Air, Thermal, and Water Management for PEM Fuel Cell Systems

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Select PEM Fuel Cell Subsystems

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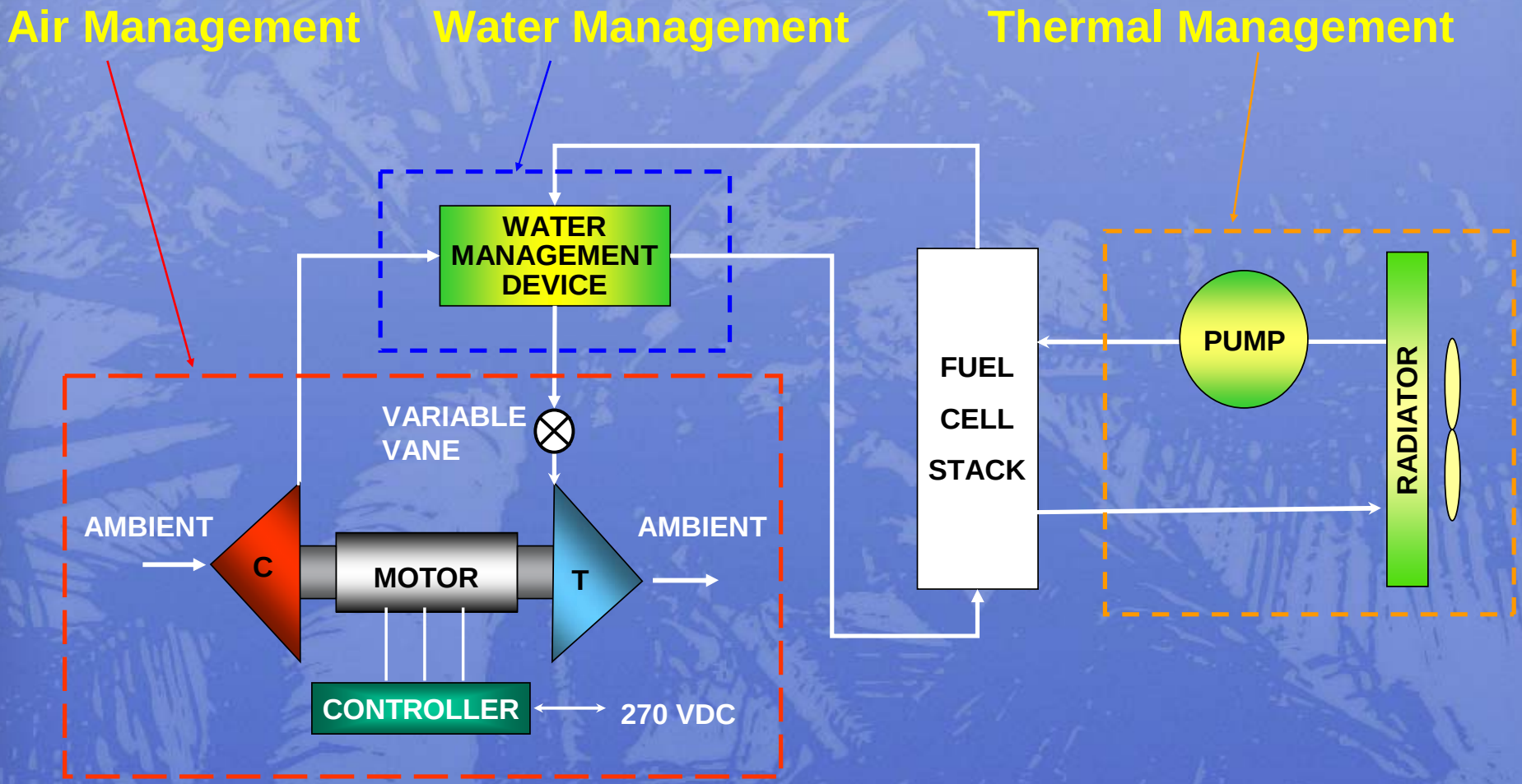

DOE Program Technical Targets

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- Net fuel cell system power: 80 kW
- Mass flow: 100gr/sec @ 2.5 pressure ratio
- Cathode inlet humidity: 60% RH at 80°C
- Anode inlet humidity: Not applicable
- Turbocompressor power consumption: 6kW
- TWM system power consumption: 2.4kW
- Stack heat rejection: 60 kW
- Operating conditions
  - Steady state only
  - Ambient conditions: hot and standard (+40 and +20°C)

