# Advanced Direct Methanol Fuel Cell for Mobile Computing

University of North Florida

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Project ID #
ARRAH2004

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# Overview

## Timeline

- Start date: January 1, 2010
- End date: December 31, 2011
- Percent complete: 16%

## Barriers

| Characteristic | Requirement |
|---|---|
| Specific Power | 100 W/kg |
| Cost | <$3/watt |
| Lifetime | 5000 hours |

## Budget

- Total project budget $3,054,464
  - DOE share $2,443,441
  - Contractor share $611,023
- Funding for FY10 $3,054,464

## Partners

- University of Florida

# Relevance: Objective

- The project objective is to develop a DMFC power supply for mobile computing using the novel passive water recycling technology acquired by UNF from PolyFuel, Inc., which enables significant simplification of DMFC systems.
  - The objective of the 2010 effort to date is to define the system concept and develop the required design requirements (system, sub-system, and component) in order to achieve the 2010 Technical Targets.
  - Initial component development effort, based on the CDRs, is nearly completed

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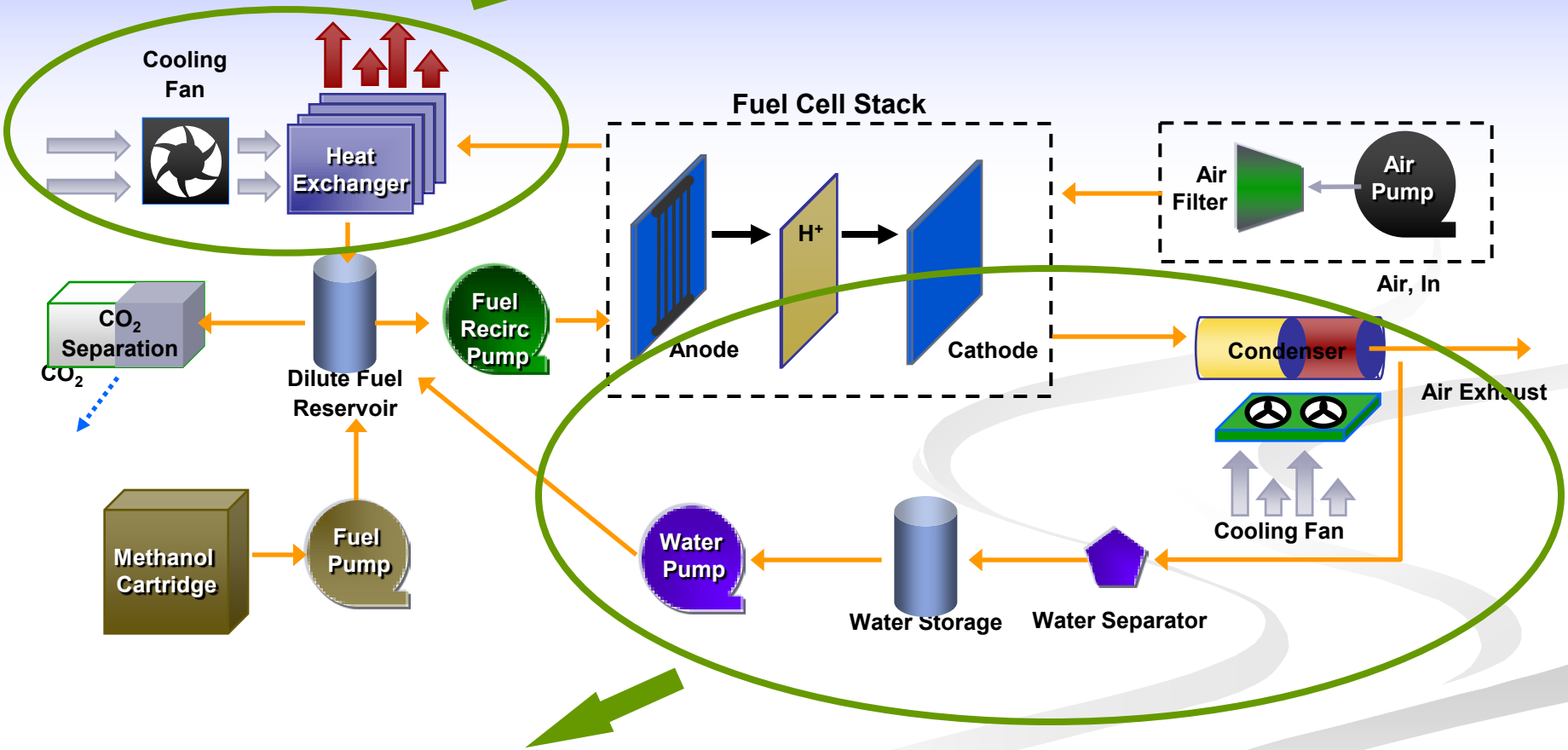
# Relevance: Conventional DMFC System

