V.J.2 Development of Thermal and Water Management System for PEM Fuel Cell

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Fiscal Year (FY) 2011 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.
- Reliability testing of select humidification system for 5,000 cycles.

Technical Barriers

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

(E) System Thermal and Water Management

Technical Targets

TABLE 1. Technical Targets for Proton Exchange Membrane (PEM) Fuel Cell Thermal and Water Management System

Characteristics	Units	Target	Honeywell Status
Humidity of PEM cell stack inlet air	**% at 80°C**	**>60**	**50%**
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	$	58	50
Reliability of radiator	hrs	5,000	Under test
Total parasitic power (air fan + cooling pump)	kW	<2.4	To be determined

FY 2011 Accomplishments

- Thermal management portion of the project was successfully completed and the final test report for the thermal management was submitted to DOE in December 2009. The full-scale radiator performance test data was provided to Argonne National Laboratory for their fuel cell system model.
- Water Management
  - Full-scale and sub-scale membrane humidier system was successfully tested. The water transfer efficiency was lower than the required 60%.
  - The enthalpy wheel-based humidification system and planer membrane-based humidity device testing is successfully completed; the test data is presented here.

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Introduction

Balance-of-plant (BOP) components of a PEM fuel cell automotive system represents a significant portion of total cost based on the 2008 study by TIAX LLC, Cambridge, MA.

The objectives of this thermal and water management 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 (lower temperature) heat 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. Four humidification devices were successfully tested, three based on membranes and the fourth based on a rotating enthalpy wheel. The lab-scale units, one membrane module and enthalpy wheel, 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 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. The results were presented in annual progress report as well as final test report submitted in 2009.

A full and half-scale Nafion® membrane module, full-scale planar membrane module with Gore memebrane and enthalpy wheel was designed, built and was tested to validate the performance. A test stand was designed and built, to test the humidification devices similating the 80 kW fuel cell stack operating conditions. The test results for the first two systems were presented in previous reports. And the results for the last two systems (enthalpy wheel and planar modules) are presented in this report.

Results

The test results for the enthalpy wheel are pesented in Figures 1 and 2. One of the variables unique to the enthalpy wheel is its rotational speed. The water transfer effICency at three flow rates was measured as a function of rotational speed. In Figure 1 the water transfer ratio of humidty outlet stream (primary out) and inlet stream (secondary in) is plotted against the enthalpy wheel rotational speed. As expected the transfer efficiency improved with higher speed. The enthalpy wheel water transfer rate reaches over 70% above 30 revolutions per minute (RPM) at high flow rate. The water balance (in Figure 2) during high flow rate tests was under 10% which is exceptionally good, however at low flow rate and low speed the water balance was poor which may be attributed to measurement error. The water transfer rate for the enthalpy wheel was the best among all the four devices tested and it met the goal of 60% required for the PEM fuel cell.

Planar membrane water transfer and balance test data are presented in Figures 3 and 4, respectively. The water transfer rate varied from 20-37% with decreasing efficiency at high humidity levels. The water balance test results show the opposite trend where the water balance improved with high inlet humidity. The average water balance error during entire water humidity range was about 15% which is not unreasonable considering the limitations of humidity measurements devices used for high flow rate and humidity levels. Due to instrumentation and test stand limitations,

