DOE Hydrogen Program

Development of Thermal and Water Management System for PEM Fuel Cells

2008 DOE Hydrogen Program
United States Department of Energy

June 12, 2008
08-75191

Crystal Gateway Marriot
Arlington, Virginia

Project ID# FC 37

Honeywell

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Honeywell Attendees

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Agenda

- Overview
- Program Status
- Objectives
- Approach
- Test Results Summary
- Milestones
- Go-forward Plan

Overview

Timeline

- Project start FY03
- Program stopped FY05/FY06
- PO end date April 2009
- 70% complete

Budget

- Total project funding
  - DOE share - 3,250K
  - Honeywell - $812K
- DOE funding in FY 2003/04
  - $1,530K
- DOE funding in FY07
  - $372K
- DOE funding for FY08
  - $400K

Barriers

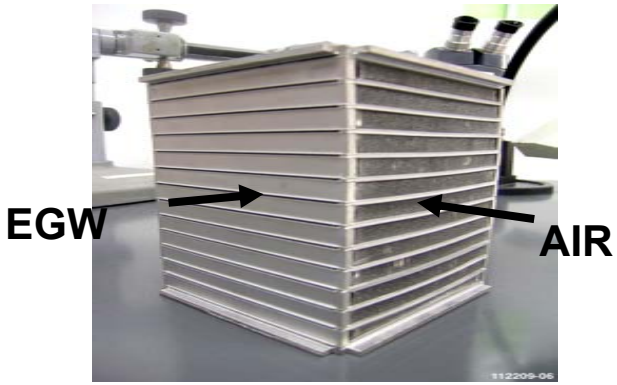
- Performance of select full scale humidification system
- Thermal performance of advance radiators to meet fuel cell cooling requirements

Partners

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

Thermal & Water Management Program Status

- DOE funding was stopped for FY 05/06
- Water management task was selected for FY 07 due to limited funding followed by thermal management
- Accomplishments during FY2003/04
  - Develop humidification and cooling system for 80 kW fuel cell for transportation
  - Performed system concept analysis
  - Radiator trade studies showed potential for improvements in current technology
  - Microchannel and advance louver heat exchanger were down selected
  - Preliminary Design & analysis completed
  - Short stack microchannel heat exchanger was fabricated



Objectives for FY 2007/2008

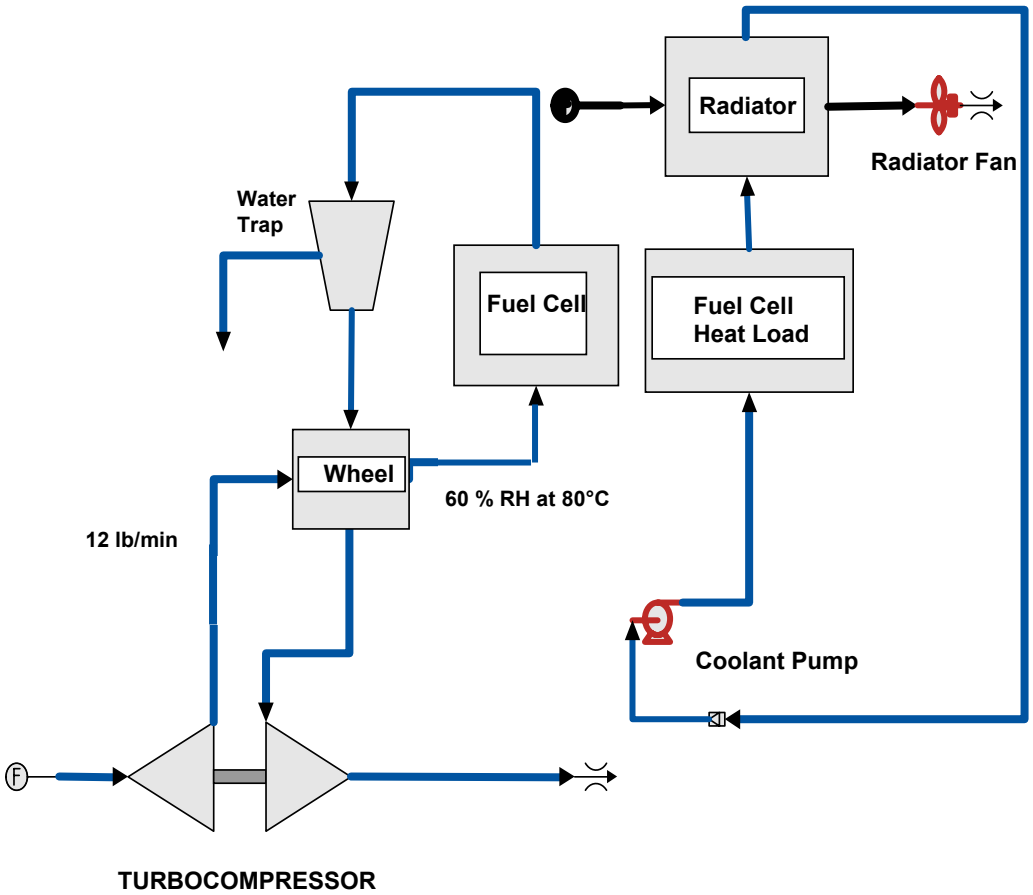
- Validate performance of full scale humidification devices sized for 80 kW fuel cell
  - Install, hook-up and checkout test stand
  - Test Emprise enthalpy wheel
  - Test Perma Pure membrane module
- To improve PEM fuel cell performance and life, the humidity of inlet air stream should be maintained at a high level (currently 60%)
- Design a full size radiator to meet the 80 kW fuel cell cooling requirements

