Development of Thermal and Water Management System for PEM Fuel Cell

Project ID No. FC066 Zia Mirza June 8, 2010



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Overview

Timeline

- Project start FY03
- Program stopped FY05/FY06
- PO end date Dec. 2010
- 90% complete

Budget

- Total project funding
 - DOE share \$3,250K
 - Honeywell \$812K
- DOE funding in FY 2003-04
 - \$1,600K
- DOE funding in FY07-09
 - \$1,250K
- DOE funding for FY10
 - \$400K

Barriers

- Performance of select full scale
 humidification system
- Thermal performance of advance radiators to meet fuel cell cooling requirements

Partners

- US Department of Energy
- Argonne National Lab
- FreedomCAR Tech Team

Objectives for FY 2010/2011

- Test two select full-size radiators to meet the 80 kW fuel cell cooling requirements
- Validate performance of full scale humidification devices sized for 80 kW fuel cell
 - Install, hook-up and checkout test stand
 - Test Emprise enthalpy wheel
 - Test Perma Pure half and full-scale membrane module s
 - Test planer membrane module
- To improve PEM fuel cell performance and life, the humidity of inlet air stream should be maintained at a high level (currently 60%)
- Check select humidifier performance at sub-ambient temperature
- Thermal and Management program final report

Approach

- The inlet air to the PEM fuel cell stack should have a minimum humidity of 60% (at 80 C) for performance and increased life
- Two humidification systems were down-selected for the fuel cells application
 - Enthalpy Wheel (ceramic honeycomb) rotates while adsorb moisture from fuel cell outlet air and transfer (de-sorb) it to the inlet air
 - The Nafion[®] membrane transfer moisture from one side of the air stream to the other side. The membrane has upper temperature limit which require a precooler in the inlet air stream
- Small scale systems met the requirements
- Humidification system testing is 85% complete

Accomplishments for FY09/10

- Full scale radiators with two fin configurations were tested
- Humidification test stand was modified to accommodate high air flow rates and improved measurement accuracy
- Enthalpy wheel was modified to reduce seal leakage
- Full scale Nafion[®] membrane humidifier was tested
- Sub scale membrane humidifier is under test
- Full scale planer membrane module was acquired for performance testing
- Submitted radiators final test report

PEM Fuel Cell Humidification Options



Enthalpy Wheel

Enthalpy Wheel supplied by Emprise, Kennesaw, GA

- Water adsorbed and de-sorbed in a rotating wheel
- Power: < 100W, Seal leakage < 1% of process air
- Volume 171 cu in, weight 17 Kg and size 8" Dia, 6" length wheel





Membrane Module

- Supplied by Perma Pure, Cincinnati, OH
- Membrane selectively allows water to pass through
- Performance sensitive to temperature
- Volume 6" Dia, 10" length cartridge
- 7,000 fibers, 0.045" OD and 11 in in² Nafion[®]





Full-scale

Planer Membrane Humidifier

- Planer humidifier has advantage in manufacturing cost and installation
- Max operating temp. 176°F (80°C), pressure of 35 psi & flow 12/min
- Supplier: dpoint Technologies Inc., Vancouver
- Size 11.5" length, 9.3" width, and 5.4" height
- Model Px4-268 mm pleated humidifier
- Max. air flow rate of 12 lb/min
- Membrane by Gore



Humidification Test Stand Improvements

- Test stand was modified to measure the water injection rate by weight
- Water was condensing inside the test article, instead of being transferred
 - Improve steam line insulation
 - Add heater tape and improved insulation to ducting to ensure duct wall temps stay above dew point temperature
- Additional humidity sensors were added in addition to dry-wet bulb devices



Humidity Sensors

Humidification Test Stand (Contd.)



Sub-scale Membrane Module under test

Full-scale Membrane Module (MM) Water Transfer Rate



Full-Scale MM Water Transfer (Extrapolated)



Water transfer across full-scale humidifier less than 60%

Sub-scale Membrane Module Water Balance



Sub-scale MM Water Balance (Repeat Run)



Sub-scale MM Humidity Transfer Ratio



Sub-scale MM Humidity Transfer Ratio (Repeat)



Water transfer across sub-scale humidifier less than 60%

Thermal Management Program Summary

- Thermal Management Program was successfully completed
 - Four sub-scale radiators with different fins configuration built and tested
 - Performance model validated, manufacturability lesson learned
 - Two down-select fin configurations; full-scale radiators built
 - Test results validated the performance model
 - Test results were used in PEM fuel cell system model by Argonne National Lab.
 - Radiators estimated cost compared well with independent consultant estimates
 - Submitted radiators final test report

Full-Scale Radiators

Size of the radiator: 27.6" width, 17.7" height, and 1.3" depth. Estimated weight of full-scale louver and microchannel radiator (with plastic tanks) will be 10 and 13 lbs respectively



40 fins/in. Microchannel Fins

18 fins/in. Louver Fins

Full size microchannel radiators built successfully

Radiator Test Set-up



Radiator Instrumented



Coolant Circulating Cart

Full-Scale 18 fpi Louver Fin Radiator

The water-glycol circulating rate 2.25 kg/sec (maximum allowable 2.5 kg/sec.)



Effectiveness and pressure drop test data in good agreement with model predictions

Full-Scale 40 fpi Microchannel Fin Radiator

The water-glycol circulating rate was 2.25 kg/sec (maximum allowable 2.5 kg/sec.)



Effectiveness and pressure drop test data in good agreement with model predictions

Collaborators

- Argonne National Laboratory
 Federal Laboratory
 - Coordination of all technical activities including requirements definition, technical data interchange, and support to overall PEM Fuel Cell model development
- FreedomCAR Tech Team
 - Participate in program reviews

US Council for Automotive Research

Emprise Corporation

Honeywell

Industry

 Designed and built humidification test stand and Enthalpy Wheel. Active participant in improvement of test stand and enthalpy wheel design

Go-Forward Plan

- Thermal Management final report
- Testing of following humidification devices
 - Enthalpy Wheel

Honeywell

- Half-scale Membrane Module
- Full Scale Membrane Module
- Planer Membrane Module
- Testing of select unit in sub-ambient environment
- Program final report

Under test Completed

FY09/10 Schedule and Major Milestones

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Go-Forward Plan

FY 2010

Honeywell

- Complete testing of:
 - Half-scale membrane module
 - Enthalpy wheel
 - Planer membrane module
- Selection of optimum humidification system

FY 2011

- Testing of select system at sub-ambient conditions
- Program final report