Fuel Cell Turbocompressor Concept

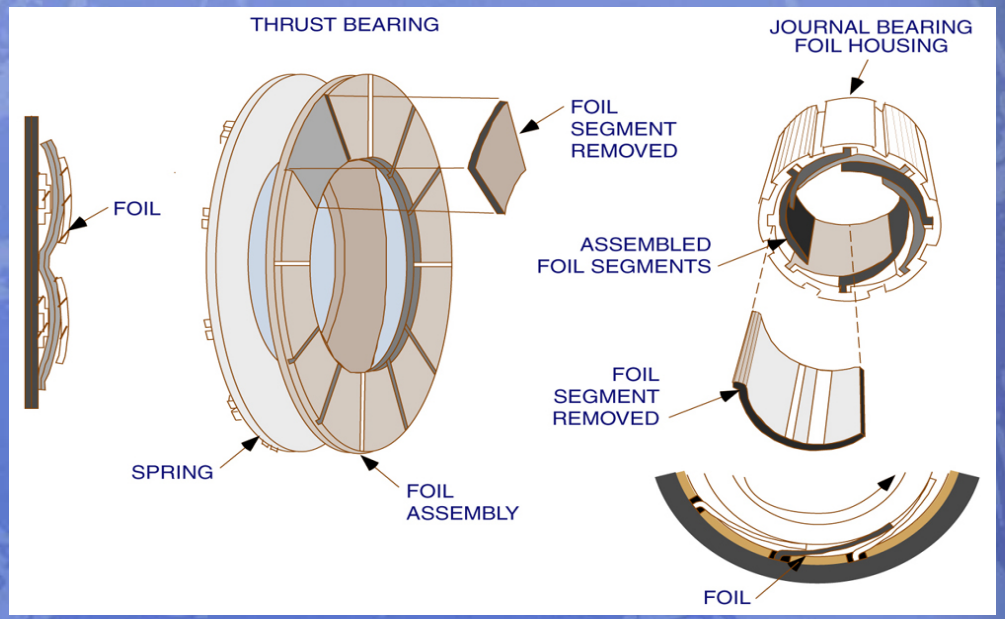
Honeywell

- Contamination free air flow to fuel cell
  - Compliant foil air bearings (no lubricants)
- Low production cost potential
- Zero Maintenance
- Reliable - one moving part
- Lightweight/Compact
- Efficient
- High temperature capable expander/turbine
- Variable geometry turbine maximizes efficiency
- Modular

Foil Air Bearings

Honeywell

- Developed by Honeywell
- Over 30 years of proven performance
- High-speed efficiency
- Compact
- No maintenance
- Up to 80k hours of continuous operation
- 50k start/stops
- Low life-cycle costs



Foil Air Bearing Technology Provides Long Operating Life without Oil Lubrication

Fuel Cell Turbocompressor History

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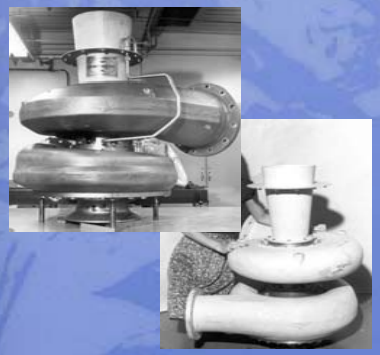
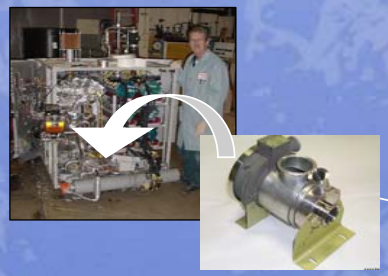


2 Bootstrap Turbocompressors
(Full and Partial Flow Sizes)
TEPCO 5MW
Phosphoric Acid
Fuel Cell Power Plant
1981



Demonstration of Motor Driven
Turbocompressor
w/315degC Temperature Capability
Turbine in
DoE/Honeywell 50kW PEM Fuel Cell
System
2001

Motor Driven Turbocompressor
PEM Fuel Cell System
for Unmanned Aerial Vehicle
2003

Motor Driven Turbocompressor
DoE 50kW PEM Fuel Cell
System
for Light Duty Vehicle
2003

Demonstration of Motor
Driven Turbocompressor
DoE 50kW PEM Fuel Cell System
for Light Duty Vehicle
1997

Demonstration of
Motor Driven Turbocompressor
w/Mixed Flow Compressor and
Variable Nozzle Turbine
DoE 50kW PEM Fuel Cell System
for Light Duty Vehicle
2001

