Development of Thermal and Water Management System for PEM Fuel Cell

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Project ID FC066

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Overview

Timeline

- Project start FY03
- Program stopped FY05/FY06
- Project end date Mar. 2011
- 90% complete

Budget

- Total project funding
  - DOE share - $3,250K
  - Honeywell - $812K
- DOE funding in FY10
  - $340K
- DOE funding for FY11
  - $0K

Barriers

- Develop efficient, cost-effective integrated thermal/water management system that effectively uses the fuel cell waste heat and water
- Develop advanced cooling/heat exchanger
- Reduce weight and cost of the components

Partners

- Argonne National Lab
- FreedomCAR Tech Team

Objectives

- Test two select full-size radiators to meet the 80 kW fuel cell cooling requirements
- Validate performance of humidification devices sized for 80 kW fuel cell
  - Test Emprise enthalpy wheel
  - Test Perma Pure sub and full-scale membrane modules
  - Test planar 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 reliability for 5,000 cycles
- Thermal and Water Management program final report

Approach

- The approach is to provide humidity >60% (at 80 C) to the PEM fuel cell stack inlet air for increased performance and life
- Eliminate need for external water source by transferring water from stack exit air stream to inlet stream
- Test humidification systems which can efficiently transfer water from one air stream to the other
- Design, build and test high-performance full-size radiators to meet the 80 kW fuel cell stack cooling requirements
  - Increase performance required to dissipate low-quality heat
  - Optimize the weight, size, and cost
- Conduct reliability testing of two select humidifiers in FY11/12.
- Submit program final report

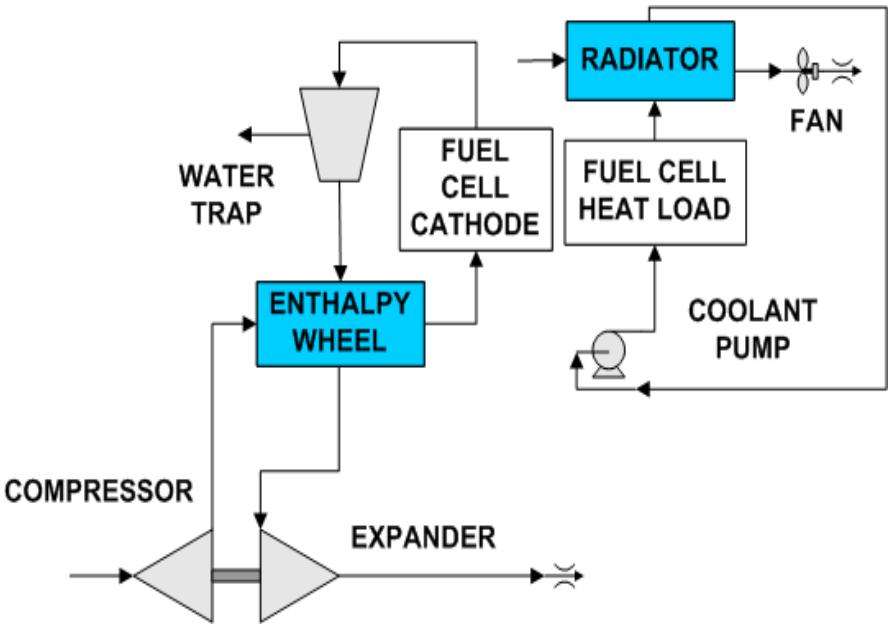
Thermal and Water Management System Program will end this year

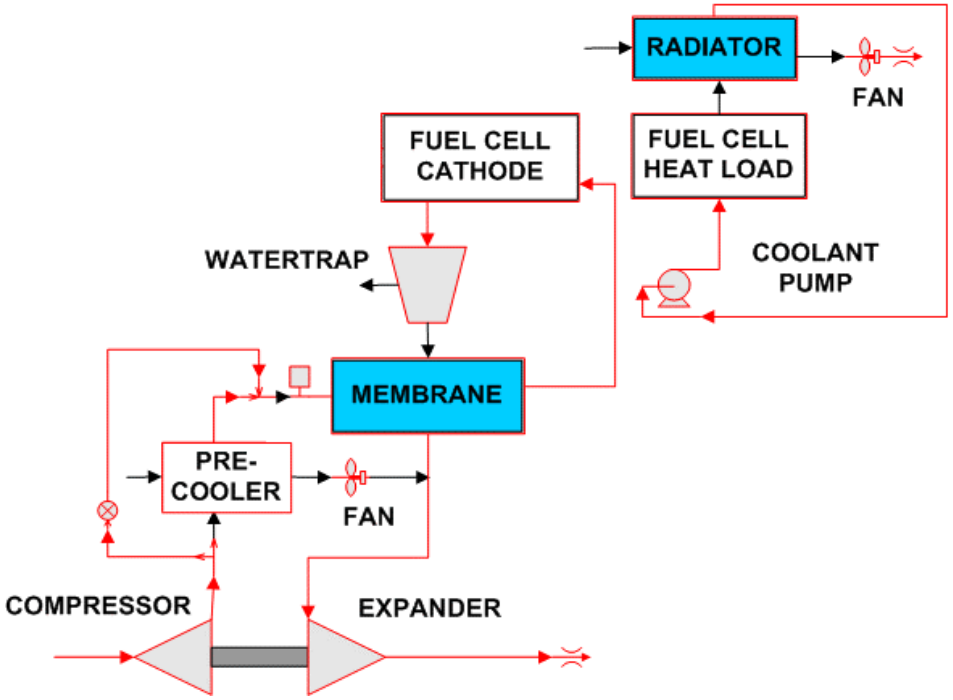
Accomplishments for FY10/11

- Thermal Management part of the program was successfully completed and test report was submitted
- Last two humidifier were performance tested
  - Sub scale Perma Pure membrane module
  - Full scale planar membrane module
- Program plan for the FY2011/12 was developed and approved by DOE Program Office
- Two humidification systems were down-selected for reliability testing
  - Enthalpy Wheel
  - Planar membrane humidifier

Testing of all humidification devices successfully completed

PEM Fuel Cell Humidification Options

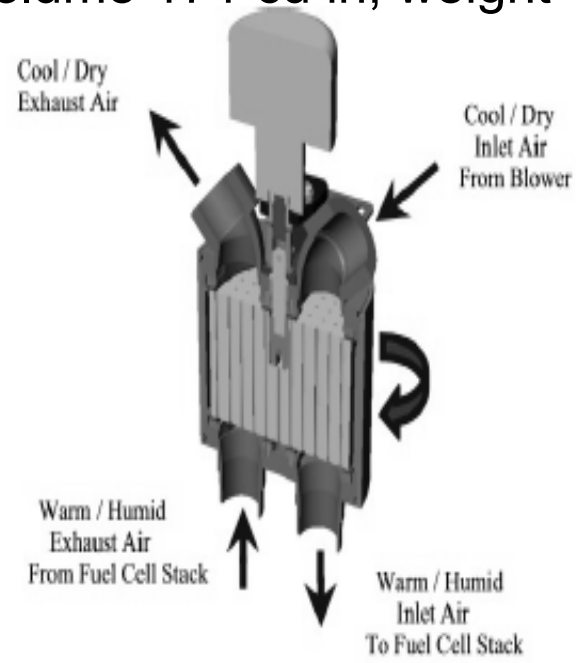




Enthalpy Wheel

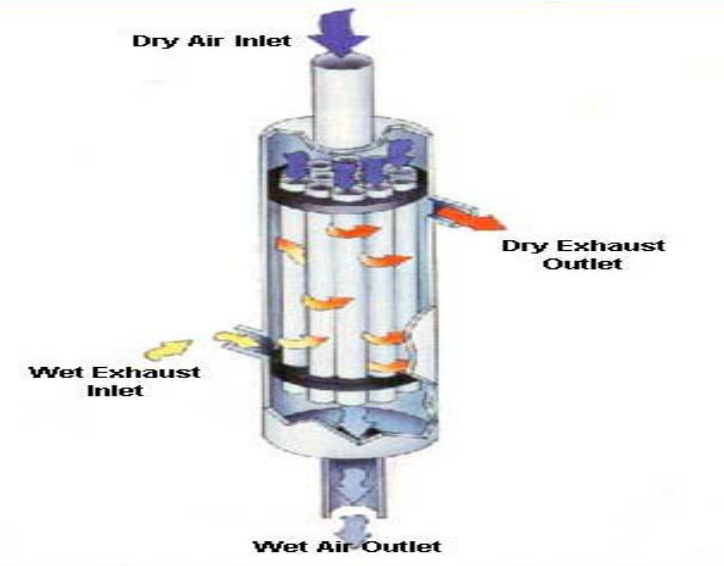
Supplied by Emprise, Kennesaw, GA

- Water adsorbed and de-sorbed in a rotating wheel
- Not sensitive to temperature
- 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®



