Integration of a "Passive Water Recovery" MEA into a Portable DMFC Power Supply

Presentation Outline:

- DMFC Background
- UNF Passive Water Recovery MEA
- UNF Portable Power Supply Performance
- Next Steps

Much of the work presented is the result of DOE collaboration and funding:

1. *New MEA Materials for Improved DMFC Performance, Durability, and Cost*
2. *Advanced Direct Methanol Fuel Cell for Mobile Computing*

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Problem Statement and Objective

- Most Direct Methanol Fuel Cell (DMFC) power supplies developed for the portable application are simply too heavy and too bulky, in large part due to the complexity and scaling difficulties of water recovery components such as the condenser heat exchanger.
- To overcome this barrier, the research objective of the University of North Florida and its project partners is to develop an innovative "passive-water recovery" MEA which eliminates the need for water recovery components, thus resulting in a small, lightweight DMFC power supply for the portable application.

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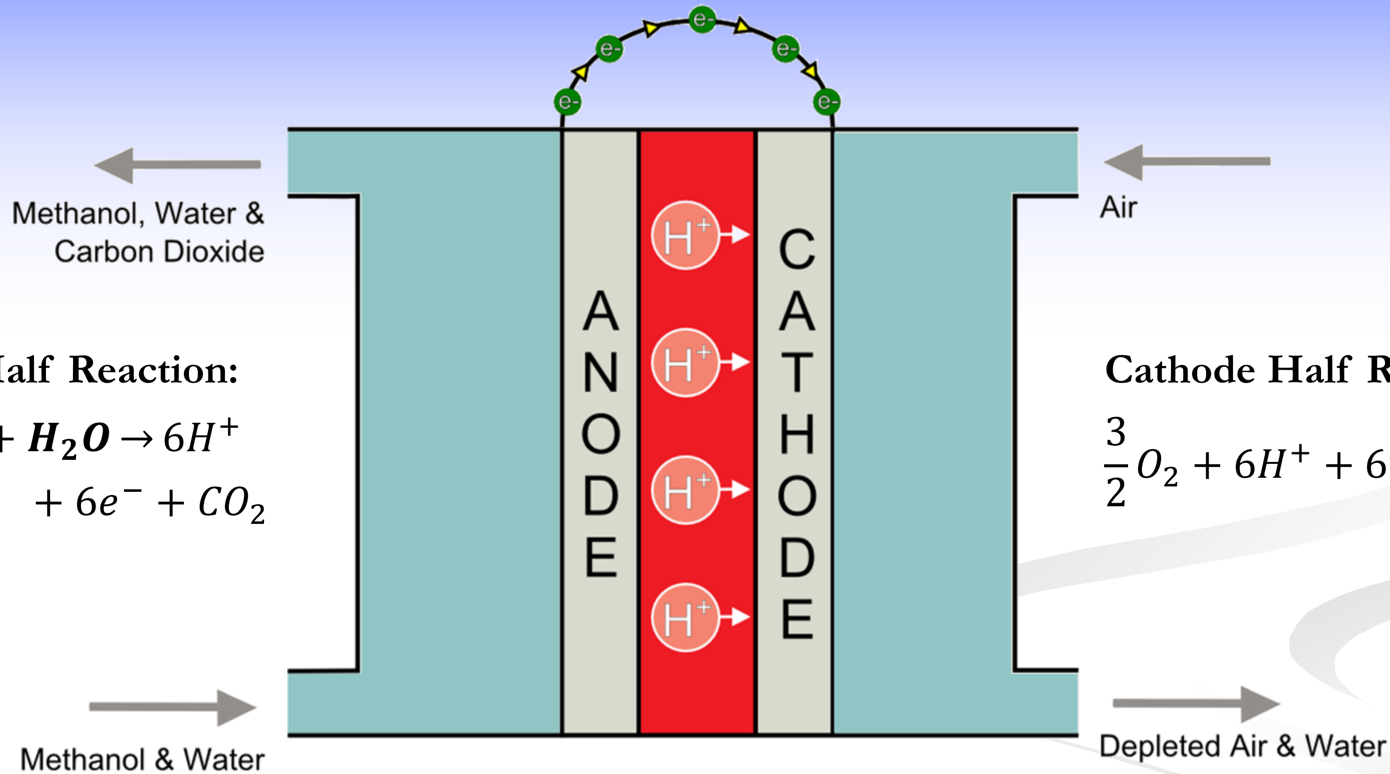
Water Management in DMFCs



