Development of Thermal and Water Management System for PEM Fuel Cell

Project ID No. FC066

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Honeywell

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Overview

Timeline

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

Barriers

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

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

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

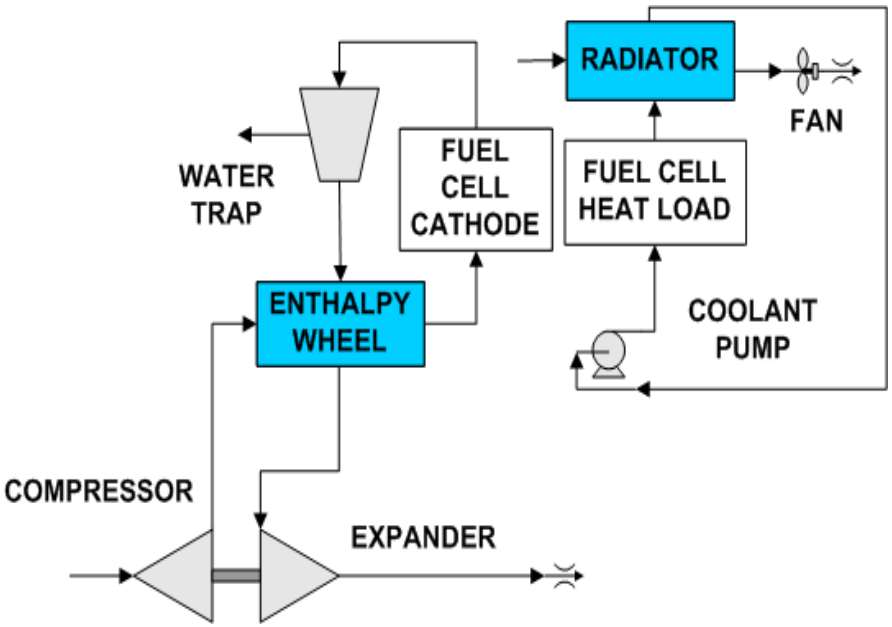
Approach

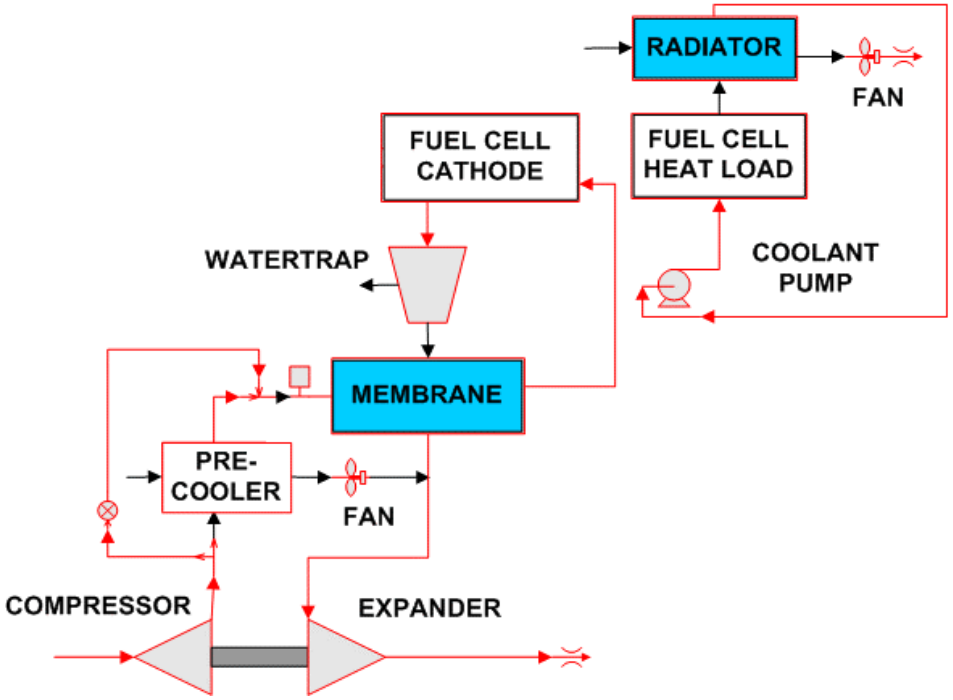
- The inlet air to the PEM fuel cell stack should have a minimum humidity of 60% (at 80 C) for performance and increased life
- Two humidification systems were down-selected for the fuel cells application
  - Enthalpy Wheel (ceramic honeycomb) rotates while adsorb moisture from fuel cell outlet air and 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