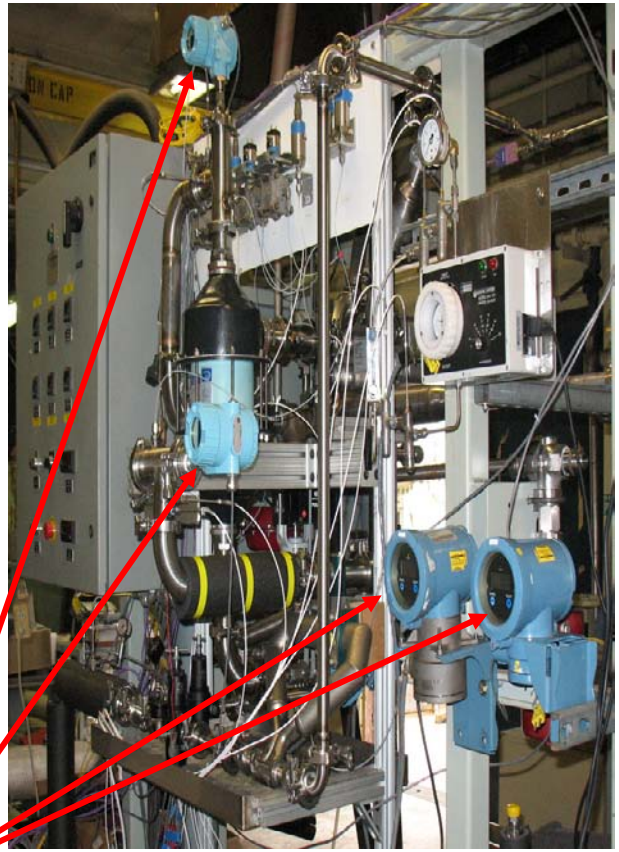
Full-scale

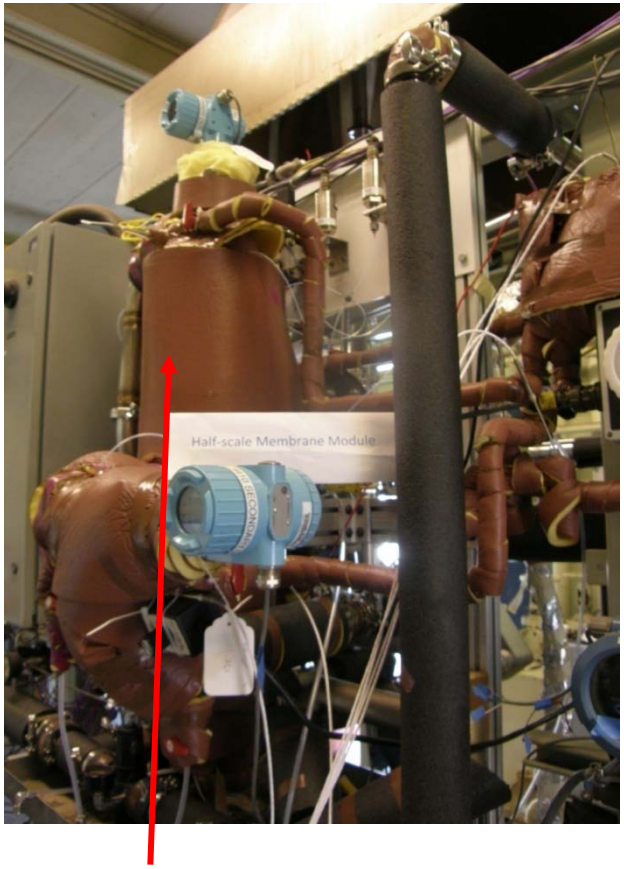
Planar Membrane Humidifier

- Supplied by dpoint Technologies Inc., Vancouver Canada
- Gore membrane selectively allows water to pass through
- Performance sensitive to temperature
- Planar humidifier has advantage in manufacturing cost and installation over circular unit
- Max operating temp. 176°F (80°C), pressure of 35 psi & flow 12 lb/min
- Size 11.5″ length, 9.3″ width, and 5.4″ height

Humidification Test Stand

- Test stand was used for performance testing of half and full- scale humidification system testing
- The test stand is being modified for reliability testing of select humidification systems

