



DOE Hydrogen Program

# **Low-Cost Manufacturable Microchannel Systems for Passive PEM Water Management**

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**FCP20**

This presentation does not contain any proprietary, confidential, or otherwise restricted information

# Overview

## Timeline

- ▶ Start – February, 2007
- ▶ End – September, 2008
- ▶ 15% Complete

## Budget

- ▶ \$1000K Total funding
  - DOE share – 100%
  - Contractor share – 0%
- ▶ \$300K FY07 funding

## Collaborations

- ▶ PNNL – PM & technology development
- ▶ ADMA – Manufacturing Support
- ▶ Protonex – Fabrication methods
- ▶ Hydrogenics – Testing Support

## Barriers

- ▶ 3.4 Fuel Cells Barriers
  - B. Cost:
  - E. System Thermal and Water Management
- ▶ Targets
  - 3.4.2 Automotive-Scale: 80 kW<sub>e</sub> Integrated Transportation Fuel Cell Power Systems Operating on Direct Hydrogen

	Target	80 kW <sub>e</sub> System	Water Mgmt Target %
Power Density	650 W <sub>e</sub> /L	123 L	2–7%
Specific Power	650 W <sub>e</sub> /kg	123 kg	2 - 9%
Cost	\$30/kW <sub>e</sub>	\$2400	< 7%

# Objectives

## ▶ OVERALL

- Create a low cost, passive technology for water management in PEM systems

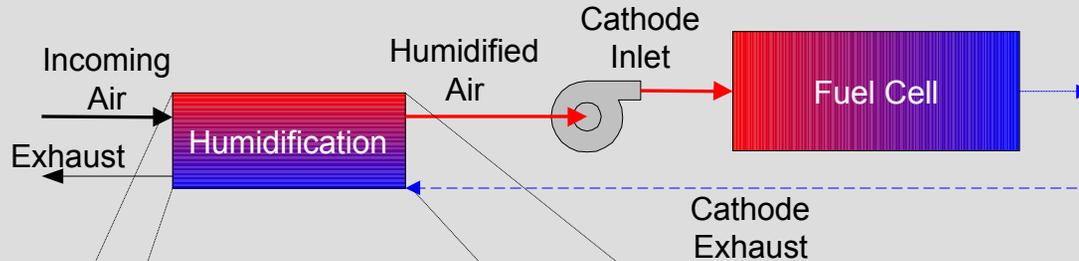
## ▶ FY07

- Complete single channel testing
- Initiate 1 kW<sub>e</sub>-scale device design and fabrication

## ▶ FY08

- Complete 1 kW<sub>e</sub>-scale testing
- Demonstrate 10 kW<sub>e</sub>-scale device in PEM system
- Validate low cost manufacturing process

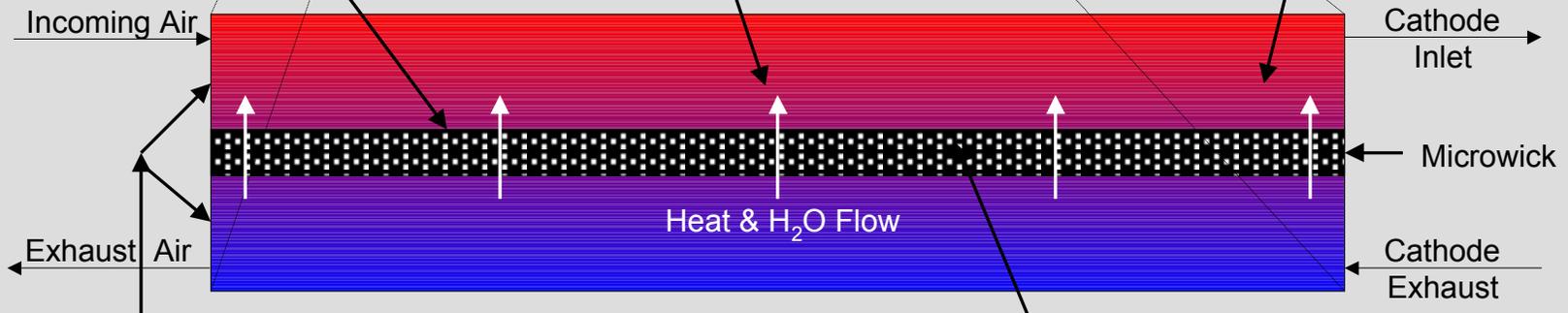
# Approach



Water evaporates at the wick wall due to both heat and mass transfer driving forces.