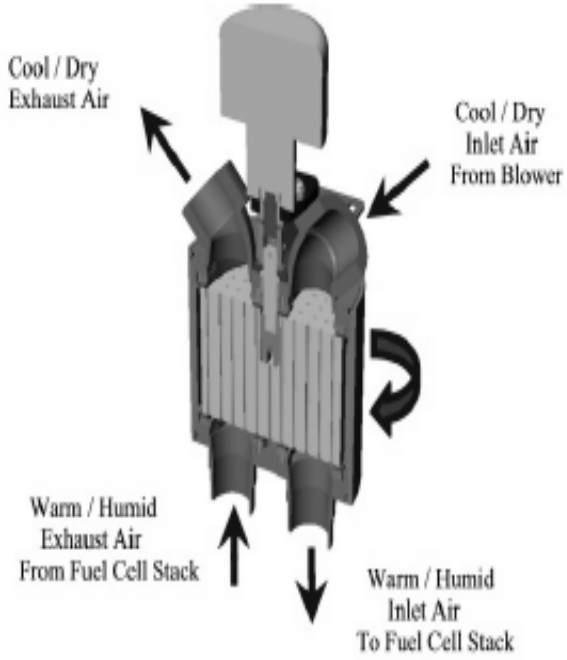




Enthalpy Wheel

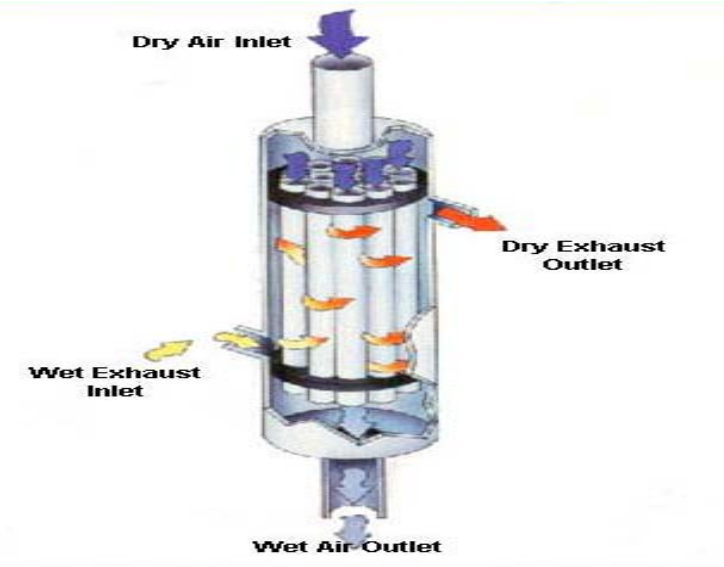
Enthalpy Wheel supplied by Emprise, Kennesaw, GA

- 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 in^2 Nafion®



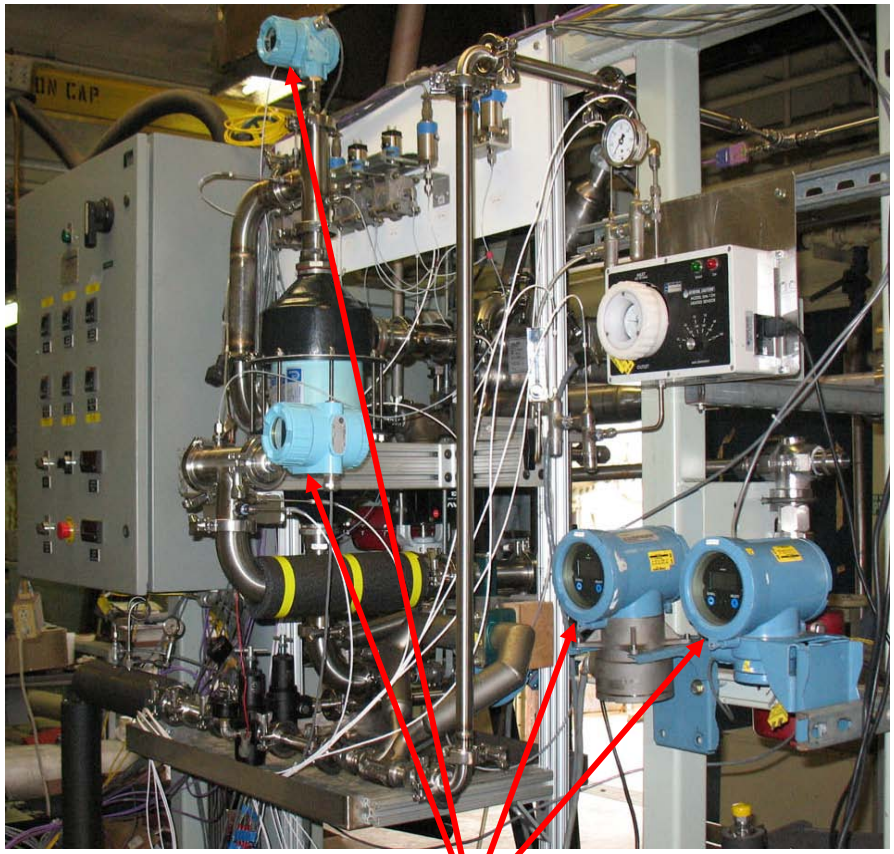
Full-scale

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

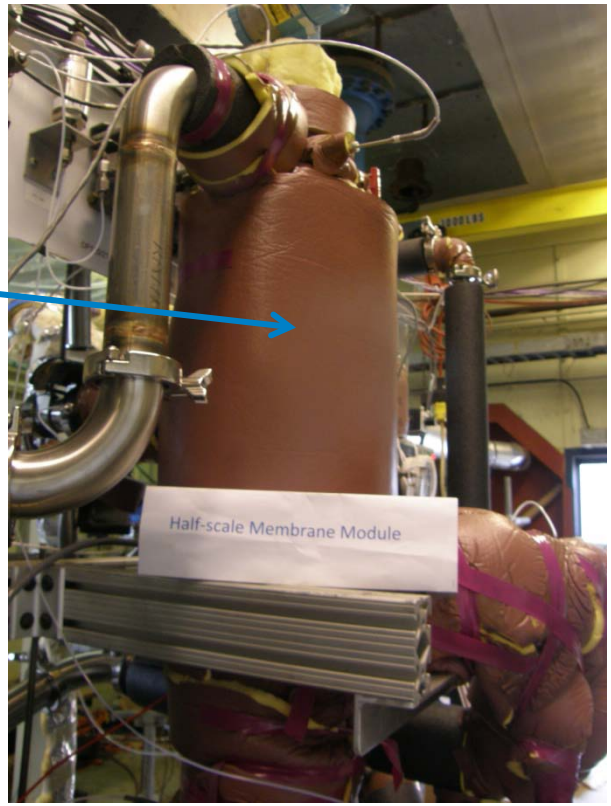
- Test stand was modified to measure the water injection rate by weight
- Water was condensing inside the test article, instead of being transferred
  - Improve steam line insulation
  - Add heater tape and improved insulation to ducting to ensure duct wall temps stay above dew point temperature
- Additional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