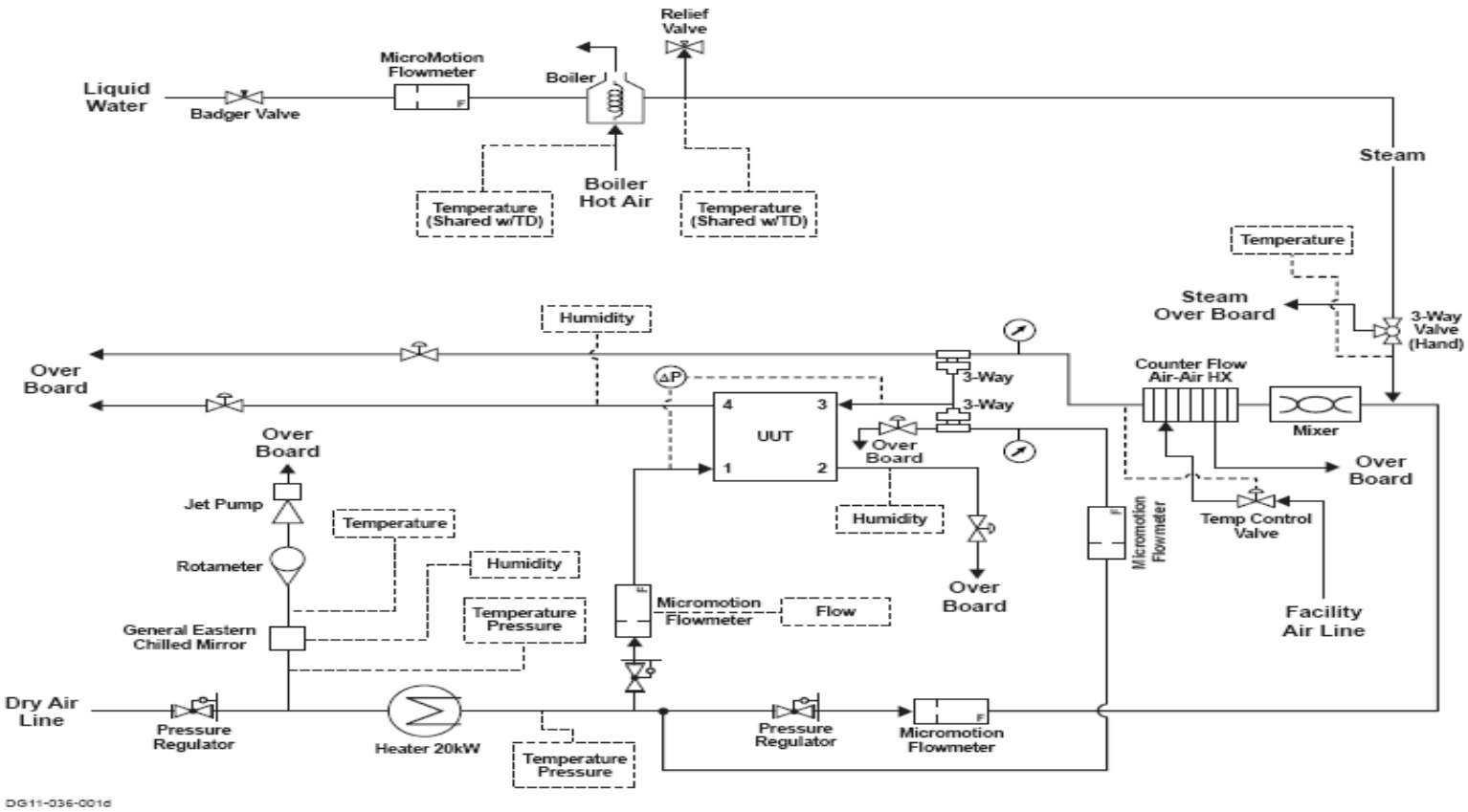




Humidity Sensors

Sub-scale membrane module under test

Humidity Systems Test Stand Schematics



Nomenclature

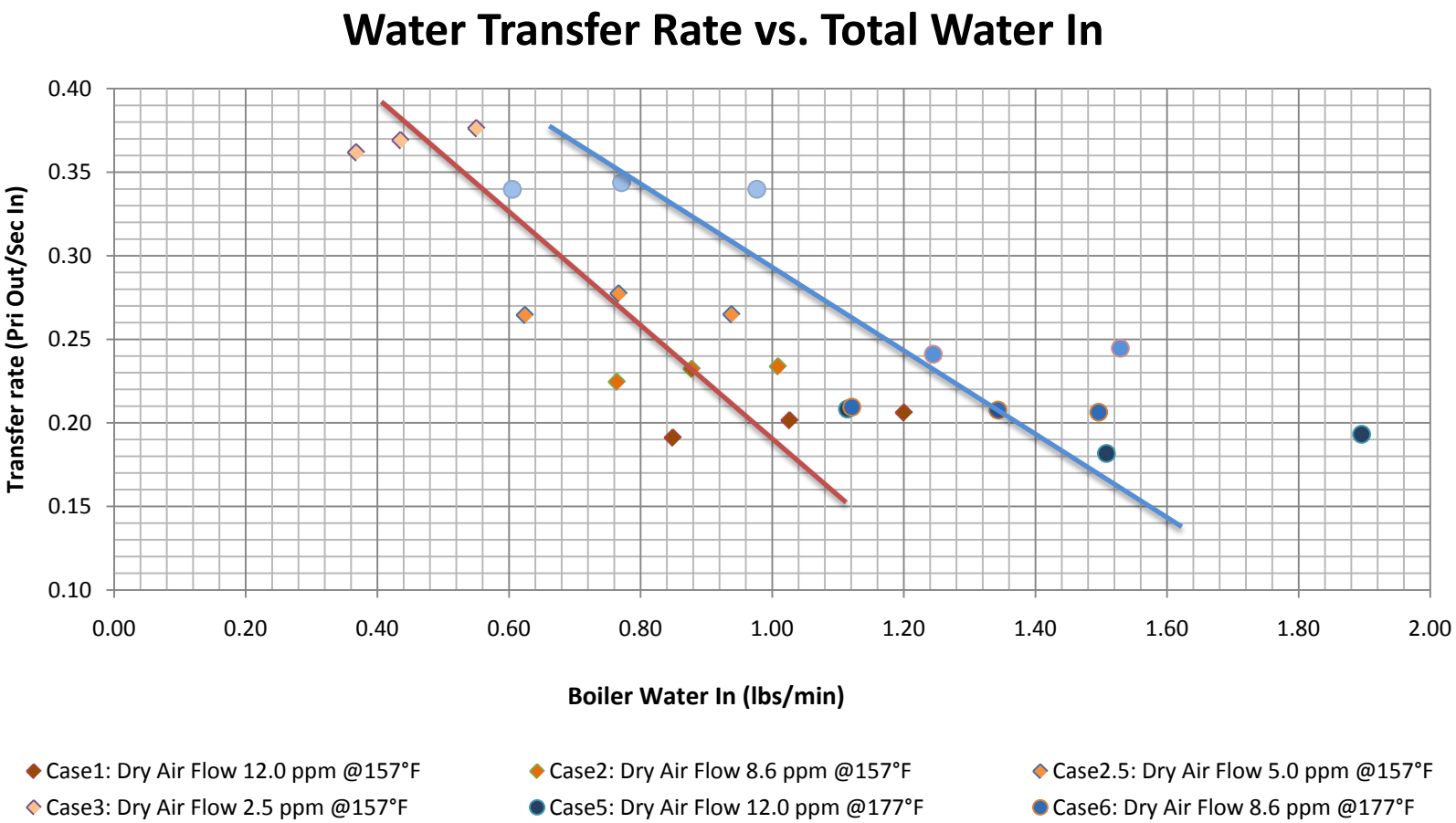
Ppm: Pounds/minute; **RPM:** Revolution per minute

Pri Out: Air stream (2) from humidifier to fuel cell;

UUT: Unit under test

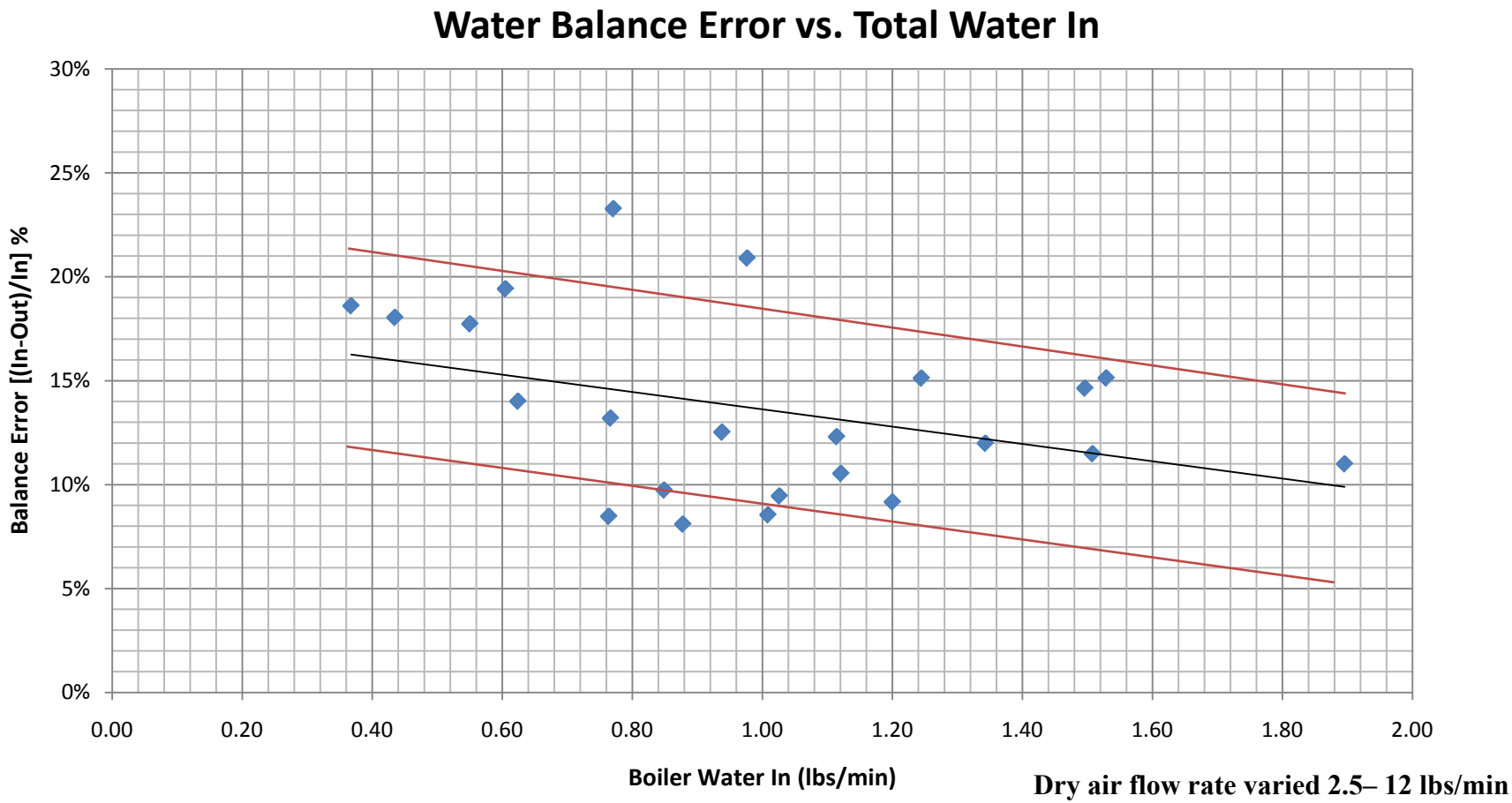
Sec In: Air stream (3) to humidifier from fuel cell