Anode Half Reaction:

$$CH_3OH + \boldsymbol{H_2O} \rightarrow 6H^+ + 6e^- + CO_2$$

Cathode Half Reaction:

$$\frac{3}{2}O_2 + 6H^+ + 6e^- \rightarrow \boldsymbol{3H_2O}$$

Other Contributors to Water Management:

Electro-osmotic Drag: 1-3 Moles of H_2O per mole of H^+ from the Anode to Cathode

Methanol Crossover: $CH_3OH + \frac{3}{2}O_2 \rightarrow CO_2 + \boldsymbol{2H_2O}$

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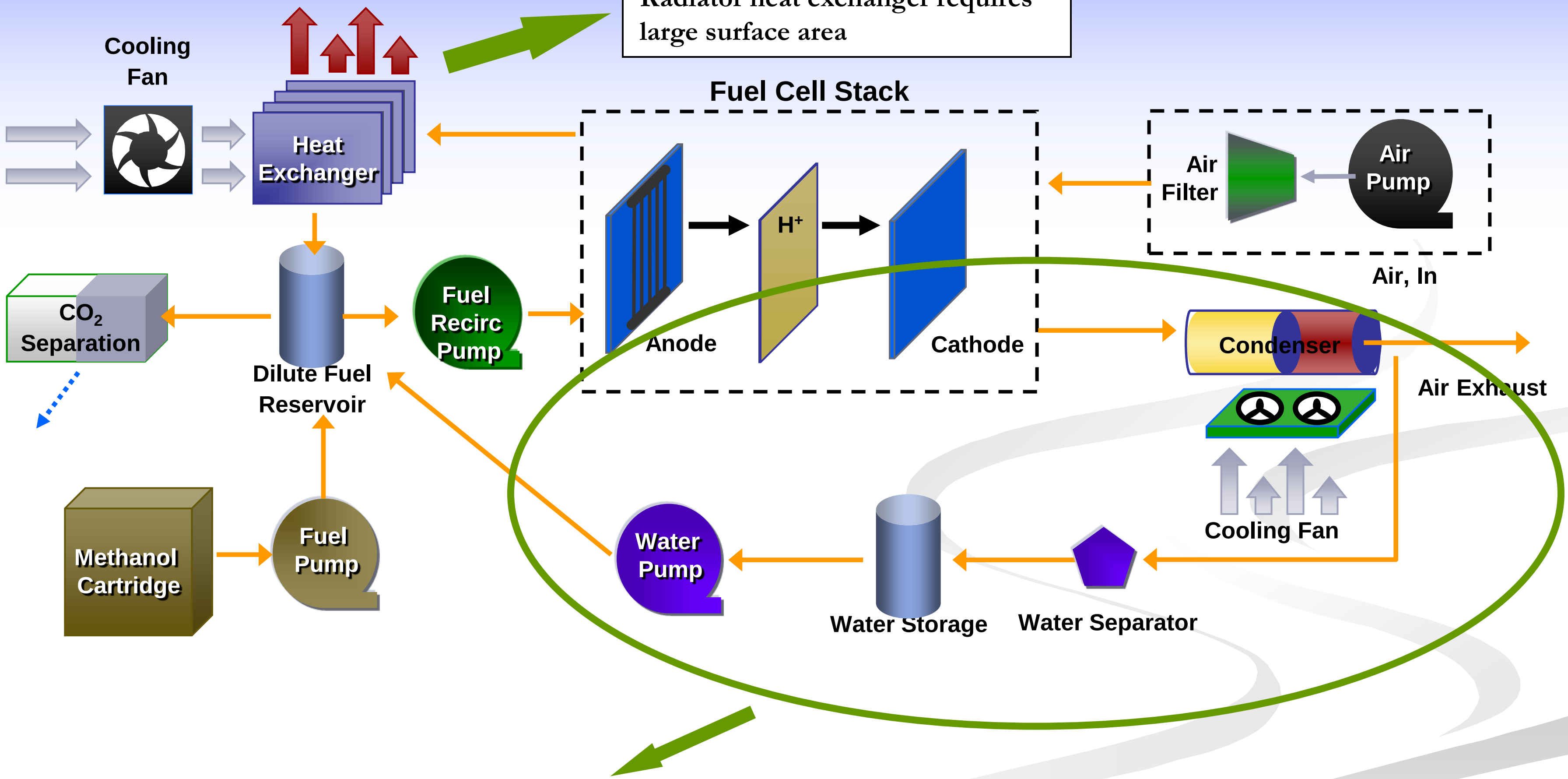
Background: Conventional DMFC System