Humidity Sensors

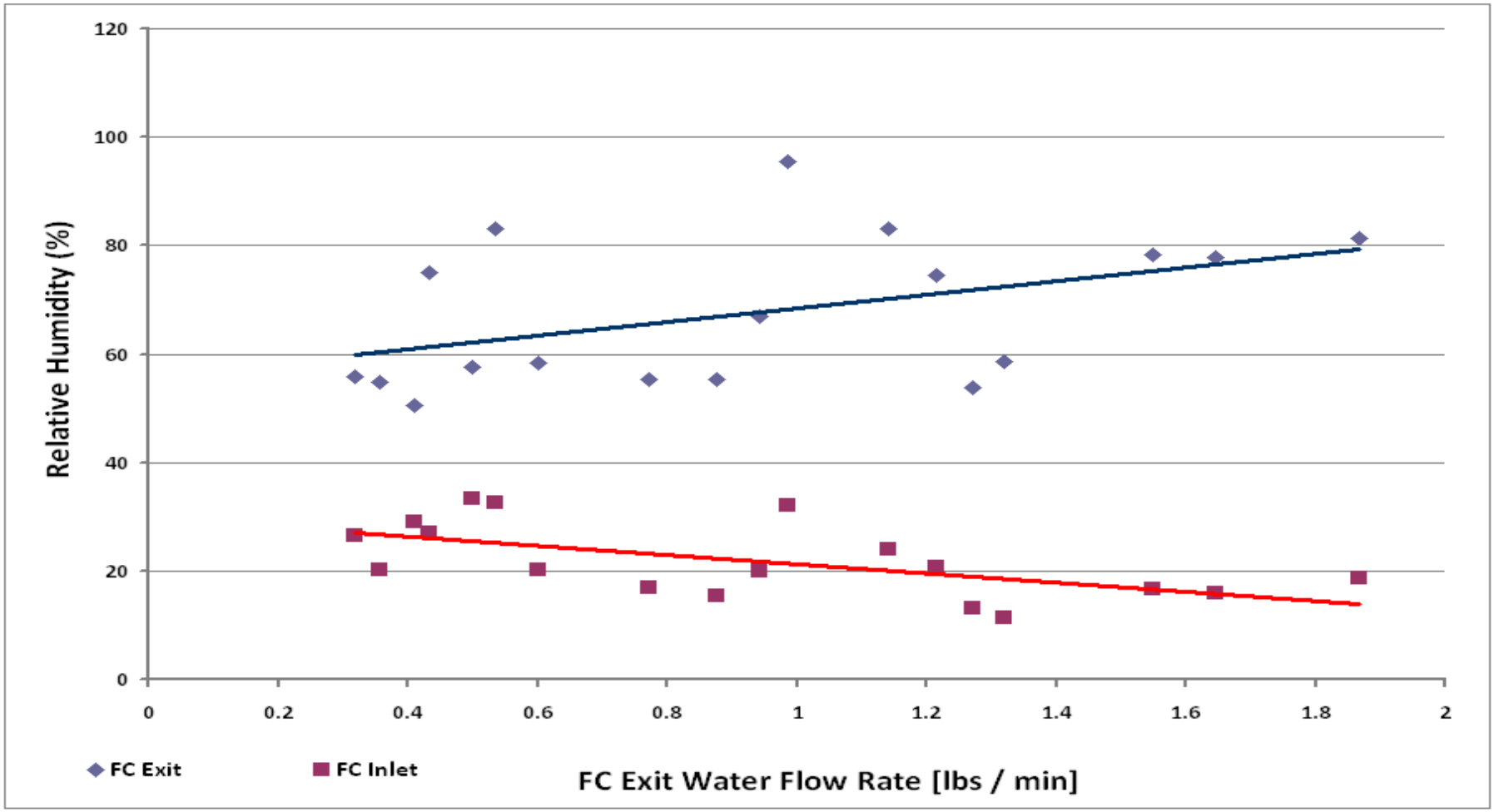
Humidification Test Stand (Contd.)