Planar Membrane Module



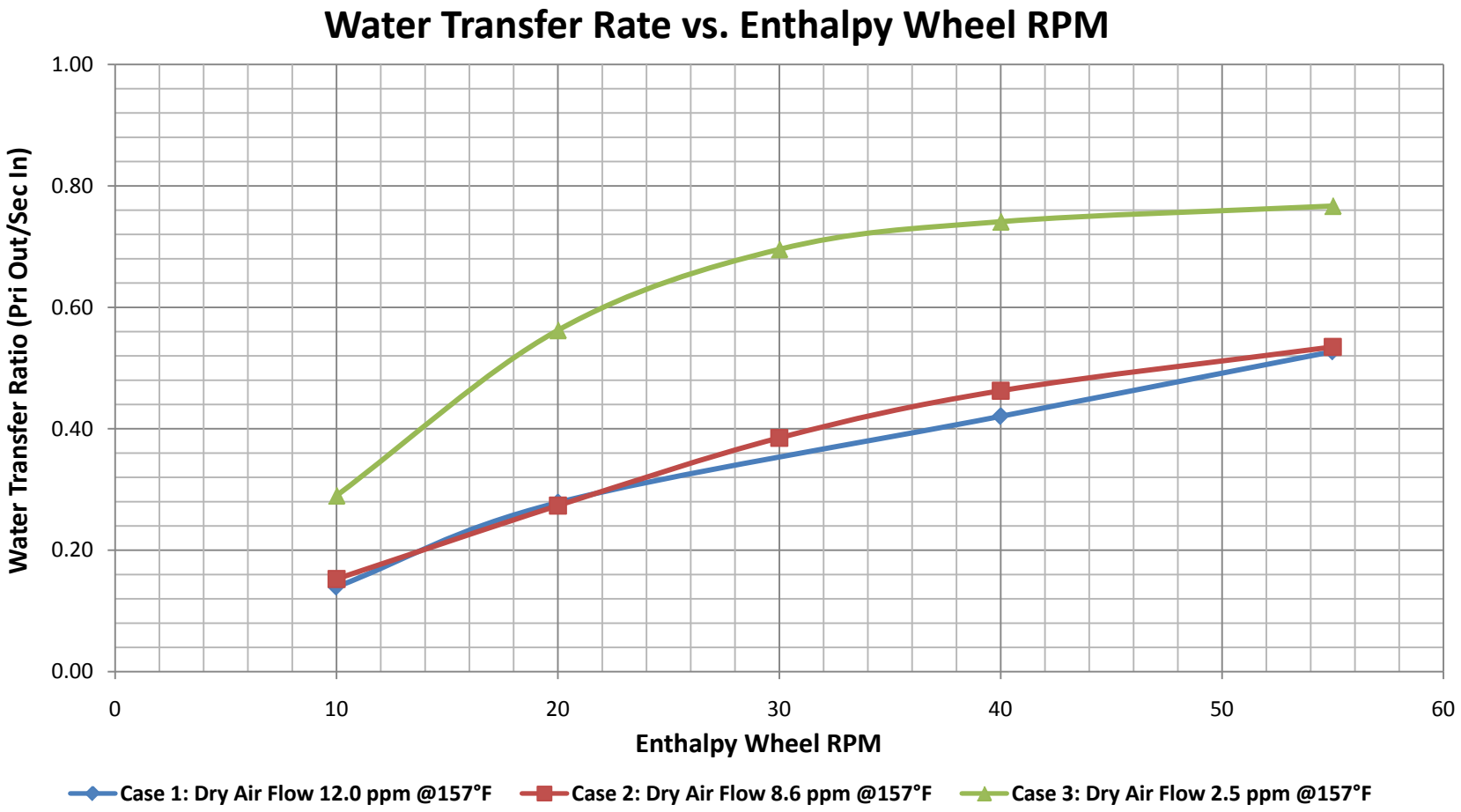
Planar membrane water transfer rate is between 20-37%

Planar Membrane Module



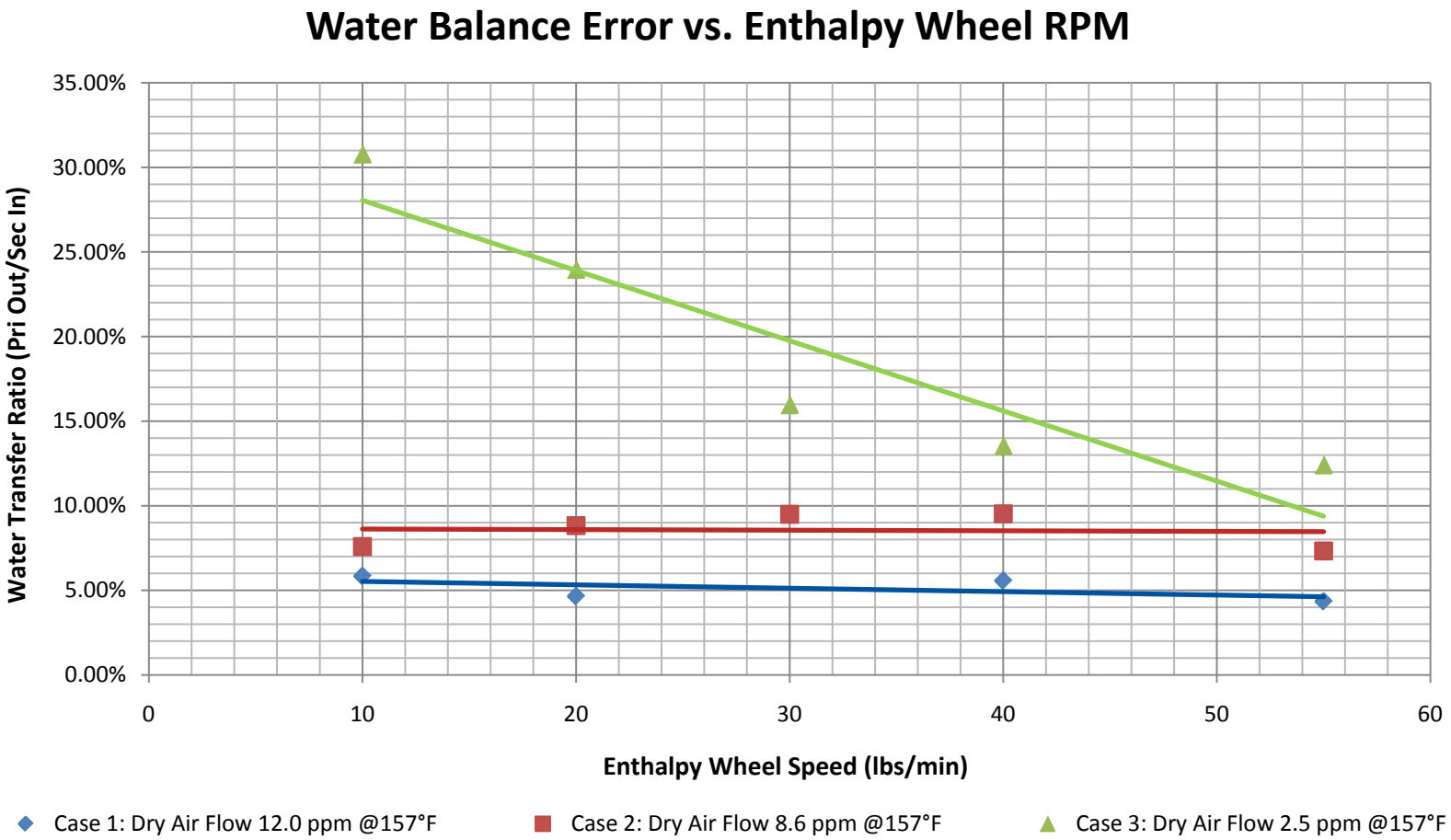
Planar membrane average water balance error is about 15%