Radiator heat exchanger requires large surface area



Water recovery components are heavy and bulky - also do not directly aid the electrochemical process

UNF Passive Water Recovery MEA

- The goal is to develop and optimize a Membrane Electrode Assembly (MEA) that accomplishes the required water management within its own structure – thus passive water recovery[1]
  - Pathway for water to travel from the cathode directly to the anode
  - Prevent or limit any water from leaving the MEA in the cathode exhaust
  - Include a membrane that limits the amount of water "dragged" through EOD from the anode to the cathode (on the order of EOD ≈ 1, not the typical 2 to 3 of other membranes)
- Integrate the "passive water recovery" MEA into a portable power supply that meets the DOE Technical Targets for the 10-50 watt range[2]

1. DOE Project: *New MEA Materials for Improved DMFC Performance, Durability, and Cost*
2. DOE Project: *Advanced Direct Methanol Fuel Cell for Mobile Computing*

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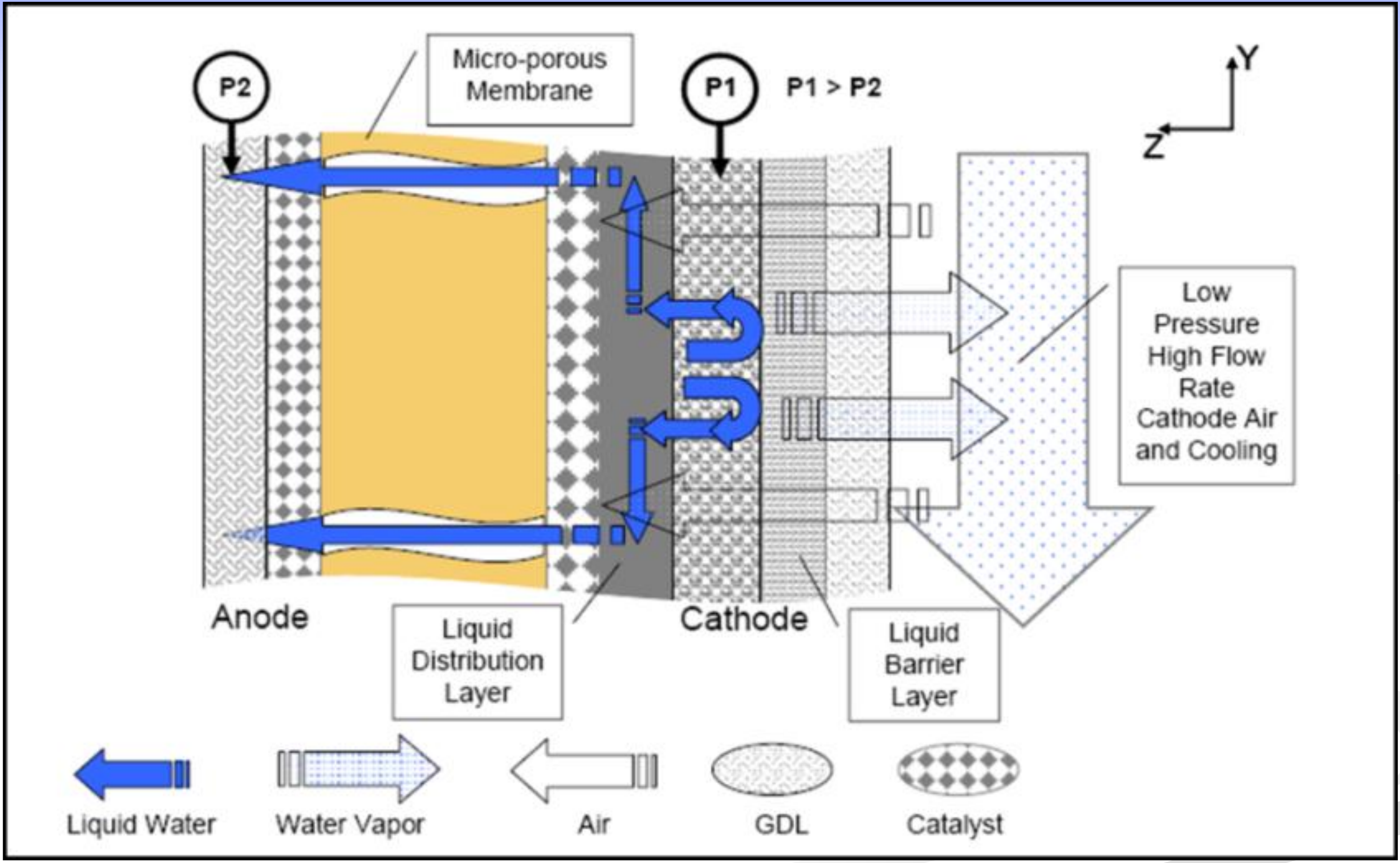
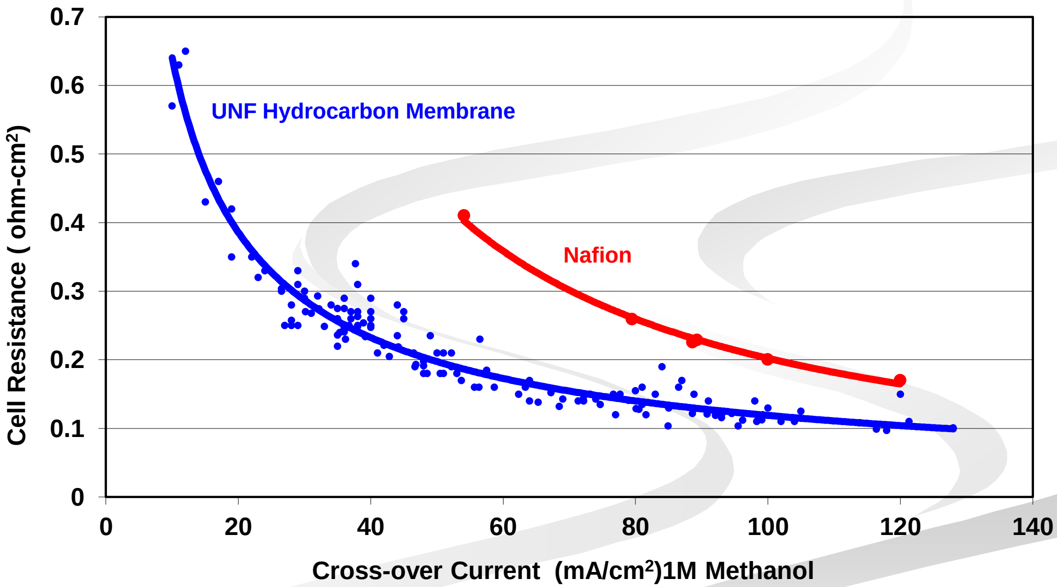
UNF Passive Water Recovery MEA Schematic