Sub-scale
Membrane Module

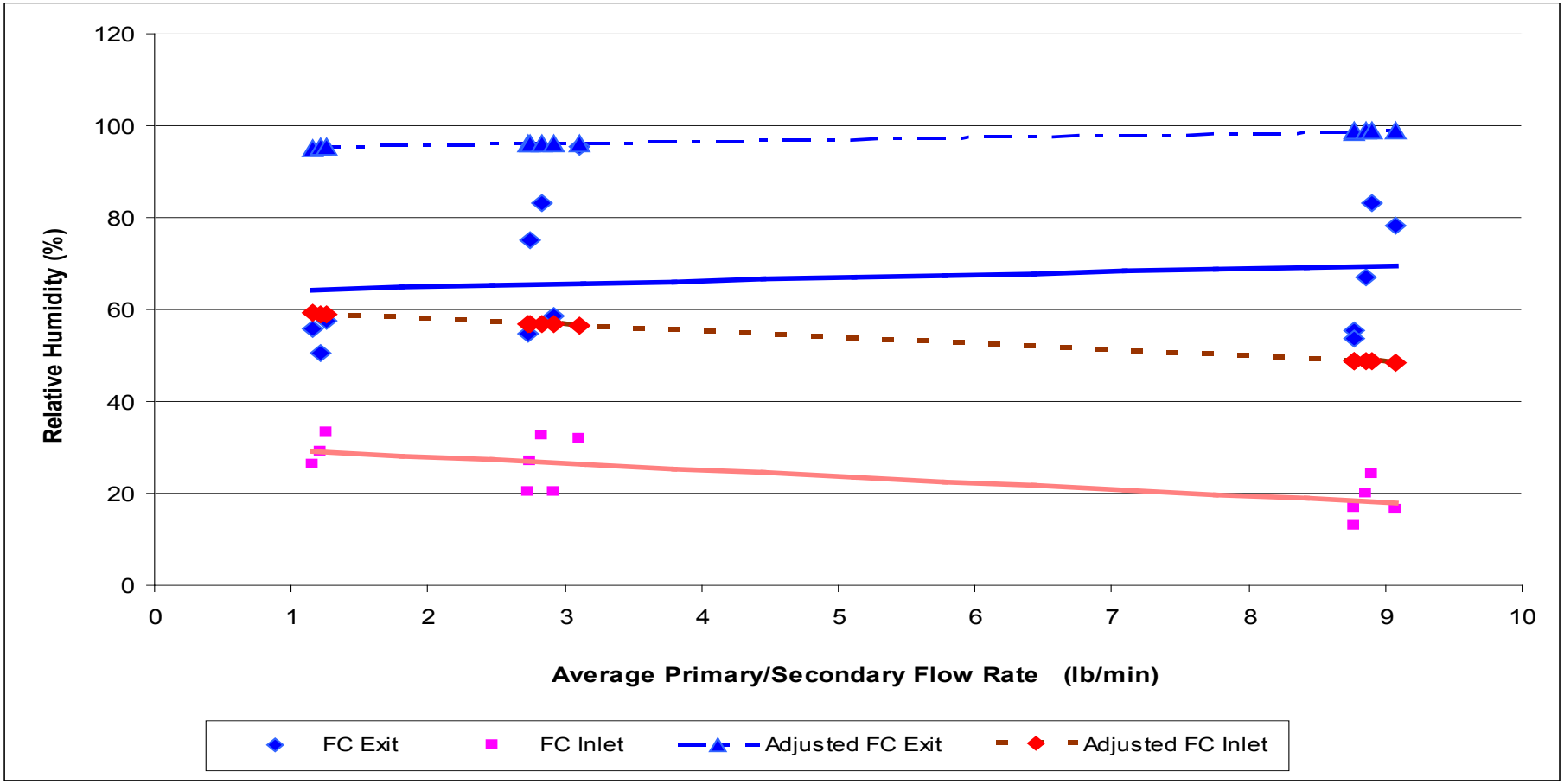


Sub-scale Membrane Module under test

Full-scale Membrane Module (MM) Water Transfer Rate

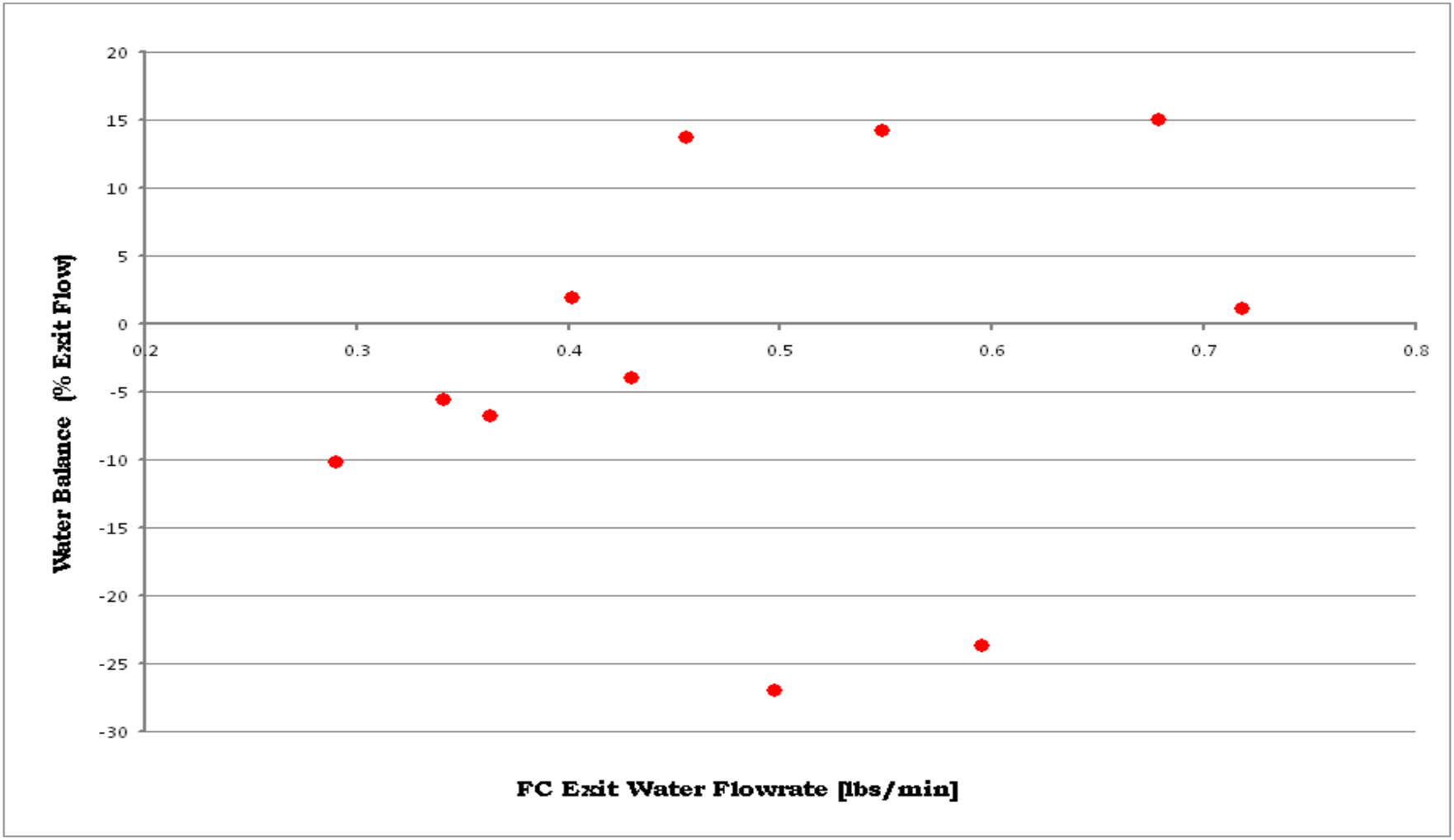


Full-Scale MM Water Transfer (Extrapolated)

