Low-Cost Manufacturable Microchannel Systems for Passive PEM Water Management

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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_e Integrated Transportation Fuel Cell Power Systems Operating on Direct Hydrogen

<table>
<thead>
<tr>
<th></th>
<th>Target</th>
<th>80 kW_e System</th>
<th>Water Mgmt Target %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Density</td>
<td>650 W_e/L</td>
<td>123 L</td>
<td>2–7%</td>
</tr>
<tr>
<td>Specific Power</td>
<td>650 W_e/kg</td>
<td>123 kg</td>
<td>2 - 9%</td>
</tr>
<tr>
<td>Cost</td>
<td>$30/kW_e</td>
<td>$2400</td>
<td>&lt; 7%</td>
</tr>
</tbody>
</table>
Objectives

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

FY07
- Complete single channel testing
- Initiate 1 kW_e-scale device design and fabrication

FY08
- Complete 1 kW_e-scale testing
- Demonstrate 10 kW_e-scale device in PEM system
- Validate low cost manufacturing process
**Approach**

Efficient heat transfer using laminar microchannels, heats cathode air feed to a close approach temp (~10°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.

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.

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.

Interconnect wicks are built into headers to remove excess water during normal operation and supply water during start up.
Technical Accomplishments/ Progress/Results

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

<table>
<thead>
<tr>
<th>Fuel cell temp</th>
<th>Ambient Temp</th>
<th>Hot End Approach Temp</th>
<th>Cold End Approach Temp</th>
<th>Excess condensate</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 °C</td>
<td>25 °C</td>
<td>12 °C</td>
<td>37 °C</td>
<td>1.6%</td>
</tr>
<tr>
<td>80 °C</td>
<td>40 °C</td>
<td>5 °C</td>
<td>34 °C</td>
<td>1.6%</td>
</tr>
<tr>
<td>60 °C</td>
<td>25 °C</td>
<td>12 °C</td>
<td>32 °C</td>
<td>34%</td>
</tr>
<tr>
<td>60 °C</td>
<td>40 °C</td>
<td>11 °C</td>
<td>27 °C</td>
<td>34%</td>
</tr>
<tr>
<td>90 °C</td>
<td>40 °C</td>
<td>2 °C</td>
<td>21 °C</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

- Water balance is possible up to 90°C FC temp and 40°C ambient
- Approach temp becomes very challenging at highest temperatures
Task – Single Channel Demonstration and Testing

- Single channel device constructed
- Test system operational
- Single channel testing initiated
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

Phase separation

Microwicks allow two phase flow

Absorption & Desorption

Integrated heat pump

Distillation

Phase separation with partial condensation

Single channel

Multichannel
Performance for Phase Separation with Partial Condensation

Vapor/gas in

Liquid flows into wick, through pore throat, and into liquid channel

Heat exchange element

Gas flows between heat exchangers and wicks

Condensate out

Liquid flow channel

Wicks

Pore throats

Cooling air through slots

Performance for Phase Separation with Partial Condensation

Water in Feed (mol\%) vs. Um (W/m² K)

Water in Feed (mol\%) vs. Energy Density (W/cm³)

Water in Feed (mol\%) vs. Specific Power (W/kg)

Air flow = 5 slpm
Air flow = 7 slpm
Air flow = 8 slpm
Air flow = 9 slpm
Air flow = 10 slpm
Air flow = 11 slpm
Relevant Prior Work in Manufacturing

- Novel automotive components and processes for high volume production
- Superplastic aluminum
- Malibu Maxx lift gift
- PACCAR Hybrid Door

Magnesium alloy, Lightweight glazing, Thermal plastic composites, Metal matrix composites, Hydroforming, Superplastic forming, Aluminum tailor welded blanks

Battelle

National Laboratory Department of Energy
Future Work

**FY07**
- Complete single channel demonstration and testing
- Initiate 1 kW_e-scale device design and fabrication
  - Construct design tool for wicking humidifiers
  - Validate design tool with single channel data

**FY08**
- Complete 1 kW_e device fabrication and testing
- Scale-up to 10 kW_e-scale device
- Demonstrate 10kW_e-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_e 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