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

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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.

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	$	57	60
Reliability of radiator	hrs	5,000	>5,000
Total parasitic power (air fan + cooling pump)	kW	<2.4	TBD

TBD - to be determined

Accomplishments

- The thermal management portion of the project was successfully completed and the final test report for 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 slightly lower than the required 60%.
  - The enthalpy wheel-based humidification system testing is successfully completed; the test data is being analyzed.
  - Planer membrane-based humidity device has been acquired and the testing is scheduled for 3rd quarter of this year.

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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 (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. 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 is based on the cooling system weight, performance, parasitic power, and initial cost. Two fin geometries -- 18 fpi louver and 40 fpi microchannel -- were down-selected. The full-scale radiators were built and tested. The results were presented in last year's annual progress report as well as final test report submitted last year.

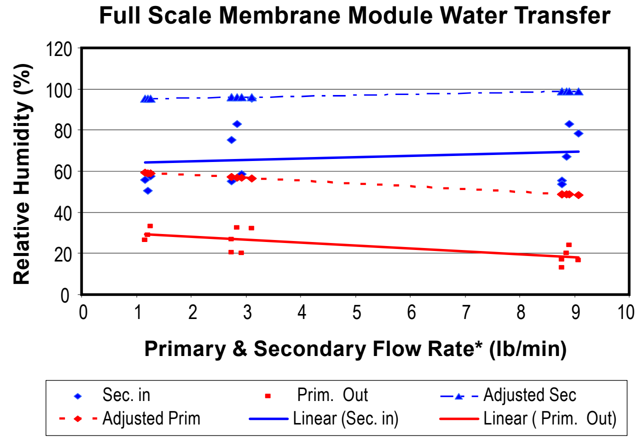
A full-scale Nafion® membrane module and enthalpy wheel was designed, built and is being tested to validate the performance. A test stand was designed and built, to test the selected humidification devices where fuel cell stack operating conditions are simulated. The test results at ambient conditions are summarized here. The testing of the planer membrane module is scheduled for the third quarter of 2010. The select humidifier with optimum performacne will be tested at sub-ambient conditions to simulate winter operating conditions.

Results

The testing of the full-scale and sub-scale Nafion® membrane module was successfully completed.

The humidity of the inlet stream (secondary flow) and outlet stream (primary in) for the full-scale module is plotted against average flow rates to humidifier inlet and outlet flow streams in Figure 1. Due to instrumentation and test stand limitations, 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.

The secondary inlet stream humidity data are adjusted higher (close to 100 percent), which resulted



*Average flow rate of primary and secondary streams is used. The flow variations were less than 11%.

FIGURE 1. Humidity of Inlet and Outlet Streams Compared with Average Flow Rates to Humidifier Inlet and Outlet Flow Streams

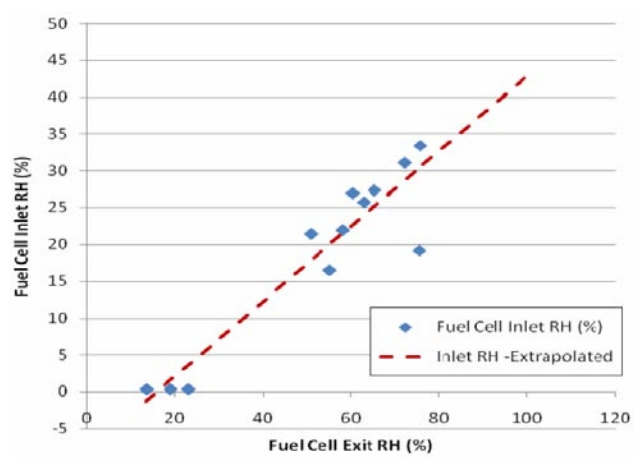


FIGURE 2. Fuel Cell Inlet Relative Humidity (RH) versus Fuel Cell Exit RH

in higher humidity for the primary flow. Even after the adjustment, the primary flow is still lower than the 60 percent required for the PEM fuel cell, particularly at higher flow rates.

The sub-scale humidier was also tested and the results are shown in Figure 2. The water transfer efficiency of the subscale humidifier was lower than full-scale by more than 10 percentage points.

Conclusions and Future Directions

The testing of full- and sub-scale membrane modules was successfully completed. The humidity of the fuel cell inlet air stream will be short of required 60% based on membrane module test results.

The testing of the enthalpy wheel is also completed the test data is being analysed. A full-scale planer-based membrane module has been acquired and the testing is planned for the 3rd quarter of this year. The rectangular configuration of the planer module and the use of membrane sheets rather than fibers will result in ease of installation as well lower cost. This full-scale unit will be tested in the existing test stand.

The humidification device down-selected from the three under considerationwill be tested at sub-ambient conditions. The completion of this testing will conclude the water management portion of this project at the end of Fiscal Year (FY) 2010 and the final report will be submitted in first quarter of 2011.

This testing project is conducted with close cooperation with Argonne National Laboratory, and the test data is provided to them for their PEM fuel cell system model.

FY 2010 Publications/Presentations

1. 20010 DOE Hydrogen Program and Vehicle Technologies Program; Annual Merit Review and Peer Evaluation Meeting – Washington, D.C. – June 8. Poster Presentation FC#39