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 precooler in the inlet air stream
- Small scale systems met the requirements
- Full scale system testing is 80% complete
  - Enthalpy wheel seal leakage of up to 18% was observed at high operating pressures
  - Membrane module performance degraded at lower air flow rate

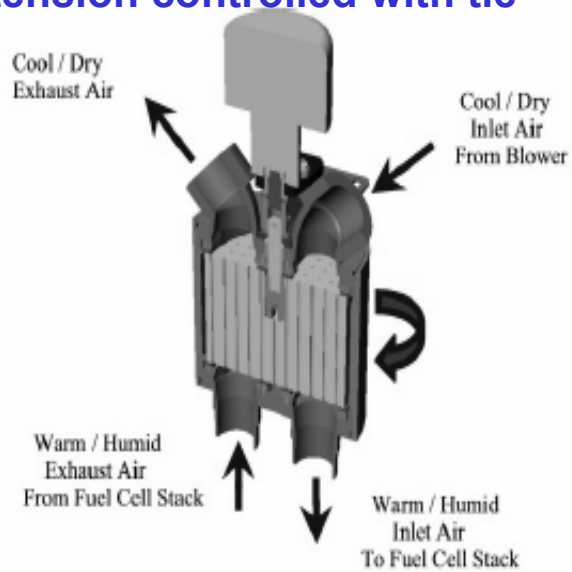
System Approach I (Enthalpy Wheel)