UNF DM-1 Membrane

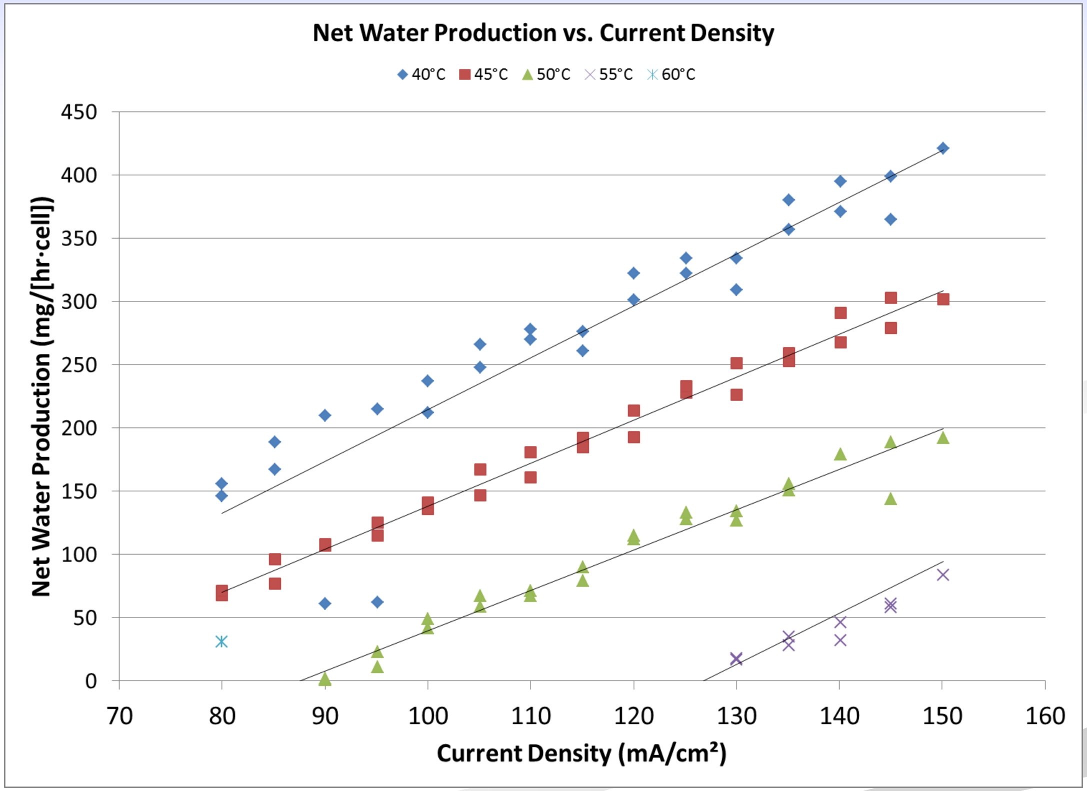
- Hydrocarbon polymer with sulfonic acid ion exchange groups – good control of membrane chemistry/properties (Technology acquired from former partner PolyFuel, Inc.)
- Benefits for Passive Water Recovery MEA
  - Good chemical and mechanical stability in alcohol solutions: laser-drilled holes
  - Minimal drag of water – EOD ≈ 1.1
  - Low methanol crossover with good ionic conductivity



Liquid Barrier Layer Optimization

- Extensive effort to control barrier layer properties (thickness, materials, etc.) to minimize water loss – inherent trade-off between water loss and oxygen access
- Improved membrane and barrier properties have increased operating temperature (~45°C to ~55°C)