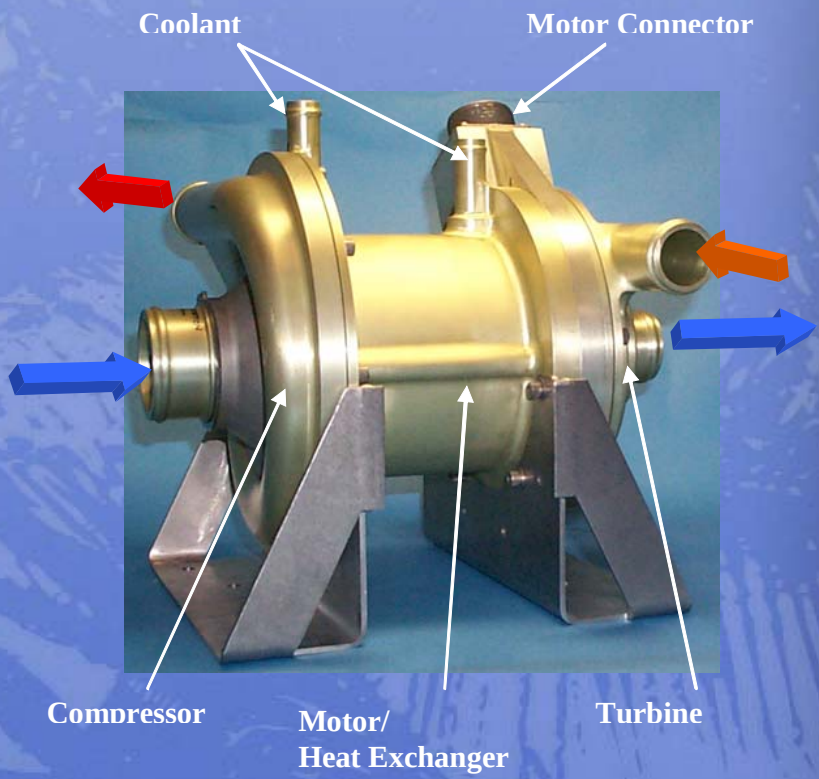
Honeywell is a Leader in Foil Air Bearing Turbomachinery for Fuel Cells

DOE Fuel Cell Turbocompressors

Honeywell

- Enhanced design for 50-80kW systems
- Compliant foil air bearings
- Lightweight/Compact - 15 kg/15 liters
- Reliable - One moving part
- Low production cost potential

	Efficiency (%)	Pressure Ratio	Flowrate (gr/sec)	Power
Compressor	72	2.5	100	
Turbine	80	2.5	100	
With turbine		2.5	100	6kW
Without Turbine		2.5	100	16kW



Water Management – Adsorbent Wheel

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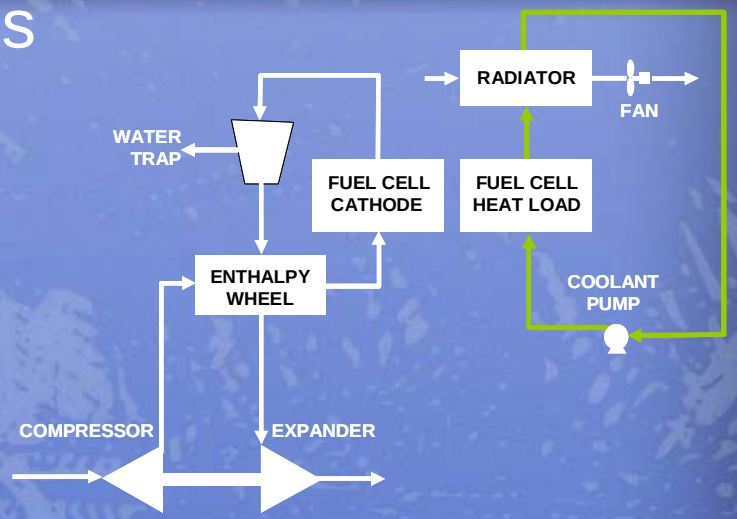
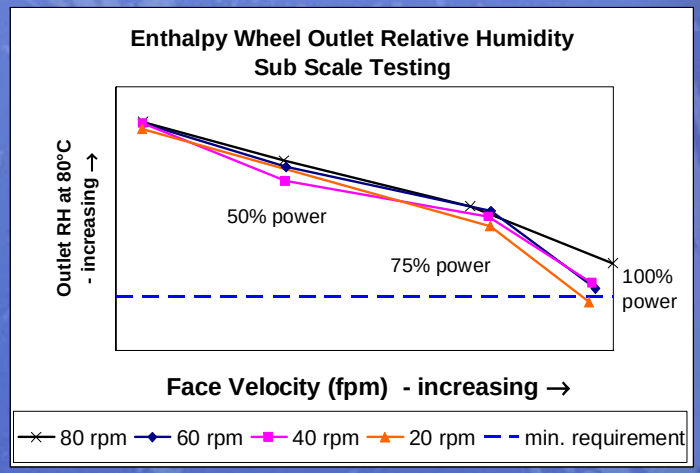
- Detailed system design and specifications
  - Emprise adsorbent wheel used
- Sub-scale component testing
  - Performance strong function of face velocity
  - dP < 7kPa
  - Power: < 100W
  - Leakage < 1% process flow
- Full scale design – Emprise
  - 8” Ø, 7” length wheel
  - vol: 17l; wt: 17kg
  - Anodized Al construction
  - Seal tension controlled with tie rods