Test Schematic



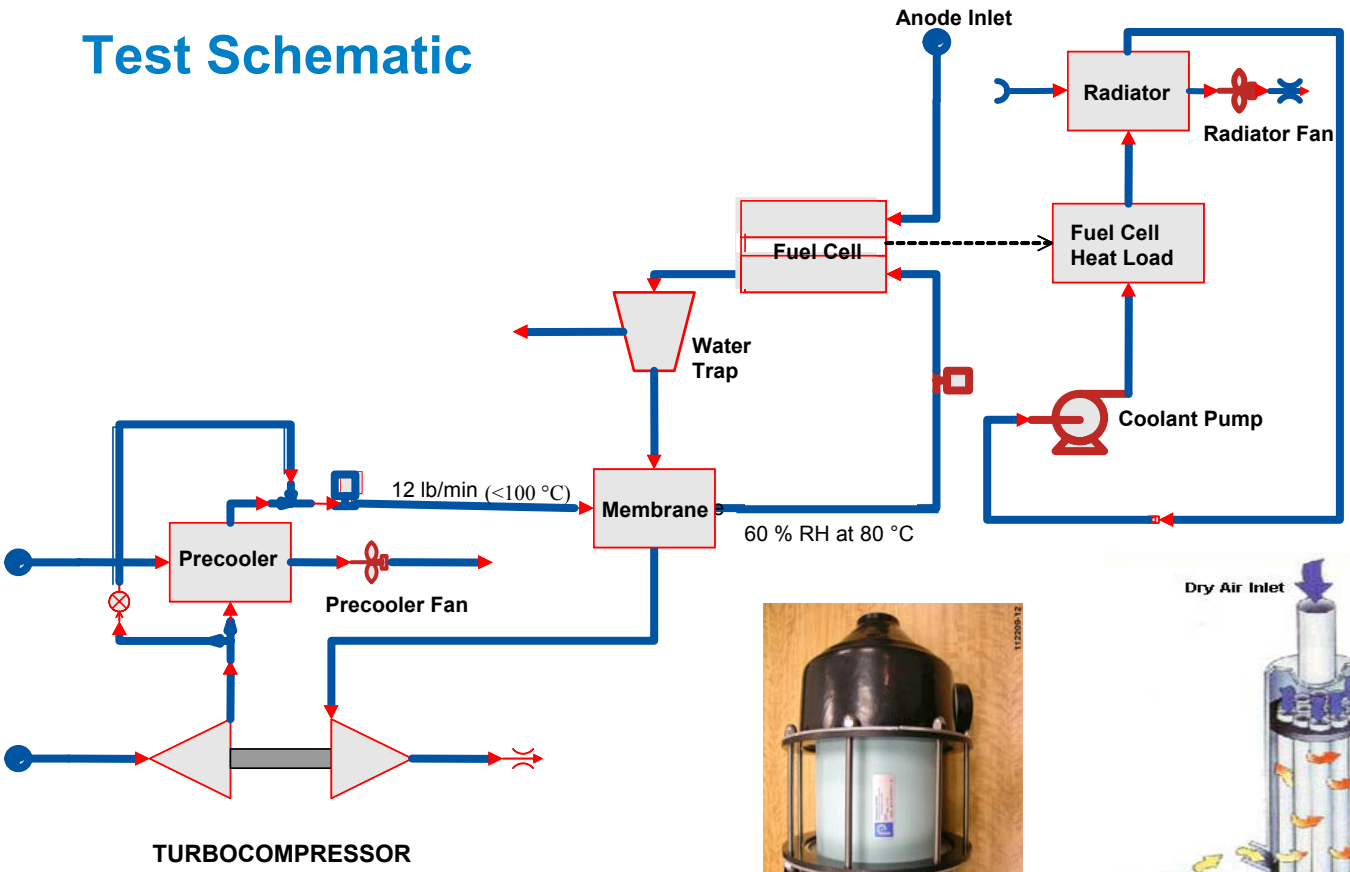
Enthalpy Wheel By Emprise

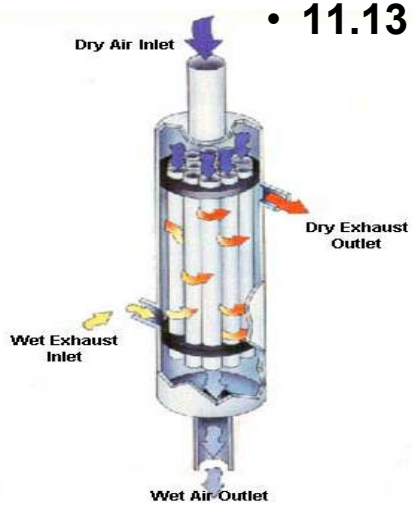
- Water adsorbed and de-sorbed in a rotating wheel
- Power: < 100W
- Leakage < 1% process flow
- 8” Ø, 6” length wheel
- Vol: 17l cu in.; Wt: 17 kg
- Anodized Al construction
- Seal tension controlled with tie rods



System Approach II (Membrane Module)

