V.H.2 Development of Thermal and Water Management Systems for PEM Fuel Cells

Zia Mirza
Honeywell Aerospace
2525 W. 190th Street
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: Reginald 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

Contract Number: DE-FC36-03G013109

Project Start Date: December 2002
Projected End Date: December 2009

Objectives

- Develop an advanced heat exchanger (radiator) that can efficiently reject heat with a relatively small difference between fuel cell stack operating temperature and ambient air temperature.
- Test humidification systems to meet fuel cell inlet air humidity requirements. The moisture from the fuel cell outlet air is transferred to inlet air, thus eliminating the need for an outside water source.
- Test the selected humidification system at sub-ambient conditions.

Technical Barriers

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

(E) System Thermal and Water Management

The technical targets for this project are listed in Table 1.

TABLE 1. Technical Targets

Characteristics	Units	Target	Honeywell Status
Humidity of PEM cell stack inlet air	% at 80°C	>60	TBD
Cooling requirements with 85°C coolant temperature and flow rate of 2.5 kg/sec, with frontal area not to exceed 0.32 sq meter	kW	50	50
Radiator cost (by TIAX LLC) without markup	$	56*	60
Reliability of radiator	hrs	5,000	TBD
Total parasitic power (air fan + cooling pump)	kW	<2.4	TBD

TBD – to be determined
*Cost based on 80 kW fuel cell system

Accomplishments

- Thermal Management
  - The radiators performance model was validated by four sub-scale radiators test data.
  - Full-scale radiators with louver and microchannel fins were built and tested.
- Water Management
  - The humidity system test stand was modified to meet the high air flow and humidity test requirements. The testing of test articles is underway.
  - The enthalpy wheel was modified by the supplier to eliminate high seal leakage rate.
  - The supplier for a planer membrane-based humidity device was identified and the testing is scheduled for later this year.

✧ ✧ ✧ ✧ ✧

Introduction

Balance of plant components of a proton exchange membrane (PEM) fuel cell automotive system represents a significant portion of total cost based on the 2008 study (Direct Hydrogen PEMFC Manufacturing Cost Estimated for Automotive Application) by TIAX LLC, Cambridge, MA. The objectives of this thermal and water management (TWM) project are twofold:

- Develop an advanced cooling system to meet the fuel cell cooling requirements. The heat generated by the fuel cell stack is a low-quality heat (low temperature) that needs to be dissipated to the ambient air. To minimize size, weight, and cost of the radiator, advanced fin configurations were evaluated.
- Evaluate air humidification systems which can meet the fuel cell stack inlet air humidity requirements. Two humidification devices were down-selected, one based on membrane and the other based on rotating enthalpy wheel. The sub-scale units for both of these devices have been successfully tested by the suppliers.

Approach

To develop a high-performance radiator for a fuel cell automobile, various advanced surfaces were evaluated, including foam; advanced, offset, and slit louver fins; and microchannel with various fin densities. A value function was developed to evaluate and compare the cost of various fin geometry radiators. The value function was based on the cooling system weight, performance, parasitic power, and initial cost. Two fin geometries – 18 fins per inch (fpi) louver and 40 fpi microchannel – were down-selected. The full-scale radiators were built and tested to validate the performance.

After extensive literature search and evaluation of existing humidification devices, two humidification systems were down-selected for TWM fuel cell applications: a Nafion® membrane-based system and enthalpy wheel-based system. Most of the humidification systems currently in use by HVAC (heating, ventilation and air conditioning), food, and chemical industries utilize low operating and differential pressure devices. The subscale units for the two selected devices were successfully tested at the supplier laboratories, meeting the fuel cell (FC) humidity requirements. A full-scale Nafion® membrane module and enthalpy wheel was designed, built and is being tested to validate the performance. A test stand was designed and built, to test the selected humidification devices where FC stack operating conditions are simulated. The testing at ambient conditions is scheduled in Fiscal Year 2009 and the sub-ambient testing will follow in FY 2010.

Results

Thermal Management

Two full-scale radiators with 18 fpi louver and 40 fpi microchannel radiators were built and tested. The size of each unit was 27.6″ wide, 17.7″ high, and 1.3″ deep, as shown in Figure 1.

FIGURE 1. Full-scale radiators with 18 fpi louver and 40 fpi microchannel aluminum fins.

Air-side effectiveness and pressure drop test data for the full-scale 18 fpi louver fin radiator is plotted against the performance model prediction in Figure 2. The test data for air-side effectiveness and pressure drop is in good agreement with model prediction. In Figure 3 the data for the full-scale 40 fpi microchannel fin radiator is plotted. The test data is also in good agreement with the performance model data.