45 μm membrane, K_{H20} = 1.1 mm/s, MeOH = 0.8 M



Increased current density key to water balance

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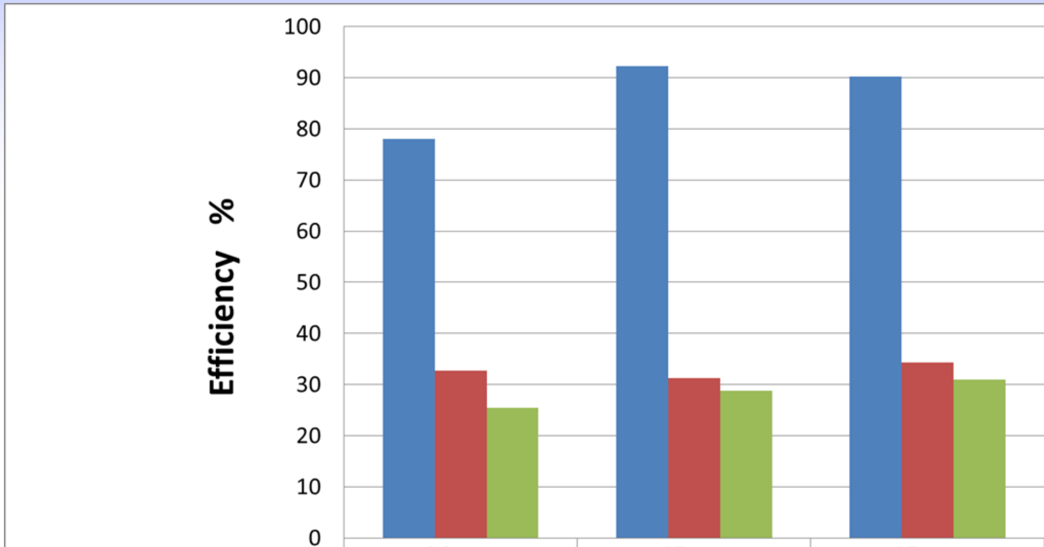
MEA Performance Optimization

- MEA optimization has resulted in significant performance improvements
- Membrane improvements have resulted in fuel utilization efficiencies >90%
- Improved barrier performance has resulted in higher electrochemical efficiency through higher operating temperature and better oxygen access



	20 µm Membrane 50°C	45 µm Membrane 50°C	45 µm Membrane 60°C
Fuel Utilization Efficency	78.1	92.3	90.2
Voltage Efficency	32.7	31.3	34.3
Overall Efficency	25.5	28.8	30.9