Test Schematic

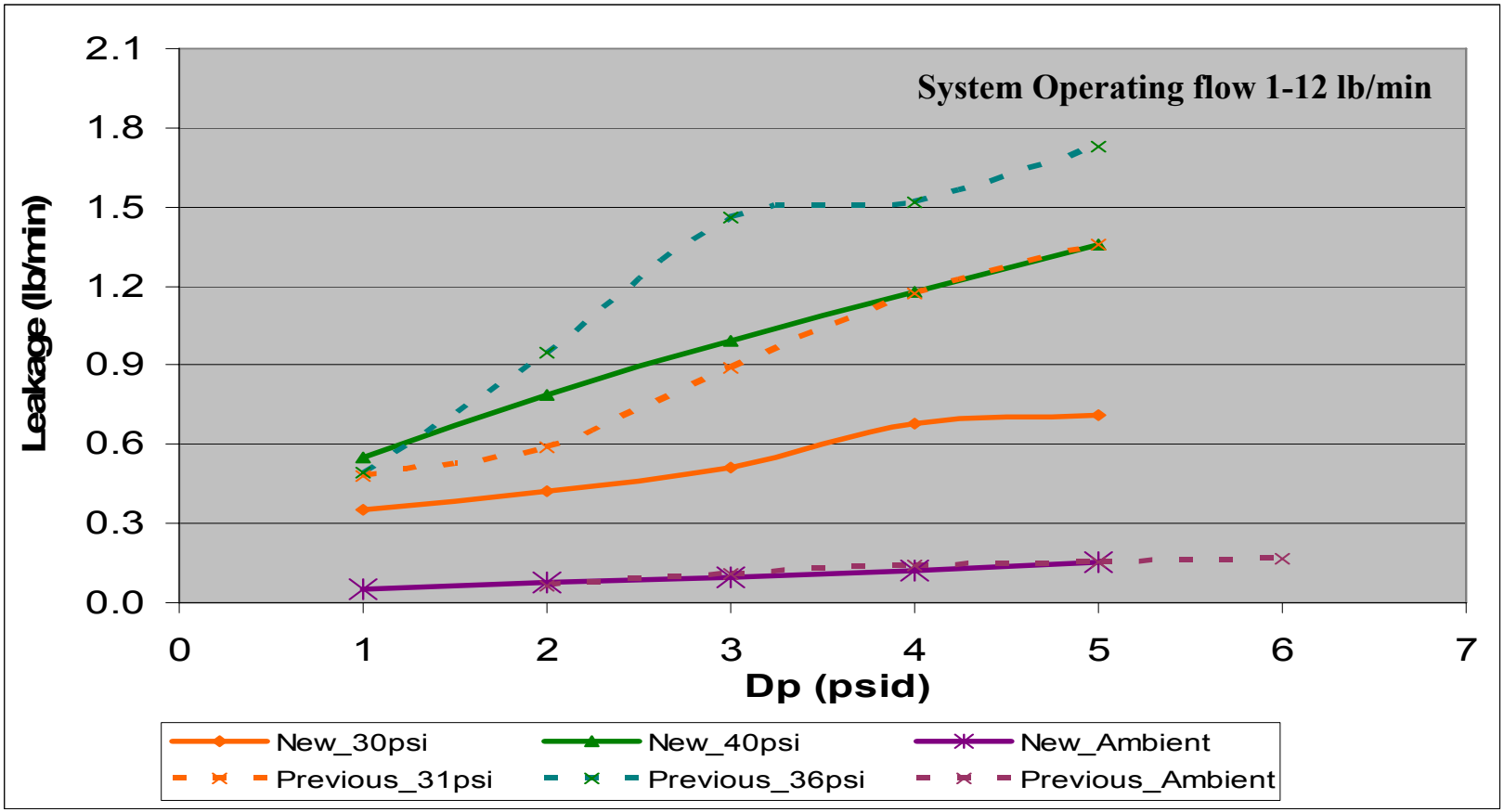




Membrane dryer by Perma Pure

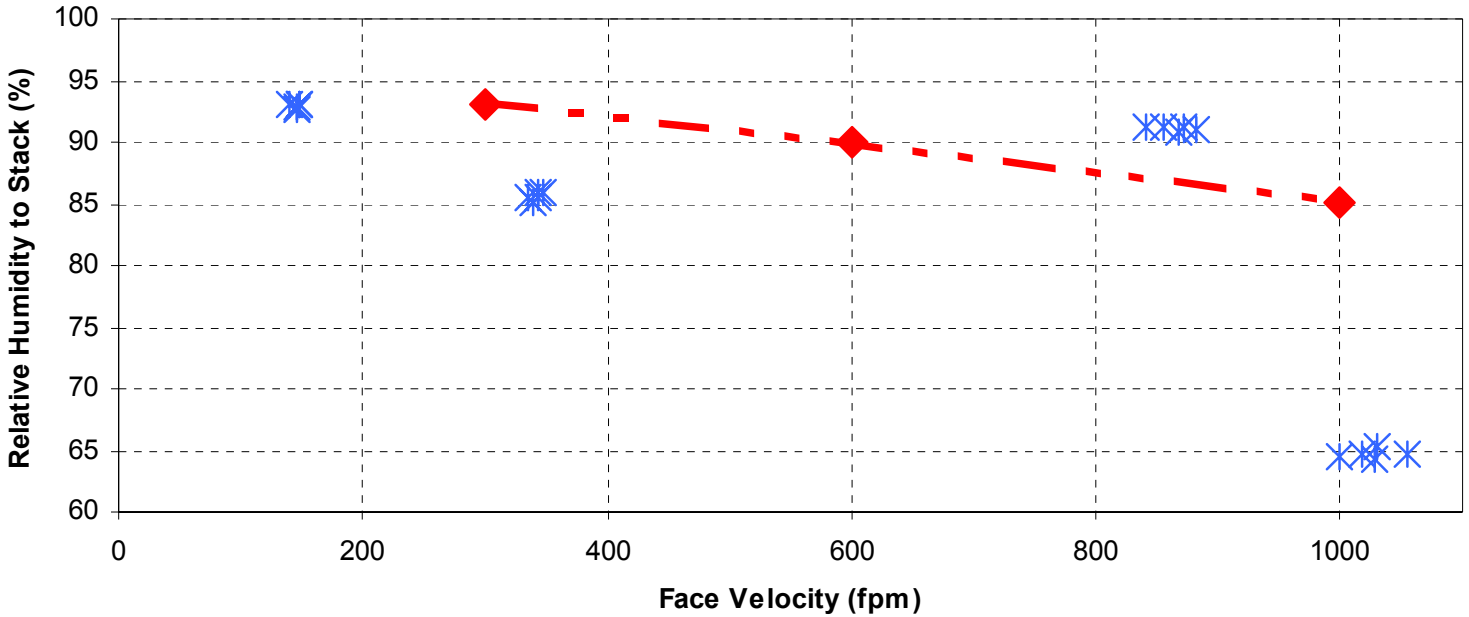
- Membrane selectively allow water to pass through
- Performance sensitive to temp.
- 6” Ø, 10” length cartridge
- 7000 fibers 0.045” OD
- 11.13 in^2 Nafion