Heat is transferred to preheat the air and to evaporate water into the stream.  
cross over of air

Efficient heat transfer using laminar microchannels, heats cathode air feed to a close approach temp ( $\sim 10^{\circ}\text{C}$ ) with incoming cathode exhaust



Interconnect wicks are built into headers to remove excess water during normal operation and supply water during start up.

Capillary forces convey water condensed from the humid exhaust to the dry incoming air and also prevent cross over of air by precluding air intrusion into the wick.

# Technical Accomplishments/ Progress/Results

## ► System Performance Requirements

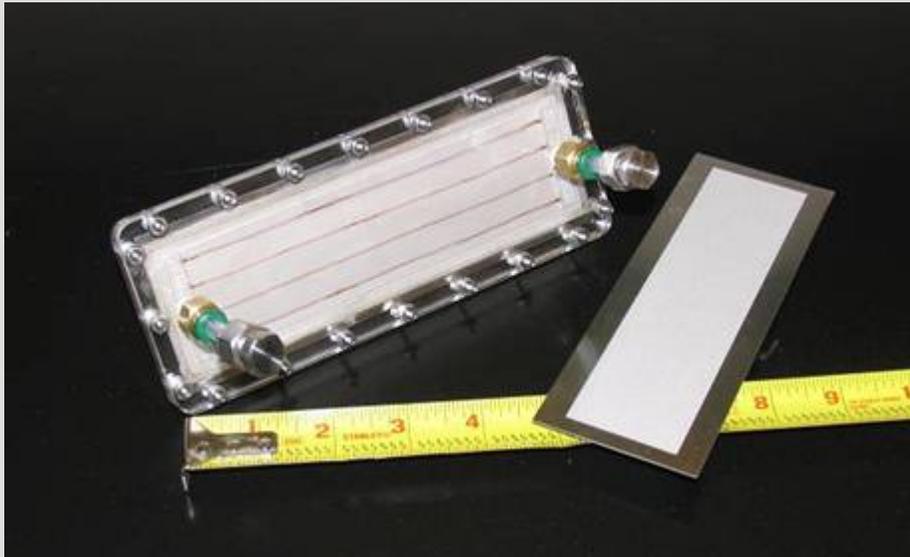
- Heat transfer and water recovery at varying fuel cell and ambient temperatures

Fuel cell temp	Ambient Temp	Hot End Approach Temp	Cold End Approach Temp	Excess condensate
80 °C	25 °C	12 °C	37 °C	1.6%
80 °C	40 °C	5 °C	34 °C	1.6%
60 °C	25 °C	12 °C	32 °C	34%
60 °C	40 °C	11 °C	27 °C	34%
90 °C	40 °C	2 °C	21 °C	0.3%

- Water balance is possible up to 90°C FC temp and 40°C ambient
- Approach temp becomes very challenging at highest temperatures

# Accomplishments/Progress/Results Slides

- ▶ **Task – Single Channel Demonstration and Testing**
  - **Single channel device constructed**