More than 20% improvement in MEA performance

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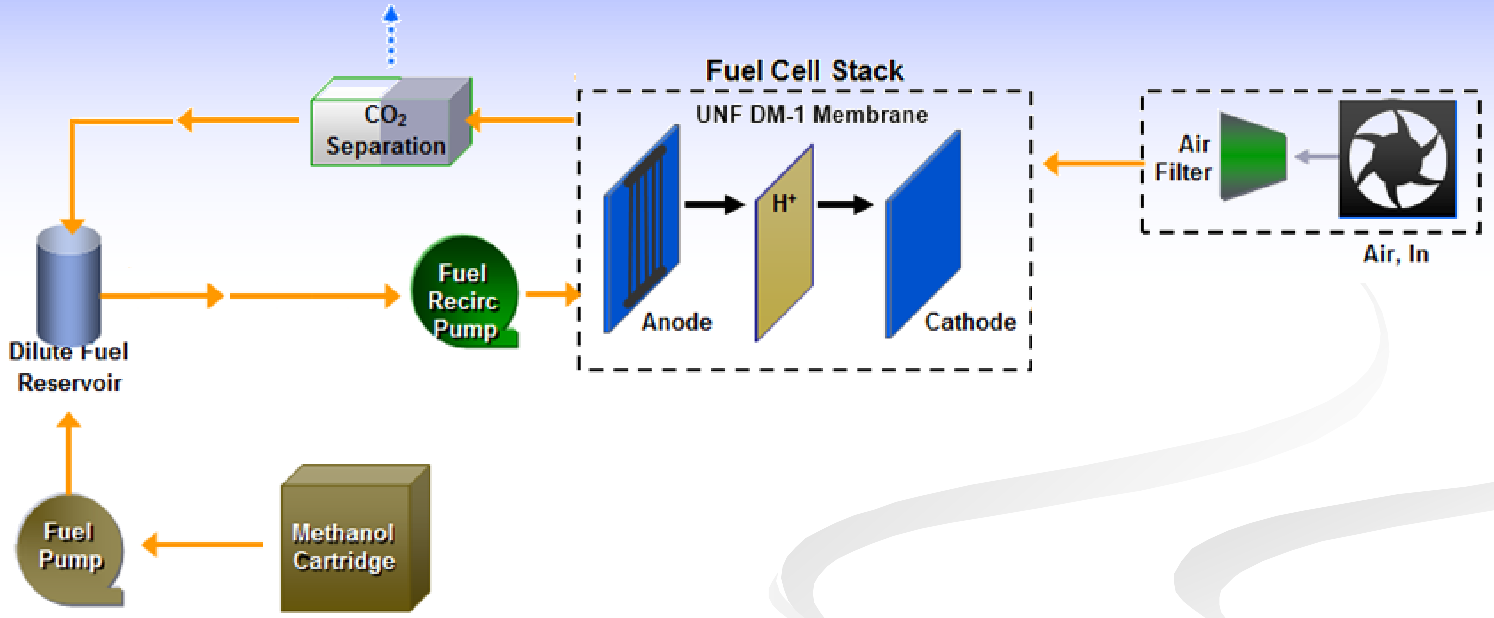
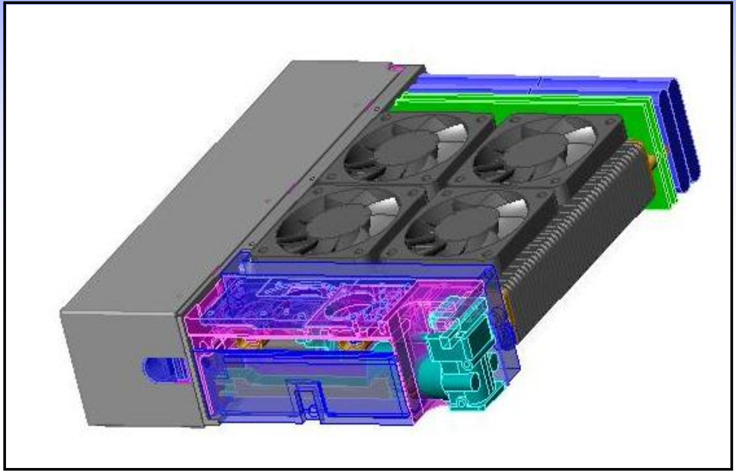
Benefit: UNF's Simplified DMFC System



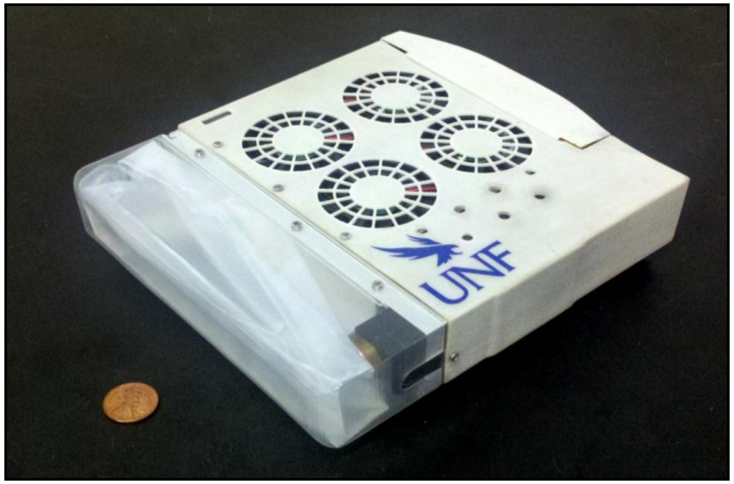
Novel passive water recovery MEA significantly reduces the number of balance of plant components