Enthalpy Wheel Module



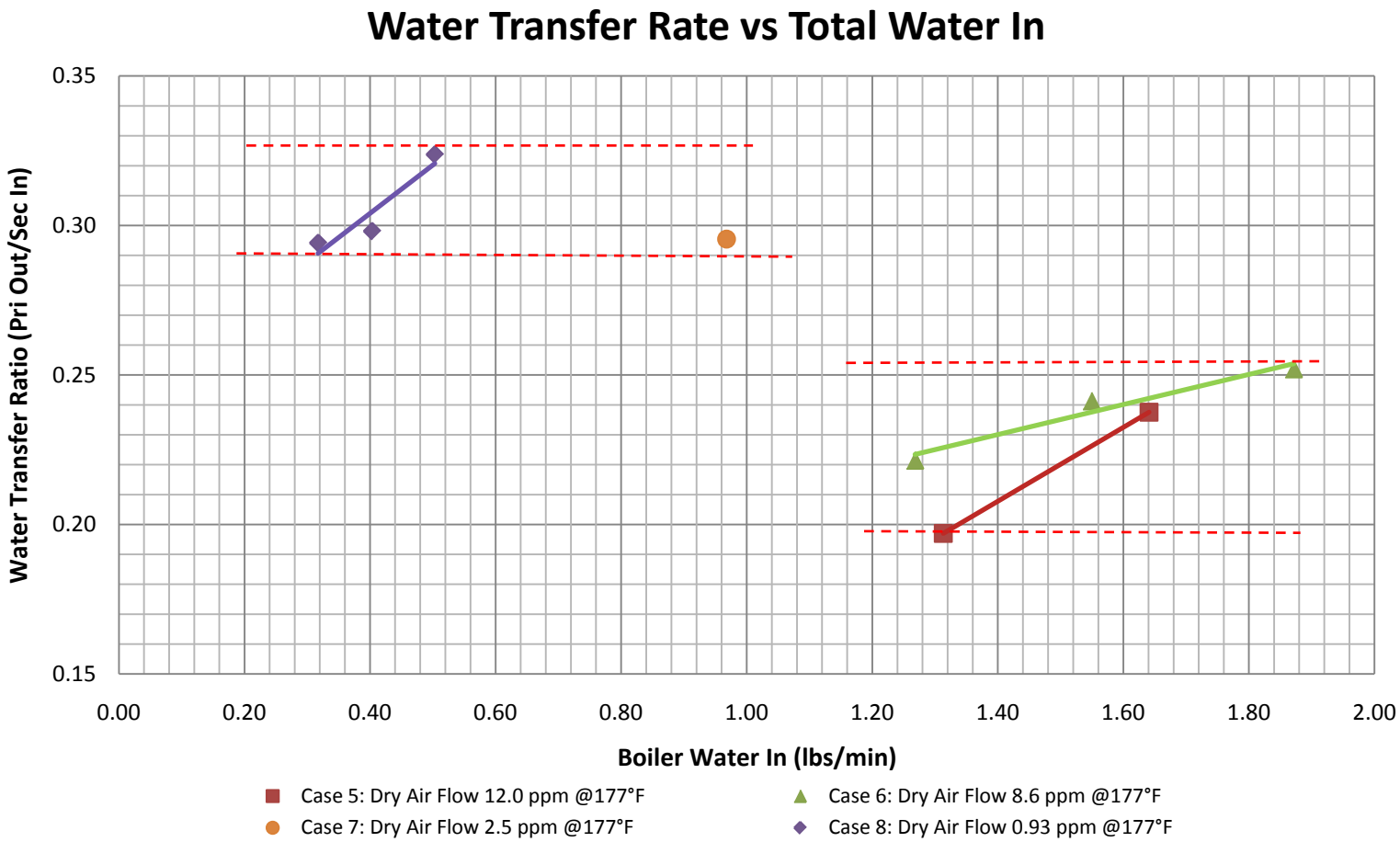
Enthalpy wheel module water transfer rate reaches 70+% with 30+RPM at low flow rate

Enthalpy Wheel Module



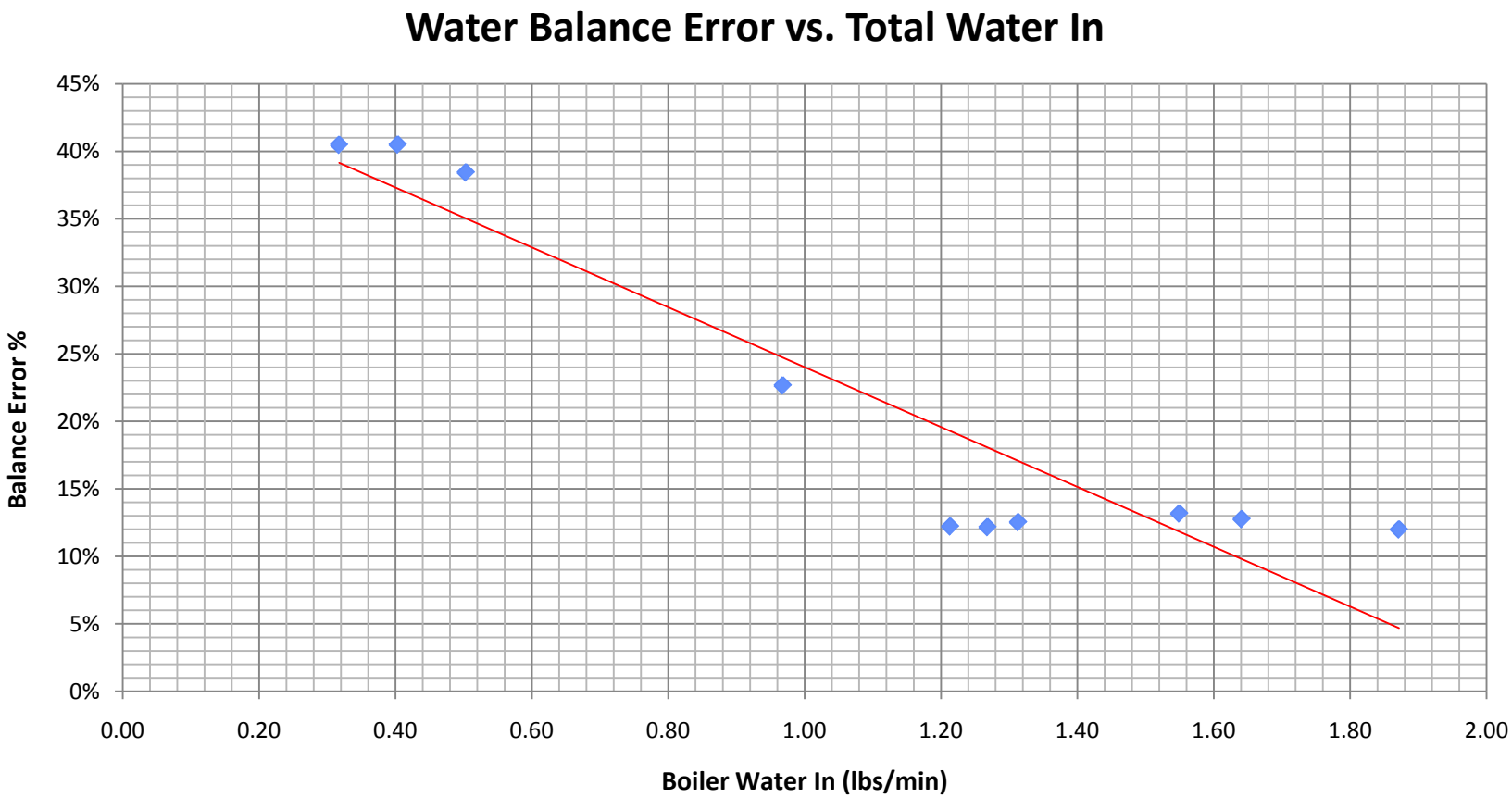
Higher Flow and Speed (rpm), Less Water Balance Error