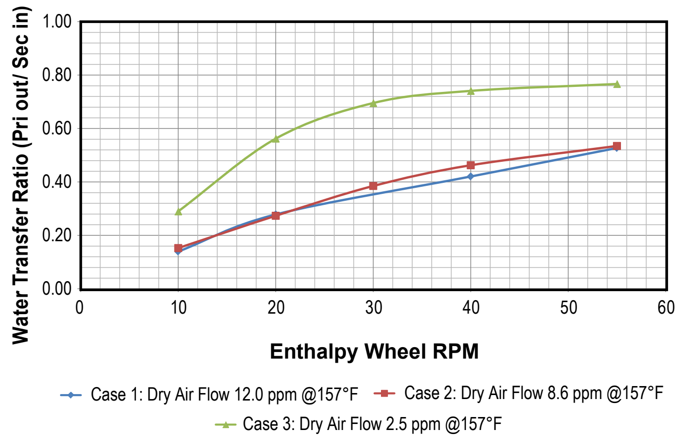

FIGURE 1. Enthalpy Wheel Water Transfer Rate vs. Rotational Speed

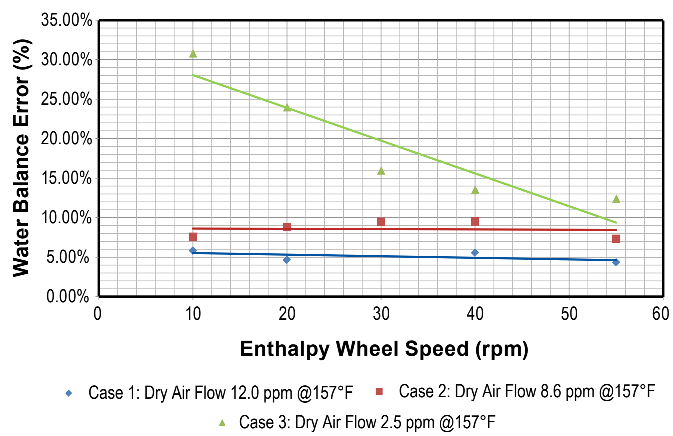

FIGURE 2. Enthalpy Wheel Water Balance Errors vs. Rotational Speed

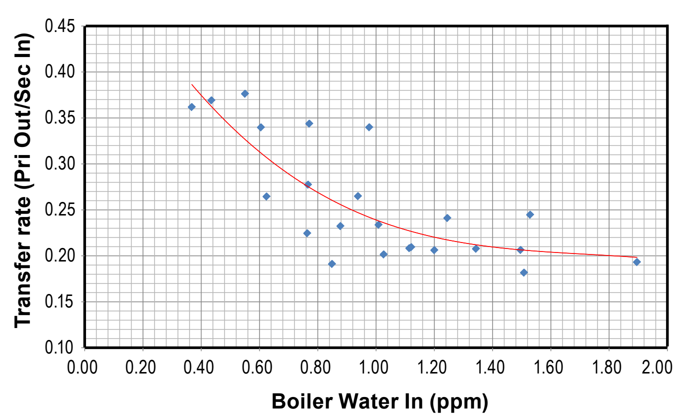

FIGURE 3. Planar Membrane Module Water Transfer Rate vs. Total Water in

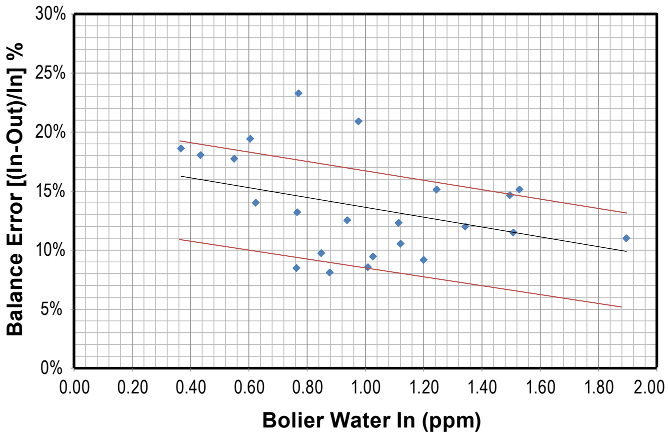

FIGURE 4. Planar Membrane Module Water Balance vs. Total Water in

the humidity of the humidifier inlet stream was limited to about 80 percent. The data scatter cannot be explained; each test point was taken when the system reached the steady-state condition.

Conclusions and Future Directions

All three different types of humidification systems were successfully tested. The enthalpy wheel showed the best water transfer efficeincy out of three different types of humidification system tested. The system has a motor for rotation of the wheel and requires seals to isolate the two flow streams.

The last remaining task for this 9-year project is to test a select himidificaiton system for 5,000 cycles reliability testing. Each cycle will consist of step changing the inlet humidity from high to low level and back to high level. The test stand has been modified and the testing has started.

FY 2011 Publications/Presentations

1. 2011 DOE Hydrogen Program and Vehicle Technologies Program; Annual Merit Review and Peer Evaluation Meeting – Washington, DC – May 9, 2011. Poster Presentation FC#039.