Technical Accomplishments

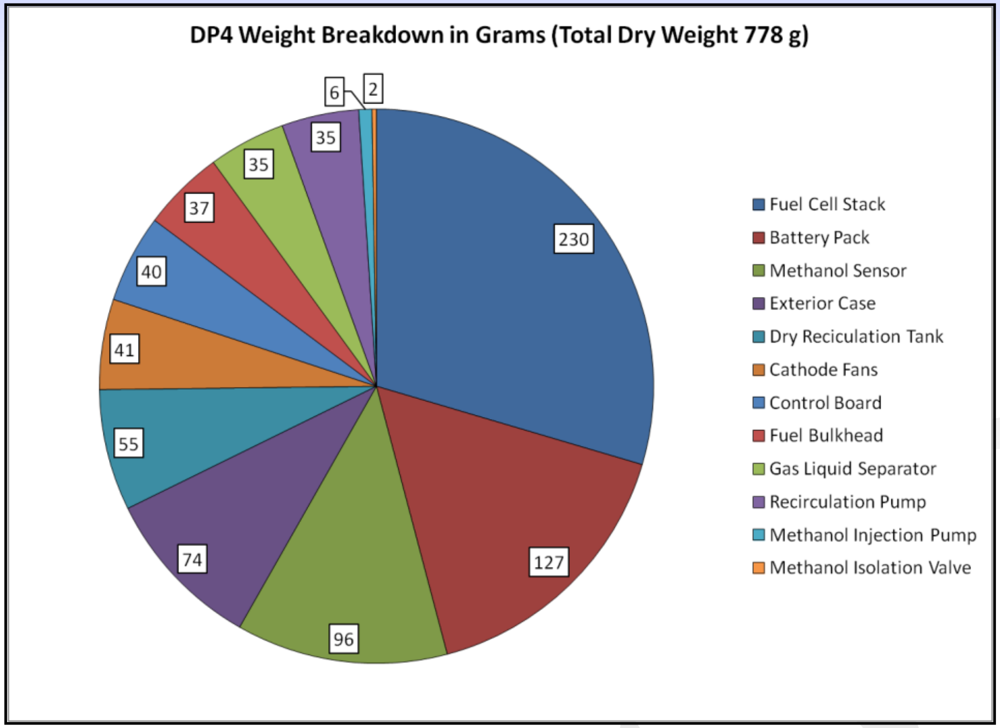
Existing DP4 Weight Breakdown



Concept Design



DP4 System



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Performance versus DOE Technical Targets

Technical Targets: Portable Power Fuel Cell Systems (10-50 Watts)					
Characteristic	Units	2011 Status	UNF DP4 2011 (25 W Net)[1]	2013 Targets	UNF 2013 (25 W Net)[2]
Operational Time	hours		10		14.3
Specific Power[1]	W/kg	15	26.3	30	30.1
Power Density[1]	W/L	20	28	35	30.6
Specific Energy[1]	(W-hr)/kg	150	263	430	430
Energy Density[1]	(W-hr)/L	200	280	500	437

1 Calculation includes weight and volume of hybrid battery and fuel as defined by the DOE.
2 Calculation assumes reduction in weight and volume based on component and brassboard (unpackaged) test results. Current MEA performance is used.

Present UNF DMFC technology nearly meets 2013 Technical Targets; more improvements underway.

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Next Steps

- Continue to optimize the liquid barrier layer with the goal of increasing the operating temperature
- Continue to improve the oxygen access in the cathode to increase the current density – cost reduction
- Continue to minimize degradation issues
- Integrate latest components into the brassboard (unpackaged) design
- Develop next generation "DP6" DMFC portable power supply that exceeds the 2013 DOE Technical Targets

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