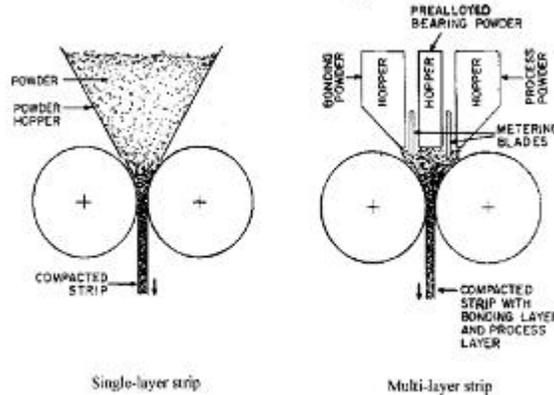


- **Test system operational**
- **Single channel testing initiated**

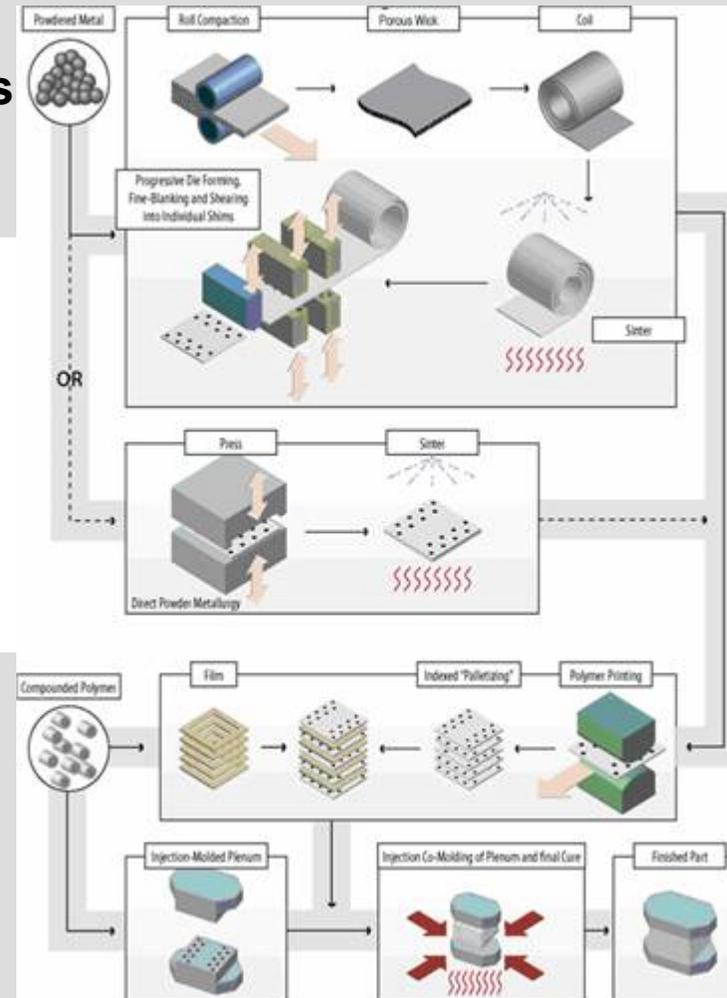
# Accomplishments/Progress/Results Slides