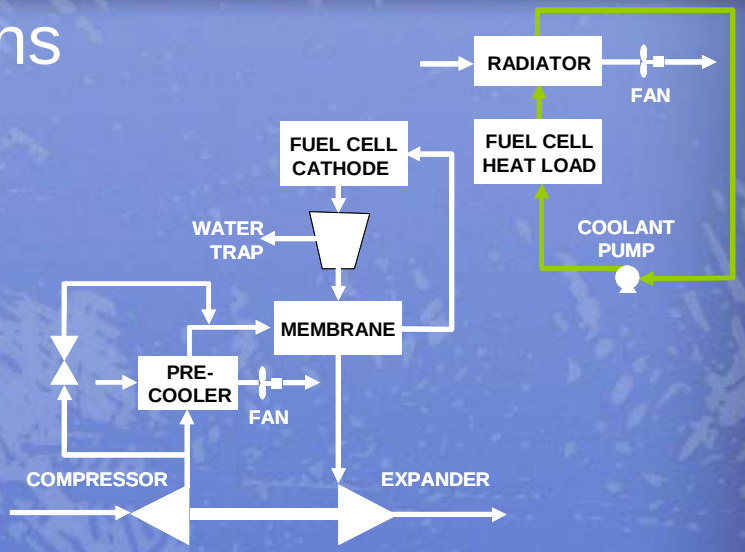


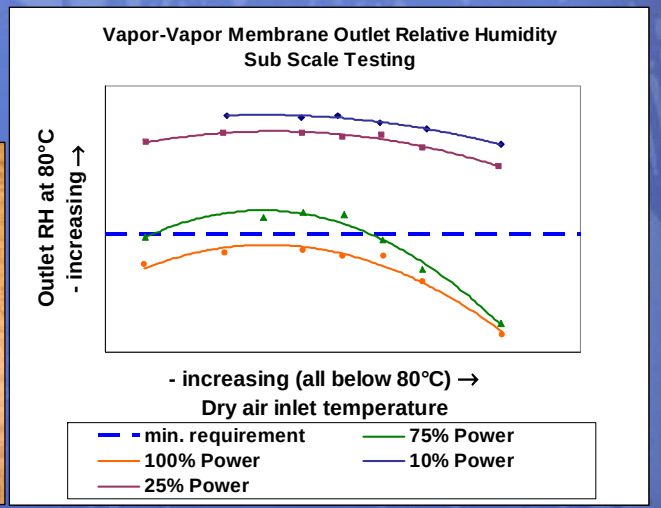


Water Management – Membrane

Honeywell

- Detailed system design and specifications
  - Nafion membrane (Perma Pure)
  - Pre-cooler dP ~ 7kPa
  - Pre-cooler fan pwr: 0.6 kW
- Sub-scale component testing
  - Performance sensitive to temperature
  - Membrane dP ~ 14kPa
- Full scale design – Perma Pure
  - 6” Ø, 10” length cartridge
  - 6.4m^2 Nafion
  - vol: 20l; wt: 6kg





Thermal Management – Trade Study

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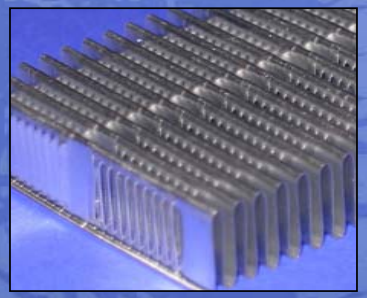
- Analysis of stack waste heat rejection options
- Utilize system weight (wt)
  - System wt = HX wt + fan wt + parasitic pwr/stack specific pwr
  - System level evaluation of HX weight