Full Scale Membrane Module



Full scale membrane module water transfer rate is between 20-33%

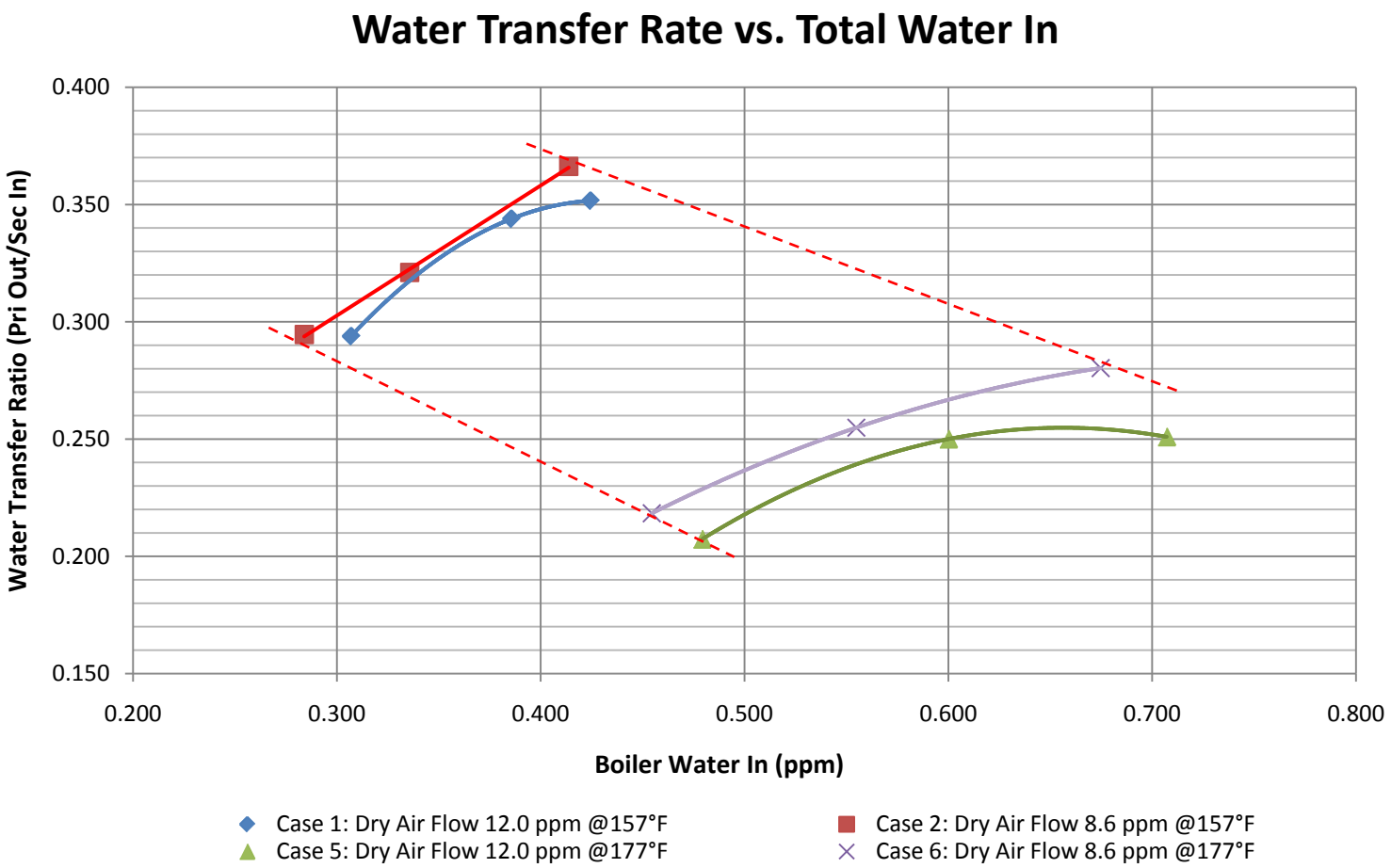
Full Scale Membrane Module



Dry air flow rate varied from 0.9 – 12 lbs/min

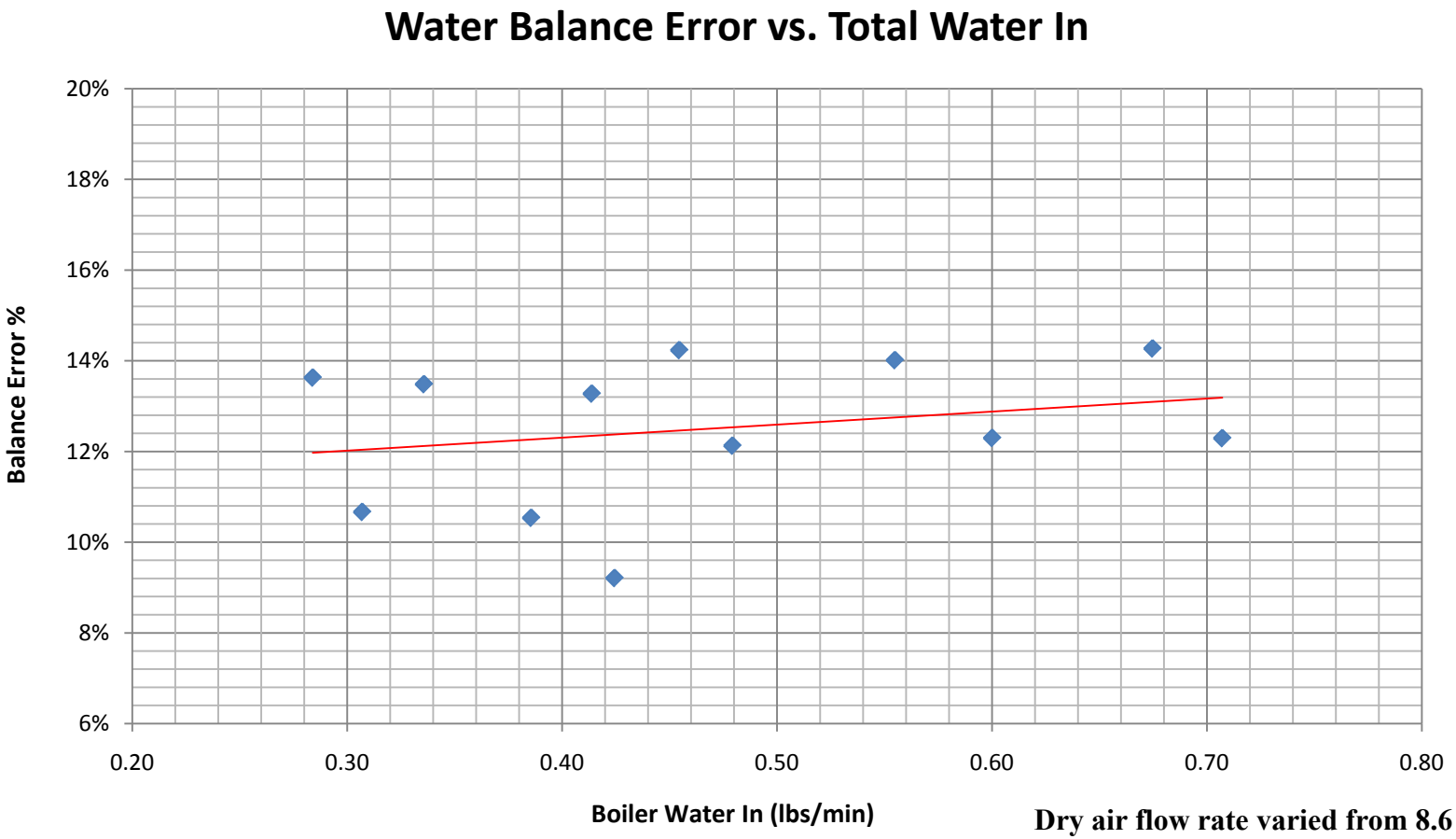
Higher Flow , Less Water Balance Error

Subscale Membrane Module



Subscale membrane module water transfer rate is between 20-37%

Subscale Membrane Module



Dry air flow rate varied from 8.6 – 12 lbs/min

For high flow cases (8-12ppm), water balance errors are 12-15%

Humidification Systems Test Results Summary

- Planar Membrane Module
  - Average water balance error for all the test points was 15%
  - Water transfer rate for the entire air flow range was between 20-37% vs. 60% requirement
- Enthalpy Wheel
  - Water balance errors for all test points were under 15% except at high flow rate with low speed
  - Water transfer rate at high air flow rate met the requirement of 60%
- Full Scale Membrane Module
  - Water balance error at high flow rate was 10-15%, however, at low flow rate the balance was poor
  - Water transfer was between 20-33% similar to other membrane modules
- Sub Scale Membrane Module
  - Average water balance error was 13%
  - Water transfer rate for the entire air flow range was between 20-37%

Enthalpy Wheel performance was better than membrane humidifiers

Thermal Management Program Summary

- Four sub-scale radiators with different fins configuration were built and tested
- Performance model validated, manufacturability lesson learned and documented
- 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 by Honeywell compared well with independent consultant estimates ($50 vs. $58)
- Submitted radiators final test report