## Task – Manufacture of Components

- Initial focus on porous materials for wicks
- Direct powder rolling with ADMA

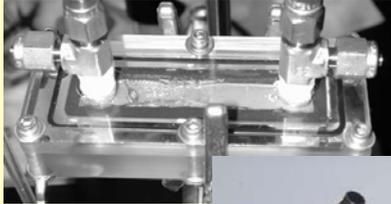


- 0.005 to 0.030 inch thicknesses
- Layered structures possible



# Relevant Prior Work: Microwick Technologies

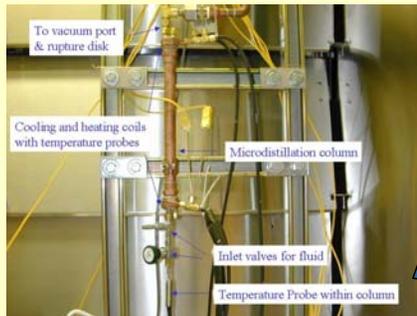
Single channel



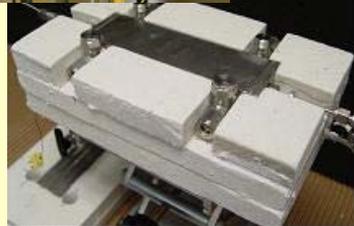
Phase separation



Multichannel



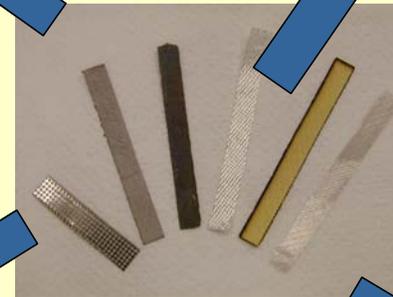
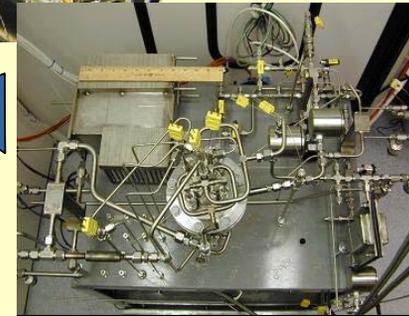
Distillation



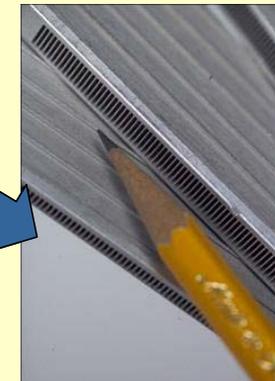
Absorption & Desorption



Integrated heat pump

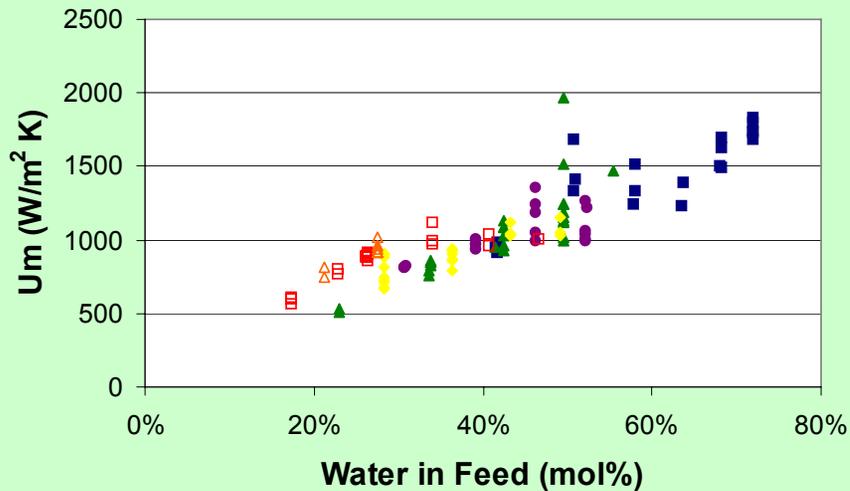
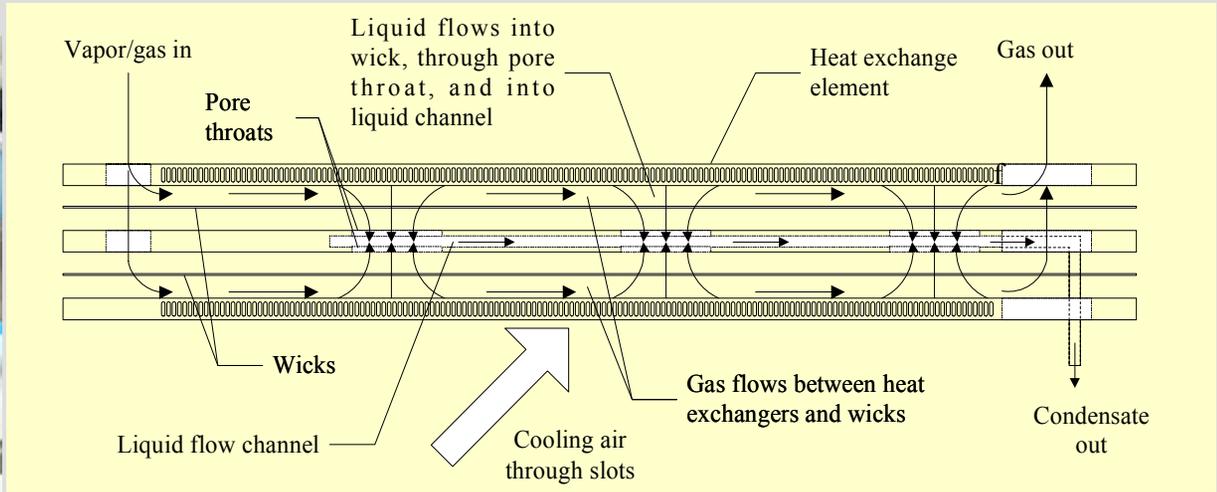