Enthalpy Wheel Seal Leakage



High Seal Leakage at higher operating pressures

Enthalpy Wheel: Humidification

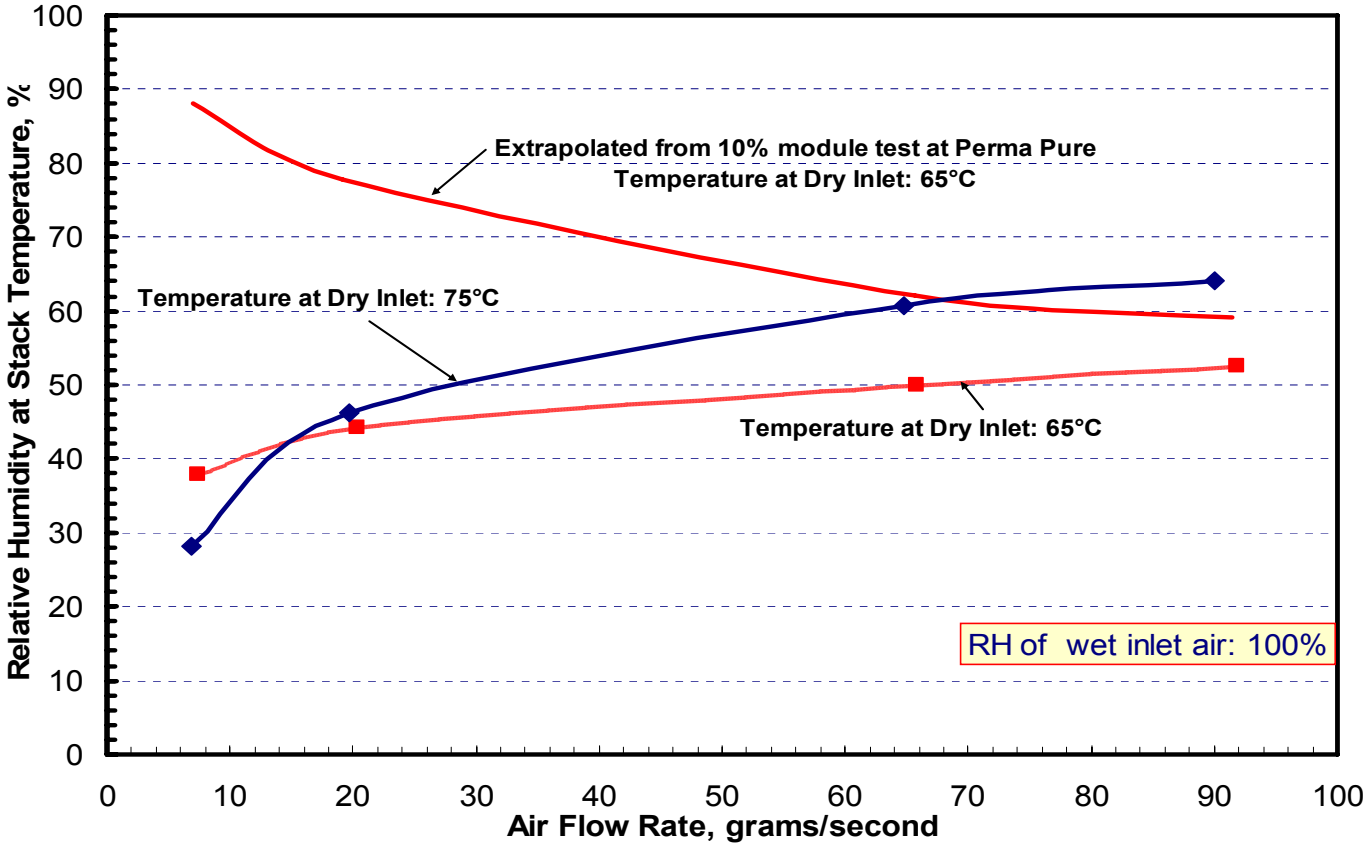


◆ 10% Sub scaled data by supplier

✳ Full-Scale 45 rpm

High Seal Leakage result in low performance

Membrane: Humidification



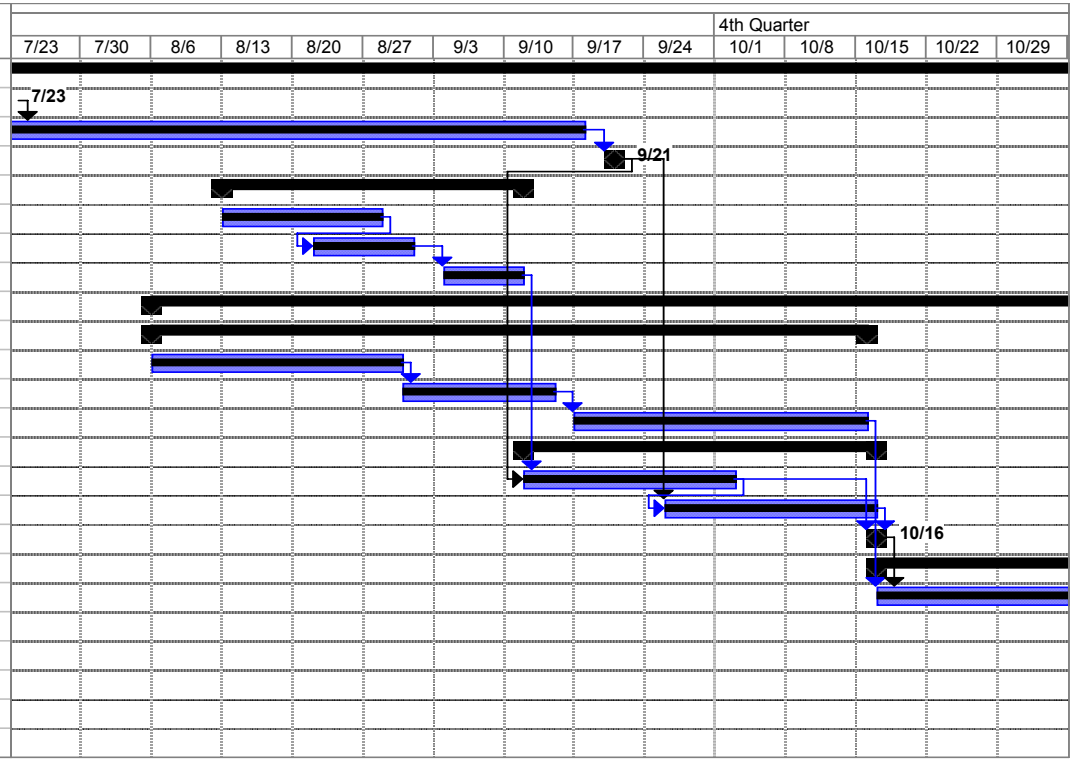
Relative Humidity less than 60% at low face velocity

Test Results Summary

- Enthalpy wheel showed leakage up to 15% across the seal at higher operating flows (pressures)
- Enthalpy wheel humidification data was scattered due to seal leakage
- Membrane module met humidity requirements at high flow rate, at low flow rate the performance degrades due to air bypassing the membrane bundle
- Honeywell is working with manufacturer to improve the performance of the humidification devices
  - Emprise have made some modification which resulted in reduced leakage
  - Plan to test half scale membrane module to validate saturated air by-passing

FY07/08 Schedule and Major Milestones

ID		ID	Task Name
1		1	**DOE PEM Fuel Cell Water Management Program**
2		2	Program Start
3		3	Define requirements
4		4	Kick-Off with DOE
5		5	**Component Modeling/Analysis**
6		6	Enthalpy Wheel
7		7	Membrane Module
8		8	Performance prediction
9		9	**Testing**
10		10	**Test stand Installation in test cell**