Radiator heat exchanger requires large surface area




Water recovery components are large and cumbersome - also do not directly aid the electrochemical process

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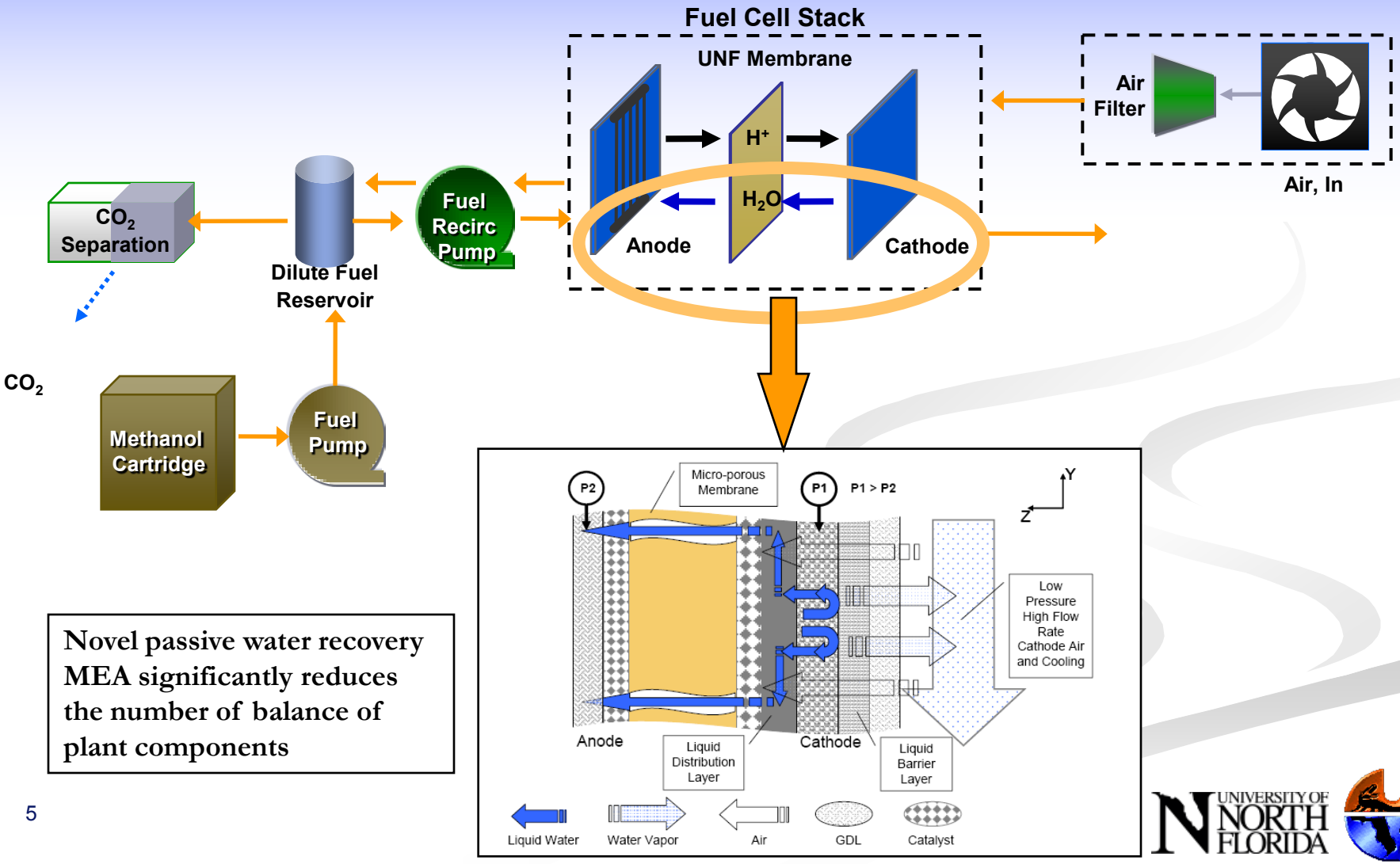
# Relevance: UNF's Simplified DMFC System