Microwicks allow two phase flow

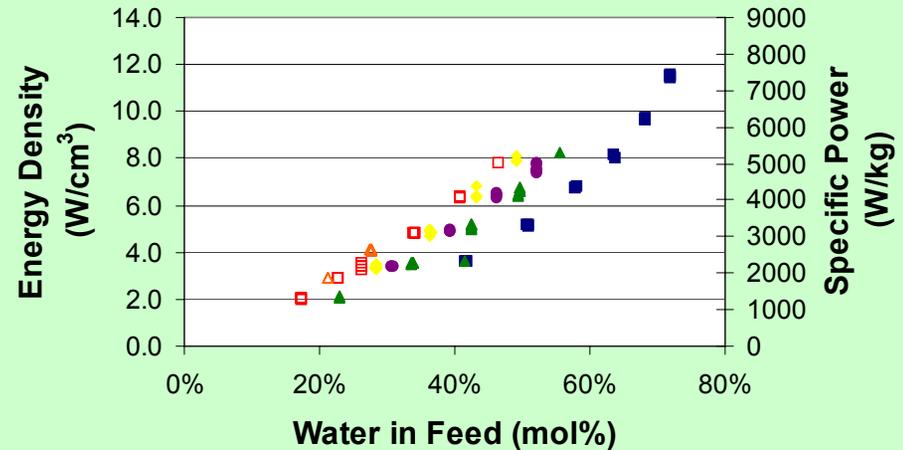


Phase separation with partial condensation

# Performance for Phase Separation with Partial Condensation



- Air flow = 5 slpm    ▲ Air flow = 7 slpm    ● Air flow = 8 slpm
- ◆ Air flow = 9 slpm    □ Air flow = 10 slpm    △ Air flow = 11 slpm



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- Specific Power Axis

# Relevant Prior Work in Manufacturing



Novel automotive components and processes for high volume production



PACCAR Hybrid Door



Superplastic aluminum Malibu Maxx lift gift

# Future Work

## ▶ FY07

- Complete single channel demonstration and testing
- Initiate 1 kW<sub>e</sub>-scale device design and fabrication
  - Construct design tool for wicking humidifiers
  - Validate design tool with single channel data

## ▶ FY08

- Complete 1 kW<sub>e</sub> device fabrication and testing
- Scale-up to 10 kW<sub>e</sub>-scale device
- Demonstrate 10kW<sub>e</sub>-scaled device in fuel cell system
- Validate low cost manufacturing process

## ▶ Key Go/No Go Decision – end of Phase 1

- Ability of device to meet weight and size targets
- Ability of device to handle varying conditions
- Costs for manufacturing 80-kW<sub>e</sub> device at <\$100

# Summary

- ▶ Balance of plant components, specifically for heat exchange and humidification, require additional development to meet requirements
- ▶ Microwick approach offers advantages for PEM Fuel Cell systems
  - Small size due to high power density heat transfer and rapid mass transfer
  - Passive operation
  - Low pressure drop enabling operation with blowers
  - Orientation independent
  - Self recovery during process upsets
- ▶ Device architecture is amenable to low cost, high volume manufacturing