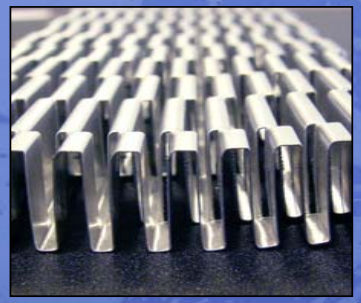
Technologies evaluated

Radiator Trade Study Technology/Design Matrix				
HX Design	**HX Technology**			
	Baseline	**Advanced**	**Microchannel**	**Al Foam**
Aerospace Plate Fin	**Offset fin**	**NA**	**Plain fin**	**20 ppi**
Automotive Tube Fin	**Louver fin**	**Louver fin**	**Plain fin**	**40 ppi**

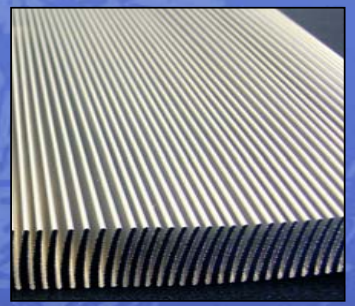
Louver fin



Offset fin



Microchannel fin



Foam

Radiator Trade Study - Results

Honeywell

- Problem Statement
  - 60 kW max steady state heat rejection
  - 6.5% grade at 55 mph w/ 600kg payload
- Results

Heat rejection rate = 60 kW				
Hot flow:	Glycol/water (50/50)			
Flow Rate:	370	lb/min	(2.8 kg/sec)	
Tin:	167	°F	(75 °C)	ΔT: 35 °C
Pin:	50.3	psia		
Cold flow:	Air			
T_in_air:	104	°F	(40 °C)	
P_in_air:	14.7	psia		

	Face Area [cm2]	Thickness [cm]	System weight [kg]	Power [kW]
Automotive Baseline	3,600	3.2	19.4	6.0
Automotive Advanced			17.2	4.1
Automotive Microchannel			14.4	2.1
Automotive Al Foam			11.6	1.7

- ***Al foam shows best performance vs. automotive baseline***
  - ***For same size – 70% system power reduction***
  - ***– 30% system weight reduction***

Validate Thermal Predictions

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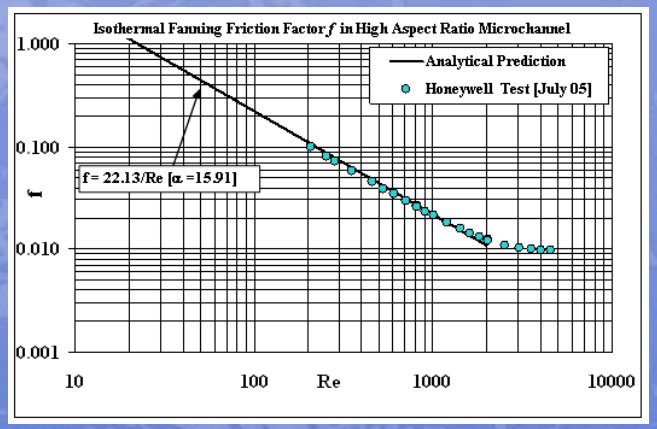
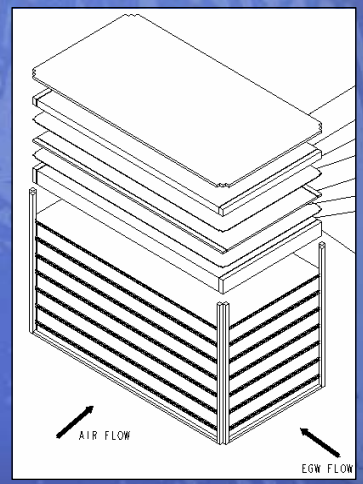
- Microchannel
  - Predictions based on laminar flow theory
  - Fabricate prototype
  - Fin only isothermal pressure drop (f test)
    - Results consistent with analytical predictions



- Aluminum foam
  - Predictions based on published data
    - Kim, et al. *JHT, Transactions ASME*, v 122, n 3, Aug, 2000, p 572-578
  - Fabricate prototype
  - Identified fouling as possible issue



Future Work

- Complete turbocompressor testing – 2006
- Validate humidifier performance – 2006
- Validate heat exchanger performance – 2006
- Build & test a full scale aluminum foam radiator – 2006
- Evaluate aluminum foam manufacturing – 2006
- Demonstrate air, thermal & water management system – 2007

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