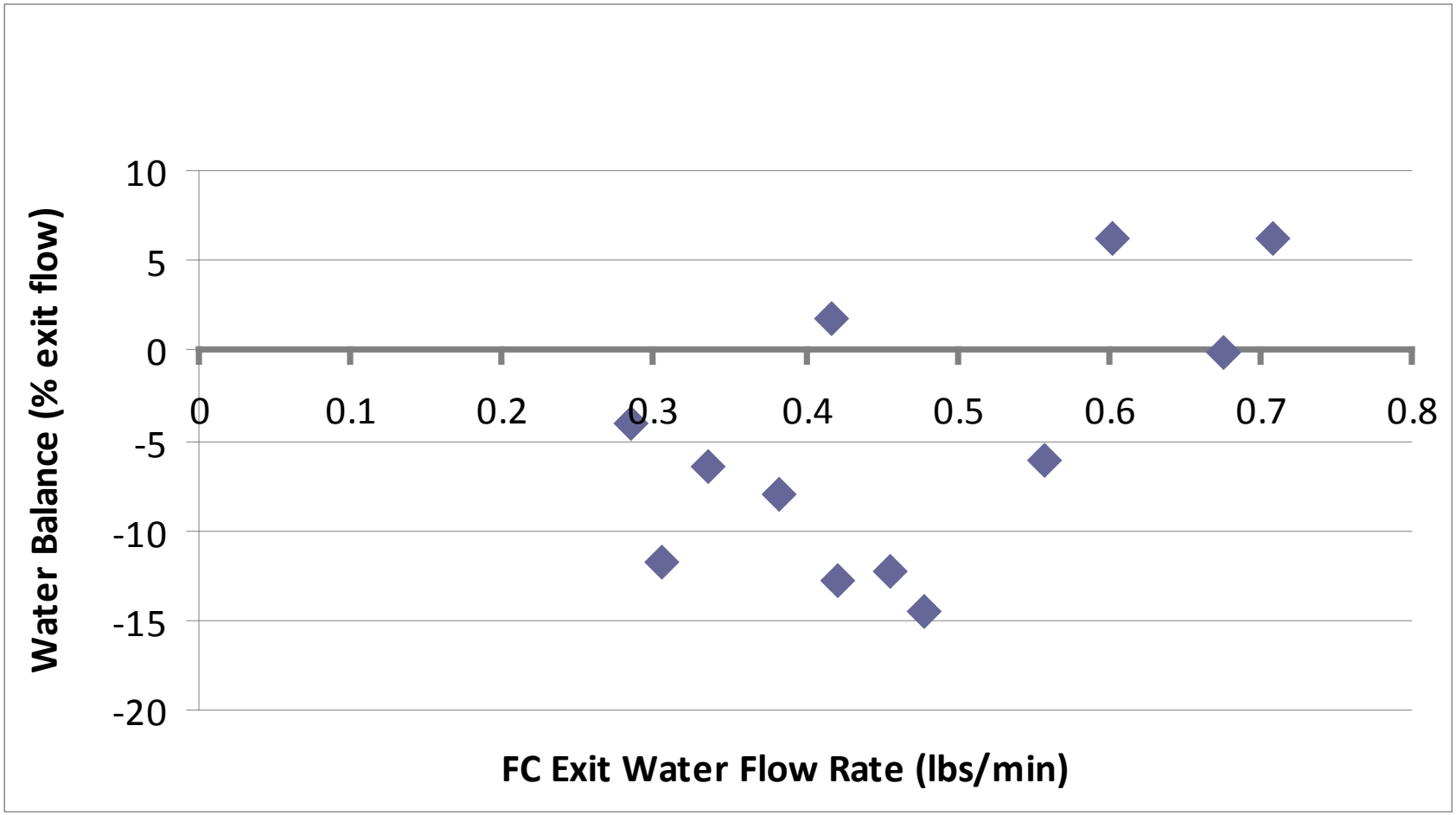


Water transfer across full-scale humidifier less than 60%

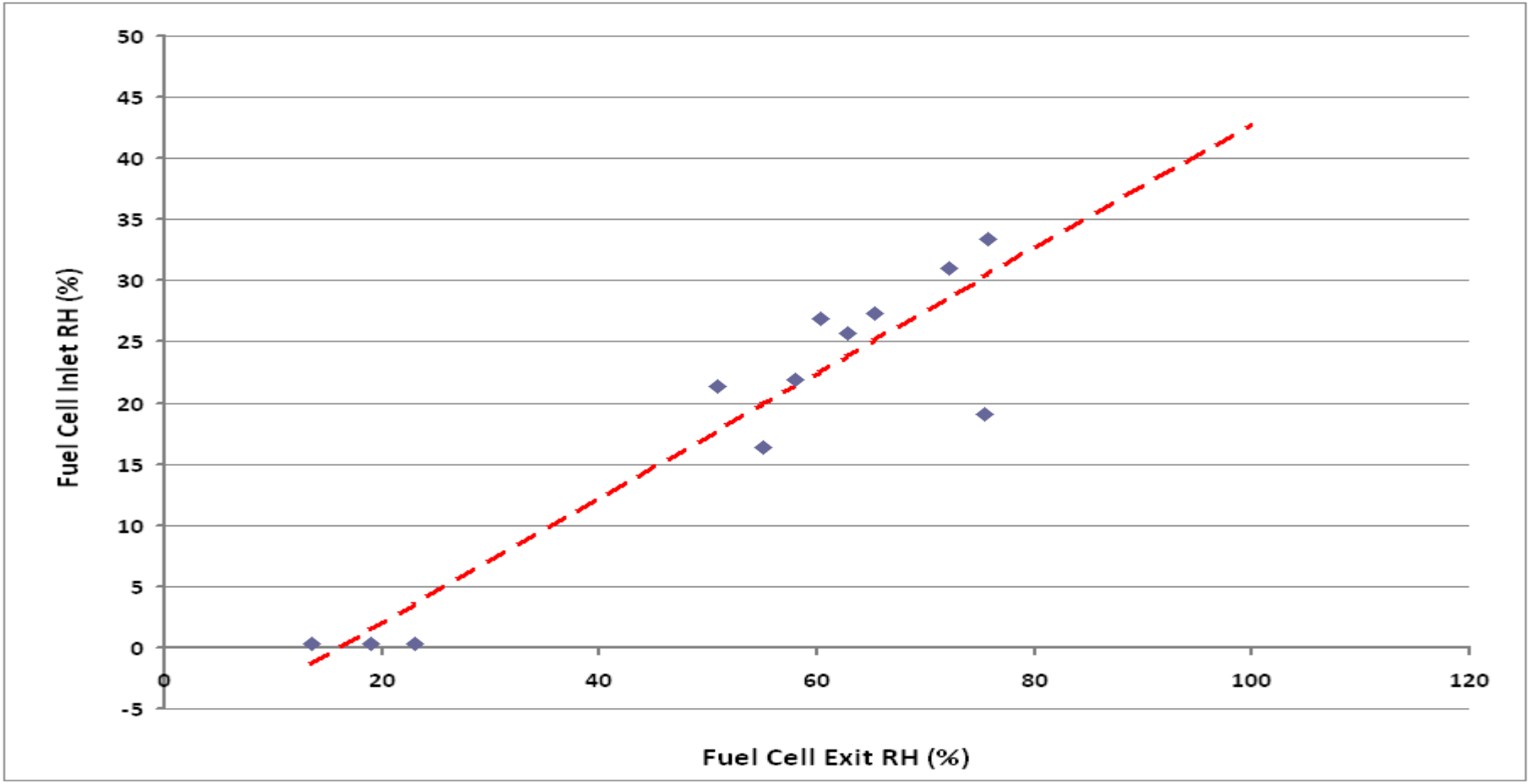