11		11	Install Test Stand
12		12	Calibrate instrumentations
13		13	Check out Test Stand
14		14	**Test Plans**
15		15	Enthalpy Wheel
16		16	Membrane Module
17		17	Test Readiness Review
18		18	**Test**
19		19	Enthalpy Wheel
20		20	Membrane Module
21		21	Data Analysis & validation
22		22	Interim Status Reports
23		23	Final Report preparation
24		24	Final report submittal to Customer



Water Management program kickoff	**7/23/07**
Requirements definition	**9/21/07**
Test system set-up	**10/2/07**
Test Readiness Review (TRR)	**10/16/07**
Enthalpy wheel testing	**11/15/07**
Membrane module testing	**12/17/07**
Thermal Management program kickoff	**3/27/08**

Thermal Management Go-Forward Plan

FY 2008

- Complete re-testing of the humidification devices
- Re-visit radiator trade study
- Evaluate performance of advanced radiator technologies
  - Radiator size & weight optimization
  - Parasitic power consumption
  - Manufacturability and cost
- Verify 80 kW PEM Fuel Cell Thermal Management CTQ's
- Radiator Fan and coolant pump
  - Power Optimization
  - Drag needs to be evaluated

FY 2009

- Design, built, and test full scale radiator for select technology
- Validate design and demonstrate performance
- System integration of thermal & water management system