After detailed analysis of the four sub-scale radiator test data, the two finalists based on value functions were the 18 fpi louver and 40 fpi microchannel. The sub-scale test data validated the performance model. The value function for the four sub-scale radiators based on the test data is shown in Figure 4. The 18 fpi louver and 40 fpi microchannel show the lower values within the radiator maximum allowable thickness of 2.75 in. The value function for the full-scale radiator is being generated, which will determine the optimum fin configuration.

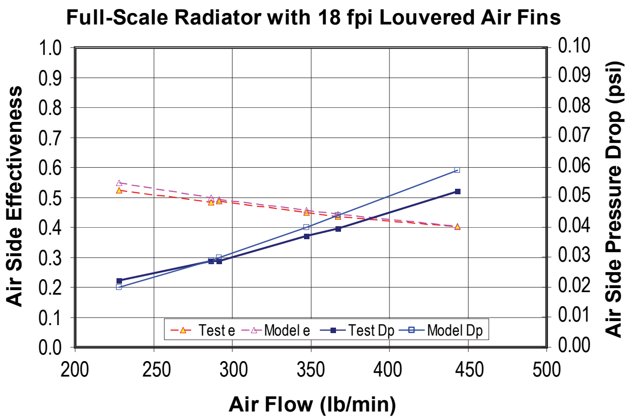

FIGURE 2. The test data for the full scale 18 fpi louver fin radiator plotted against performance model prediction with coolant flow rate of 32 gallons per minute.

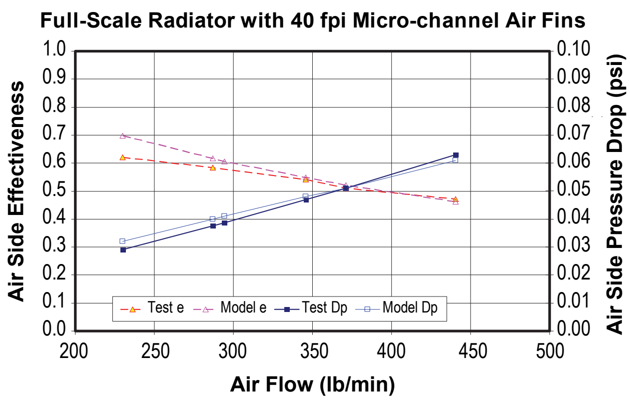

FIGURE 3. The test data for the full scale 40 fpi microchannel fin radiator plotted against performance model prediction with coolant flow rate of 35 gallons per minute.

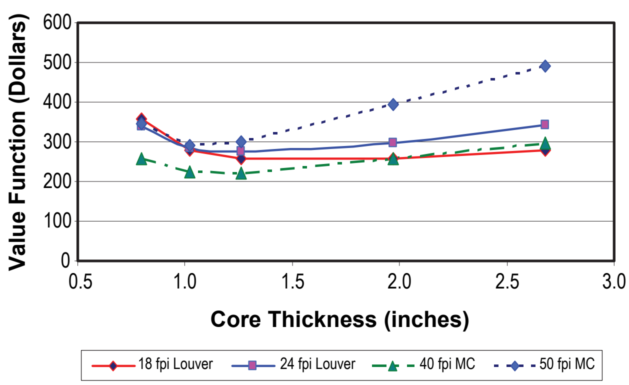

FIGURE 4. Value function is plotted against the radiator thickness for all four sub-scale radiators. The maximum allowable thickness of the automobile radiator is 2.75 inches. Based on sub-scale data the 40 fpi microchannel radiator has the best value for FC automobile applications.

The humidity system test stand was modified to be able to operate at higher air flow and humidity conditions. During the test stand modification additional sensors were added to improve the measurement accuracy. High air leakage across the enthalpy wheel seal was observed during low air flow testing, as previously reported. The unit sealing system was modified by the supplier. The testing of the selected humidification devices is expected to be complete by the mid 2010.

Conclusions and Future Directions

The testing of two full-scale radiators sized for a FC automobile was completed. Both units meets the cooling requirements, however the final selection will be based on the results of the value function analysis. Based on sub-scale data, the 40 fpi microchannel radiator has the best value for FC automobile application.

The selected radiator performance data will also be used by Argonne National Laboratory to validate the FC automotive system model. A final report will be submitted, which will conclude the thermal management portion of this project.

The testing of the enthalpy wheel, full- and half-scale membrane module is underway. A planer-based membrane module has been evaluated for FC application. The rectangular configuration will be beneficial from an installation point of view. A supplier of planer membrane-based humidification devices has been identified who is designing a full-scale unit to meet FC humidification performance requirements. This full-scale unit will be tested in the existing test stand. The humidification device down-selected will be tested at sub-ambient conditions. The completion of this testing will conclude the water management portion of this project by mid-FY 2010.

FY 2009 Publications/Presentations

1. 2009 Hydrogen Program and Vehicle Technologies Program; Annual Merit Review and Peer Evaluation Meeting – Washington, D.C. – May 2009. Presentation FC#39.