Sub-scale Membrane Module Water Balance



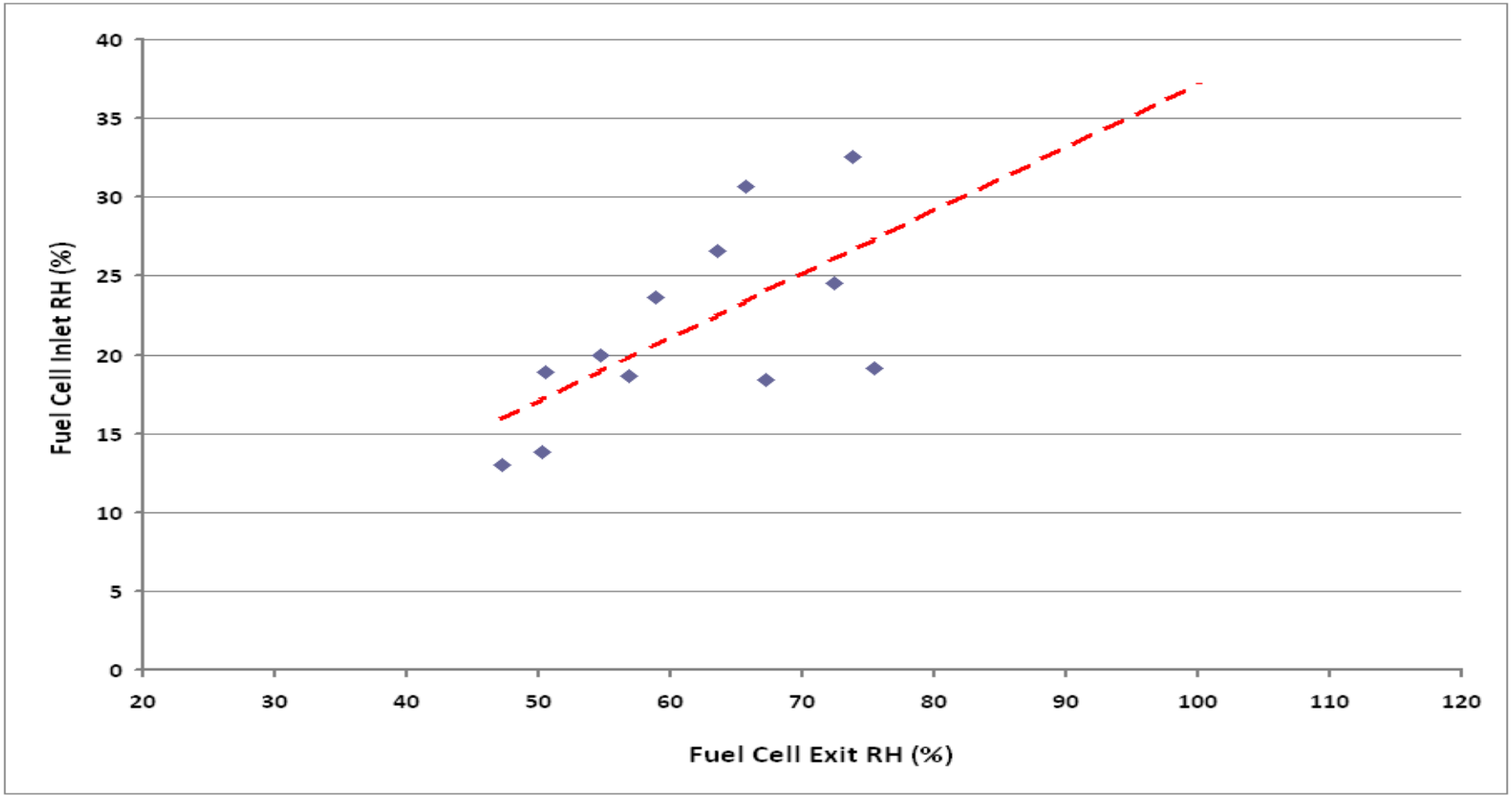
Sub-scale MM Water Balance (Repeat Run)



