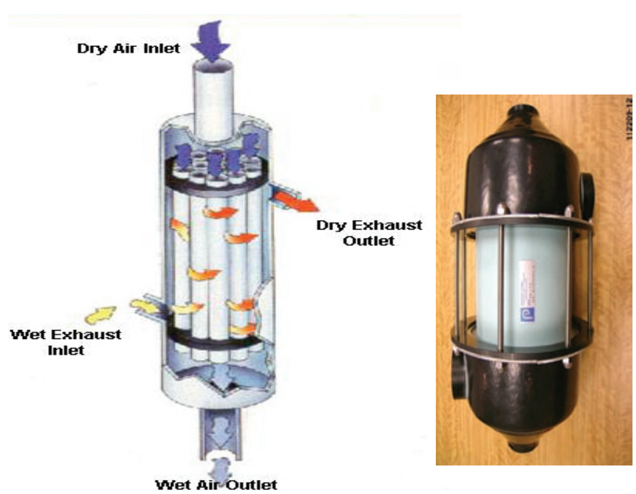
Thermal Management

- Develop a high-performance radiator that will meet the cooling requirements of the fuel cell stack within the specified constraint presented in the technical target section. Two advanced surfaces (micro-channel and advanced louver fins) were selected to build and test the sub-scale radiator to validate the radiator model parameters.
- Build a prototype full-scale radiator to demonstrate performance.

Results

A full-scale enthalpy wheel and a membrane module have been acquired from the manufacturer, and testing is underway. Due to high seal leakage, the enthalpy wheel is being modified by the supplier. The test stand has been operational; however, the humidity measurement sensors did not perform satisfactorily. Two different types of sensors have been acquired to make sure that the data is consistent and accurate.

Preliminary analysis has been completed for the fuel cell radiator for the following four fin configurations:



- Water adsorbed and desorbed in a rotating wheel
- Performance sensitive to temperature
- 6" Ø, 10" length cartridge
- 7000 fibers 0.045" OD
- 11.13 in^2 Nafion®

FIGURE 2. Membrane Module by Perma Pure Showing Unit Cut-Out With Flow Path Shown

- Conventional (18 fins/in) louver fins
- Advanced louver fins (24 fins/in)
- Two micro-channel fins with (40 and 50 fins/in)

Preliminary analysis of four surfaces in terms of value function (provided by Argonne National Laboratory) vs. weight was performed, and the results are shown in Figure 3. Based on this preliminary analysis, the 50 fins/in micro-channel provides optimum value.

Four sub-scale (9" by 9") radiators with different fin configurations have been fabricated (Figure 4). The test stand is being set up for performance testing and validation of the design model that will be used for full-scale radiator design.

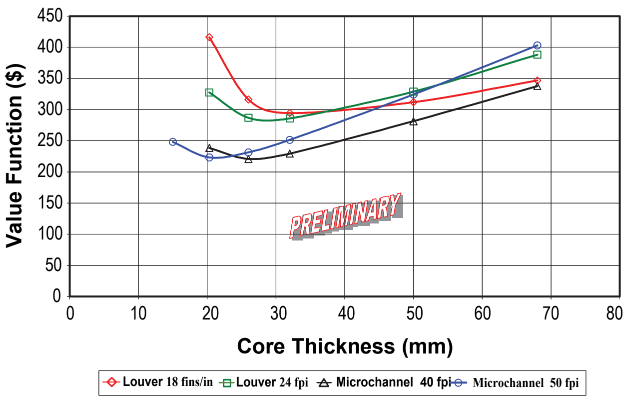


FIGURE 3. Curves Represent the Value Function Vs. the Radiator Thickness for Four Fin Configurations

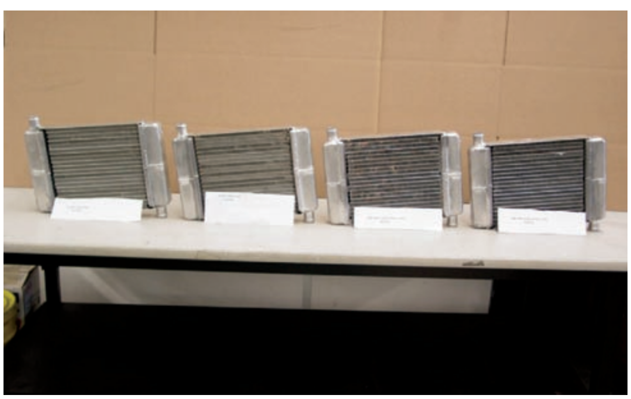


FIGURE 4. Sub-Scale (9" x 9") Radiators with Four Different Fin Configurations

Conclusions and Future Directions

Due to high seal leakage with the existing enthalpy wheel, the performance may not meet the requirements. The leakage rate of the modified wheel will be evaluated. Testing of the wheel will continue through Fiscal Year 2009.

The membrane module may have more potential for fuel cell humidification. It does not have any moving parts; however, due its upper temperature limitations, a precooler may be required. Testing of the module will continue through FY 2009.

Based on the preliminary analysis, the full-scale advanced radiator will meet the 50-kW cooling requirements of the fuel cell.

The sub-scale (9" by 9") radiators have been successfully fabricated and will be tested to validate the design parameters used for the full-scale radiator model during FY 2009.

The full-scale prototype radiator will be built and tested with the optimal advanced fin configurations during FY 2009.

A final report will be submitted after conclusion of these tasks.