Thermal Management program was successfully completed

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

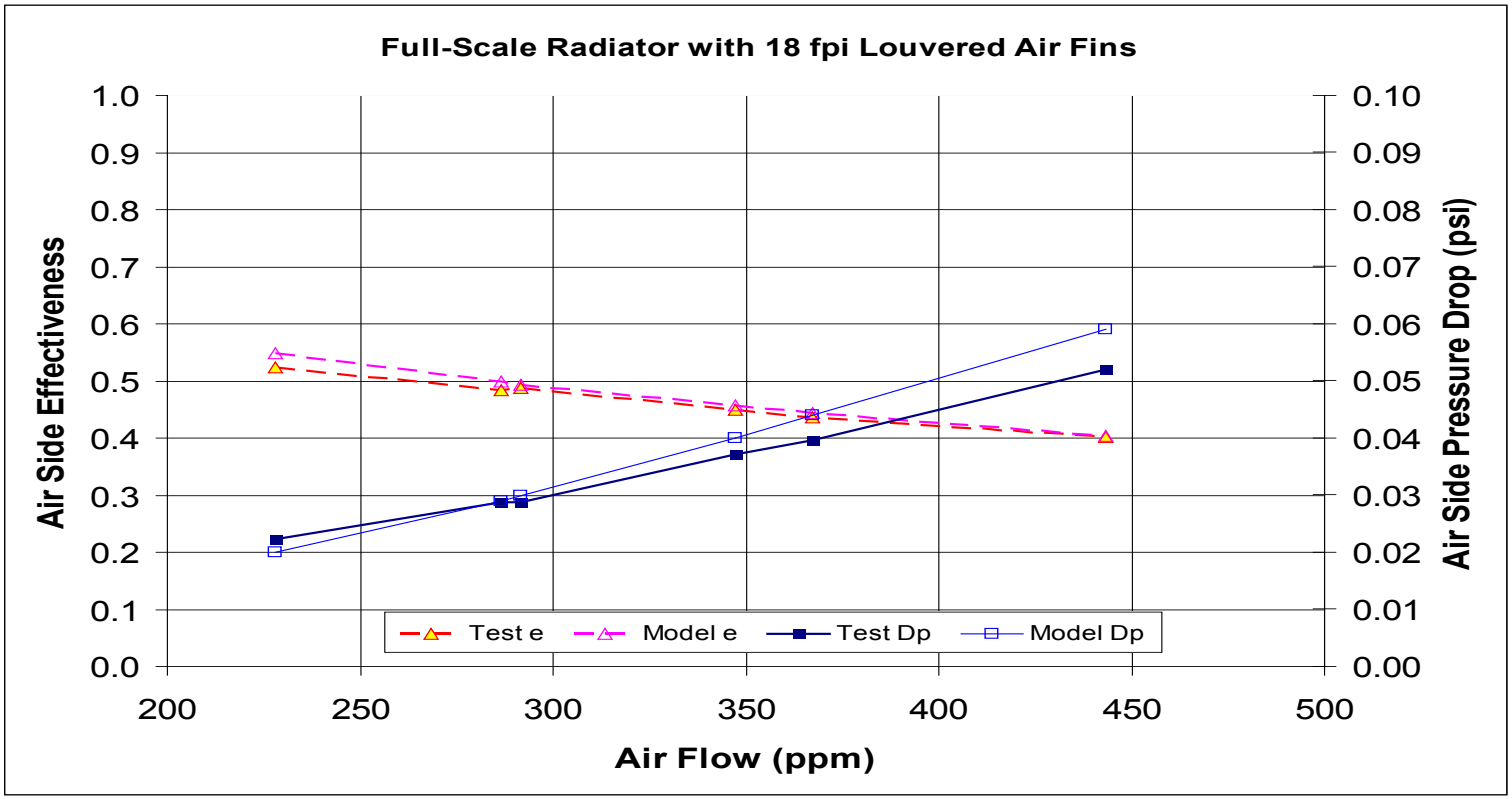
Radiator Test Set-up

Radiator Instrumented

Coolant Circulating Cart

Full-Scale Advance Louver Fin Radiator Performance

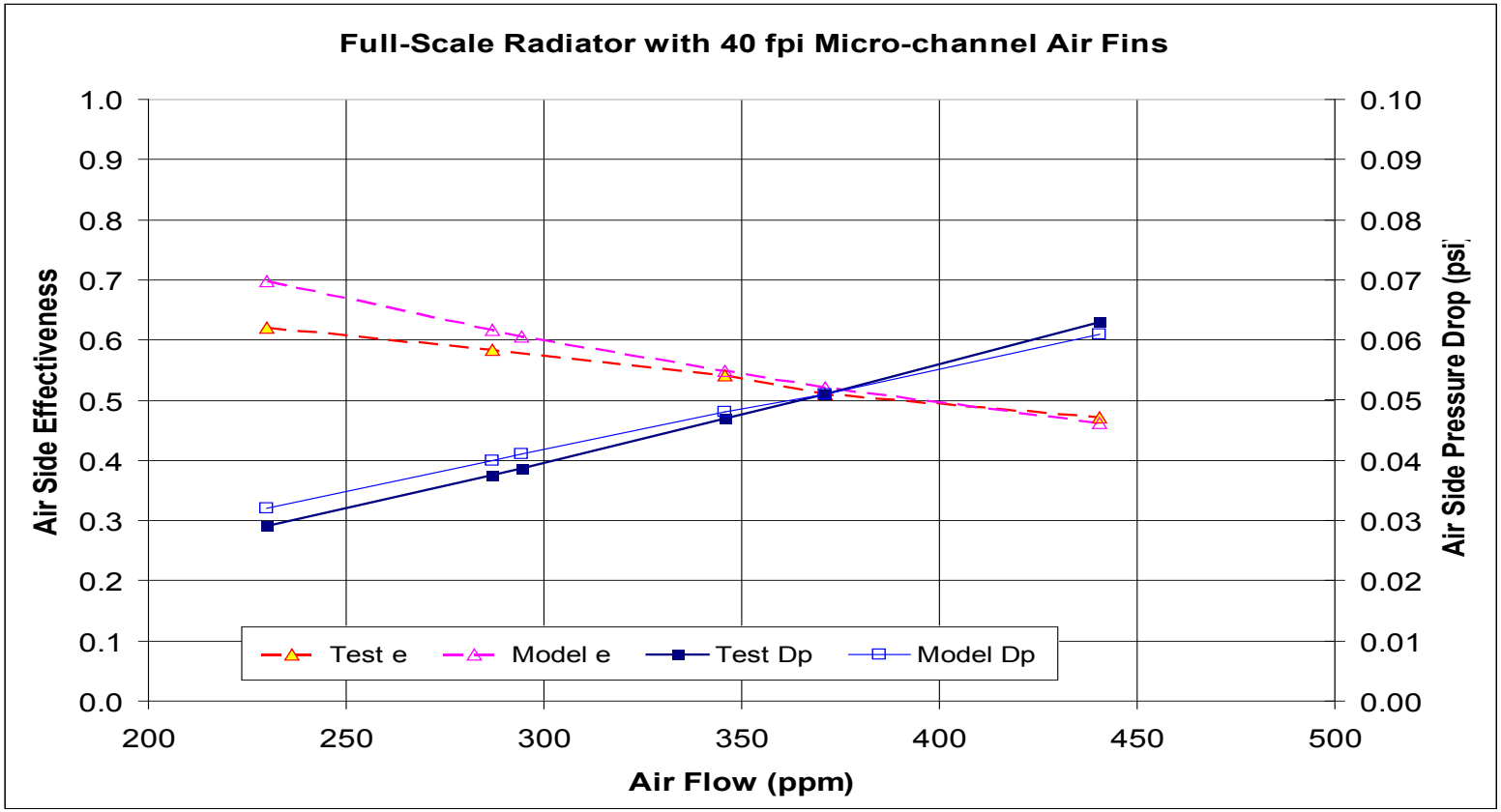
The water-glycol circulating rate 2.25 kg/sec (maximum allowable 2.5 kg/sec.)



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

Full-Scale Microchannel Fin Radiator Performance

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*
  - Coordination of all technical activities including requirements definition, technical data interchange, and support to overall PEM Fuel Cell model development

Federal Laboratory

- *FreedomCAR Tech Team*
  - Participate in program reviews
  -

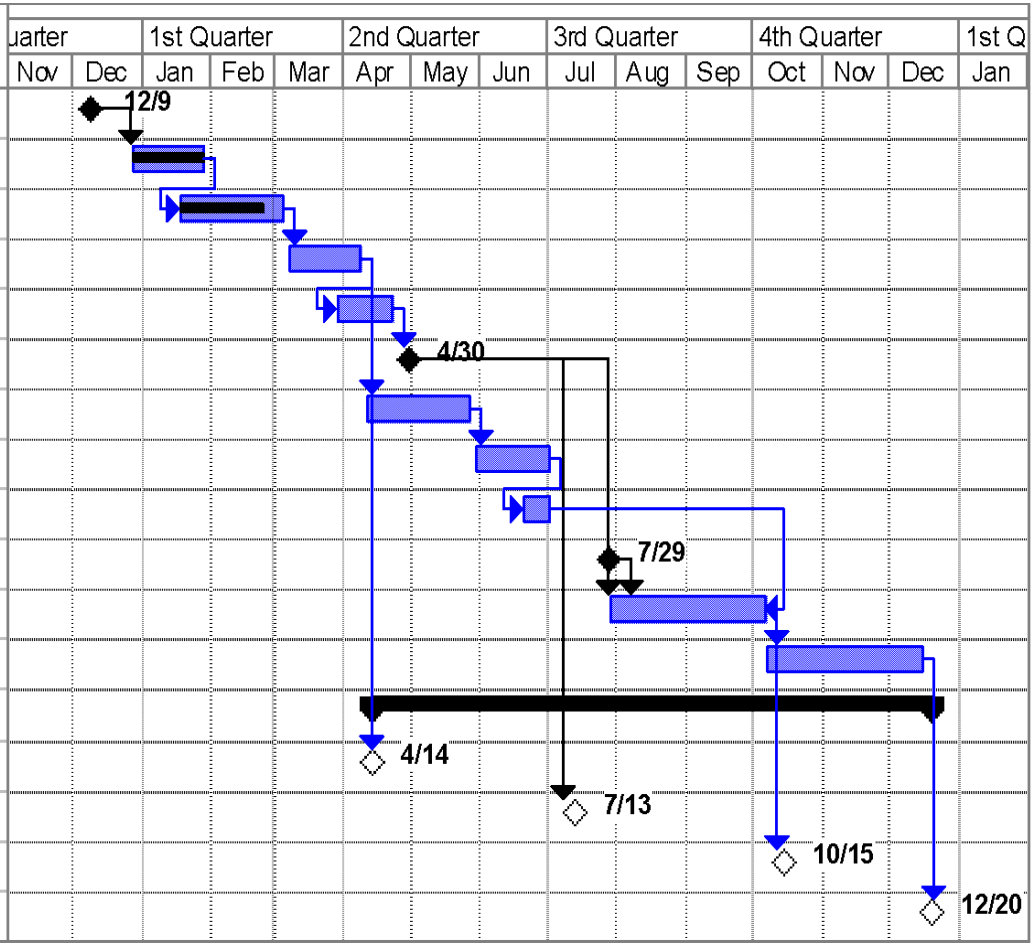
US Council for Automotive Research

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

Industry

FY11/12 Schedule and Major Milestones

ID		Task Name
1	✓	Go-forward plan approval
2	✓	Finalize Test Plan with ANL
3		Modify Test Stand
4		Testing of Humidifier 1
5		Data Analysis
6		Testing of Humidifier 1 complete
7		Modify Test Stand
8		Testing of Humidifier 1
9		Data Analysis
10		Testing of Humidifier 2
11		Program Final Report Draft
12		Incorporate DOE comments
13		**Data Items**
14		First Quarterly Report
15		Second Quarterly Report
16		Third Quarterly Report
17		Final Report submittal



Go-Forward Plan

FY 2011/12

- Test humidification systems for reliability
  - Modify the test stand for reliability testing
  - System will be tested for 5,000 cycles at full scale fuel cell operating conditions
  - The humidity will be cycled from 0 to 80% at 2 minutes intervals
- Submit program final report