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

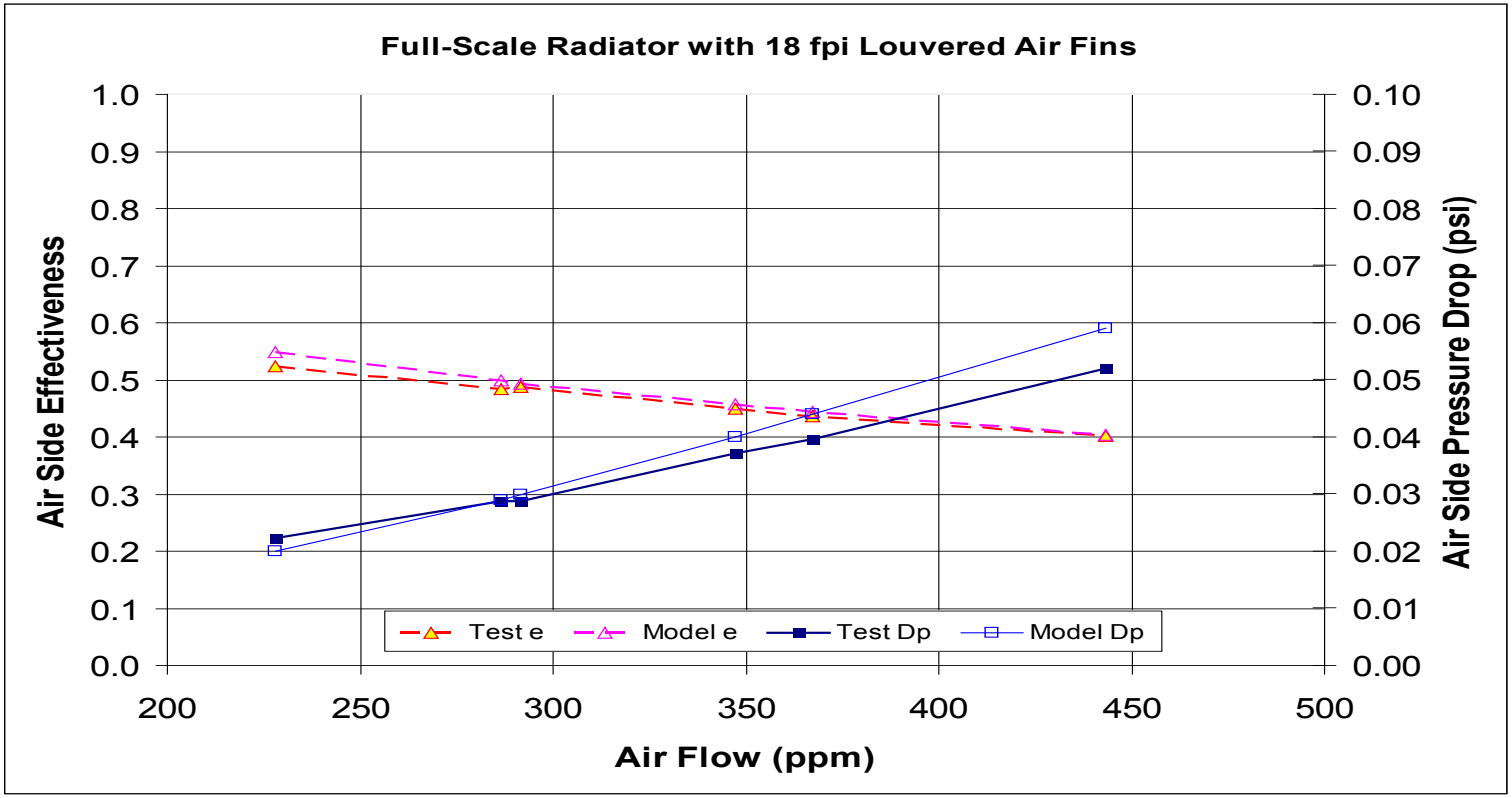
Radiator Test Set-up

Radiator Instrumented

Coolant Circulating Cart

Full-Scale 18 fpi Louver Fin Radiator

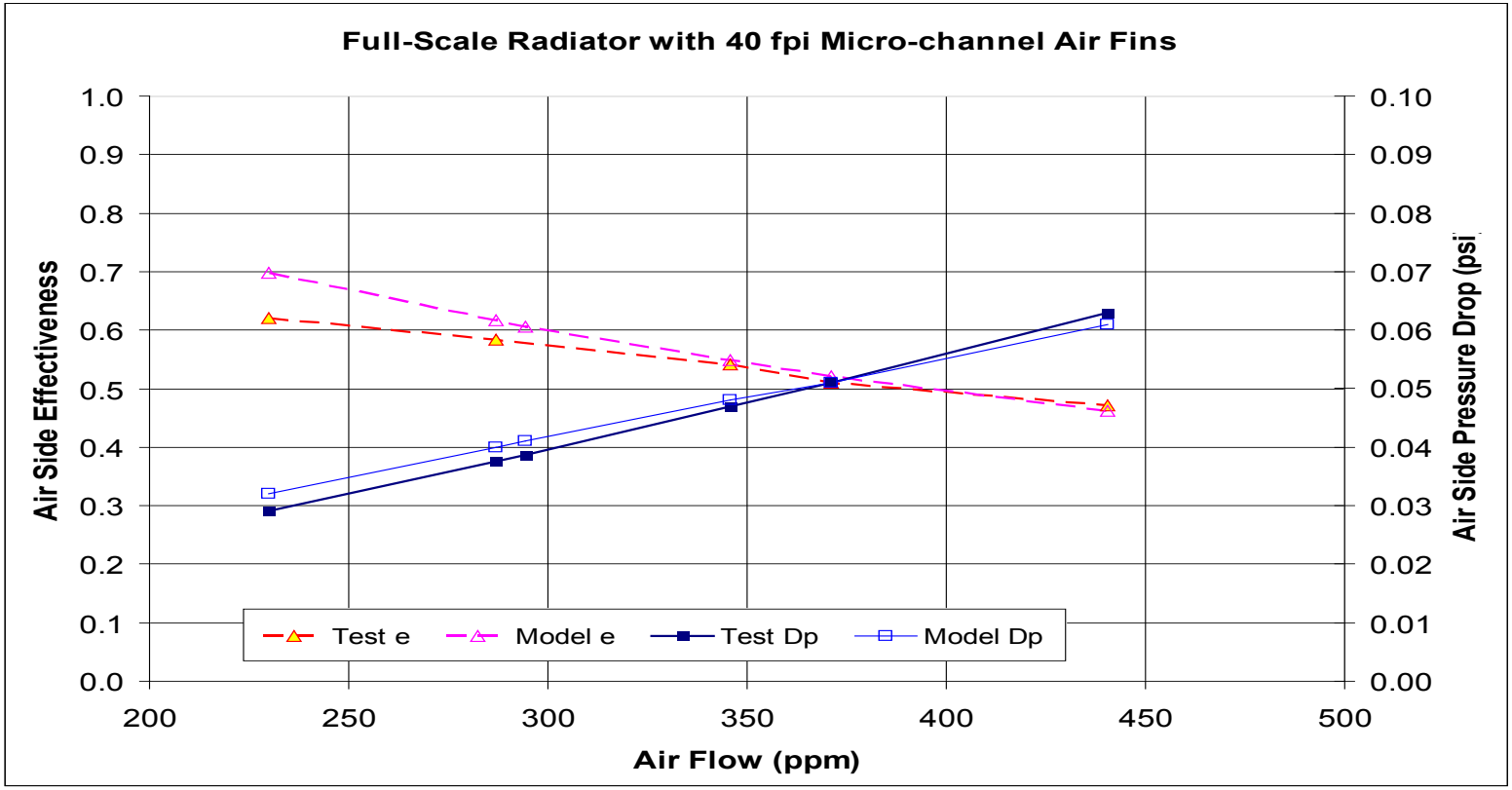
The water-glycol circulating rate 2.25 kg/sec (maximum allowable 2.5 kg/sec.)



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

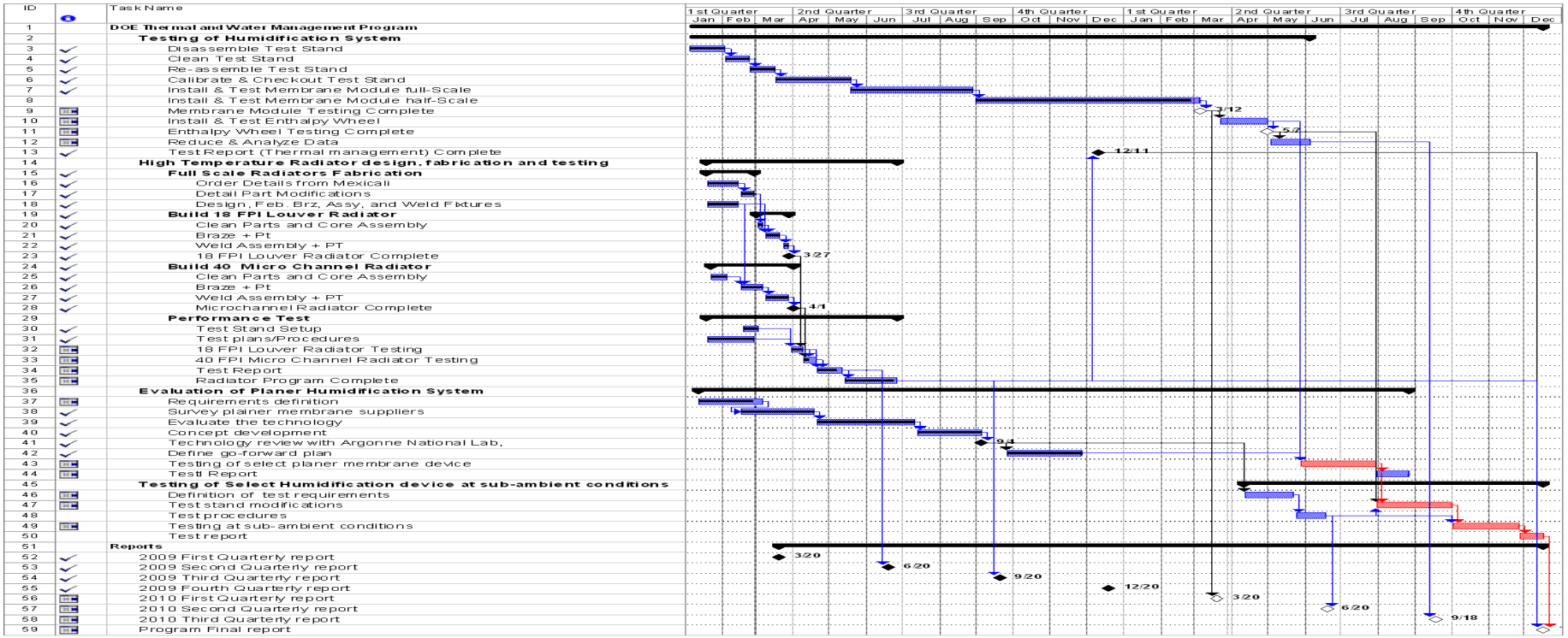
Collaborators

- *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* — US Council for Automotive Research
  - Participate in program reviews
- *Emprise Corporation* — 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
  - Half-scale Membrane Module — Under test
  - Full Scale Membrane Module — Completed
  - Planer Membrane Module
- Testing of select unit in sub-ambient environment
- Program final report

FY09/10 Schedule and Major Milestones



Thermal systems final test report	12/11/09	Completed
Full-scale membrane module testing	1/12/10	Completed
Sub-scale membrane module testing	3/5/10	Completed
Enthalpy wheel testing	4/30/10	
Planer membrane module testing	6/15/10	
Sub-ambient testing	9/17/10	

Go-Forward Plan

FY 2010

- 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