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

# Relevance: Impact

- Incorporating the novel passive water recovery technology results in significant reduction in the number of components

| Characteristic | Units | UNF<br>15 W DP3<br>2008 Status | DOE 2010 Target | UNF Proposed<br>20W System Design |
|---|---|---|---|---|
| Specific Power [a] | W / kg | 35 | 100 | 54 |
| Power Density [a] | W / L | 48 | 100 | 63 |
| Energy Density | W-hr / L | 250 (1 x 100ml)[b]<br>396 (1 x 200ml)[b] | 1000 | 198 (1 x 100ml)<br>313 (1 x 200ml)<br>507 (3 x 200 ml) |
| | W-hr/kg | 155 (1 x 100ml) [b]<br>247 (1 x 200ml) [b] | N/A | 180 (1 x 100 ml)<br>302 (1 x 200 ml)<br>532 (3 x 200 ml) |
| Lifetime [c] | Operating Hours | 1,000 hrs<br>in single cell | 5,000 | 2,500<br>Integrated System |
| Cost | $ / Watt | 11<br>(est. in volume) | <3 | < 10<br>(est. in volume) |

[a] Beginning of life, 30°C, sea level,50% R.H., excluding hybrid battery, power module alone
[b] Normalized from DP3 data from 150 ml cartridge to either 100ml or 200ml for comparison purposes
[c] Lifetime measured to 80% of rated power

Marked improvement on the road towards commercialization.

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# Approach: Project Integration

- This project is focused on the balance of plant (pumps, blowers, etc.) development and overall system integration

- This effort is highly integrated with the UNF-led Topic 5A: *New MEA Materials for Improved DMFC Performance, Durability, and Cost* project (DOE funded) which focuses on optimizing the passive water recovery MEA
  - The passive water recovery MEA performance will be improved
  - As part of the Topic 5A program, industry partner Johnson Matthey will apply commercial processes to the MEA production
  - Critical to achieving cost, robustness, and lifetime goals for the DMFC power supply

Integrating the commercially produced MEA into the improved balance of plant is an important step towards commercialization.

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# Approach: Milestones

25% Complete

- Component Engineering
  - CDRs Revised
  - Component DFMEAs
  - Key Subsystems – Prototypes
  - Shell Body and Interface Prototypes
  - Fuel Cartridge Prototype

15% Complete

- Component/Subassembly Testing
  - Component Performance & Durability
  - Integrated Subsystem Testing

25% Complete

- System Engineering
  - Concept Design
  - DFMEA, DFMA of System
  - Brassboard Assembly & Testing
  - System Assembly & Testing

10% Complete

- Control System Development
  - Rest /Rejuvenation Protocol Optimization
  - Start-up & Shut-down Protocol
  - Operating Protocol Tuning Revised System

10% Complete

- System Validation Testing
  - Test Plan Released
  - Operating and Storage Durability Testing
  - Ex-Situ System Testing
  - In-Situ System Testing

- Program Management
  - Quarterly & Annual Report
  - Go /No-Go Decision
    - Specific Power: 40 W/kg
    - Power Density: 55 W/l
    - Energy Density: 575 W·hr/l
    (3 x 200 mL cartridges)

The project is on schedule.

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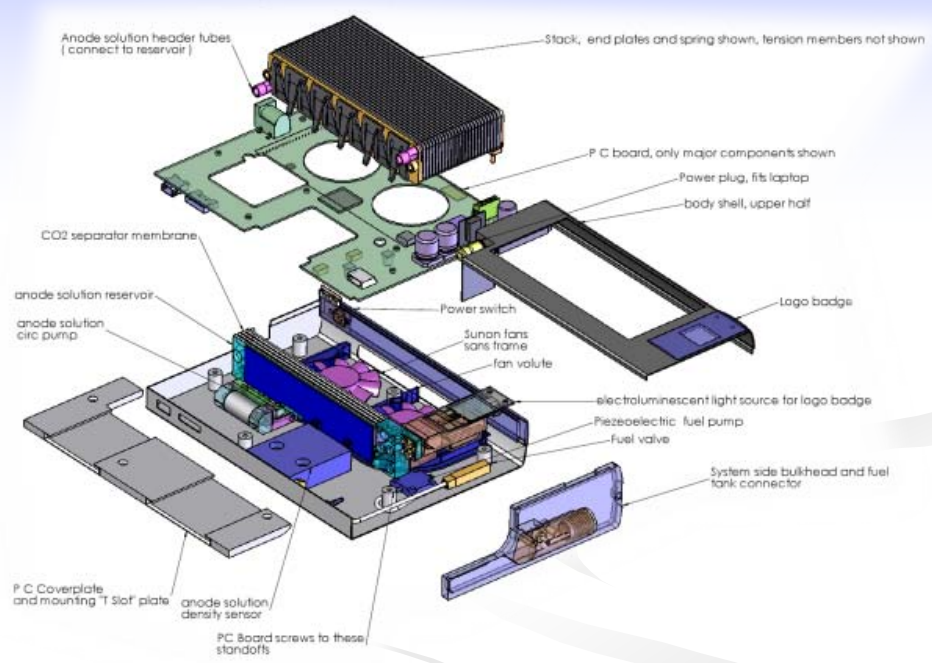
# Previous Accomplishments: Existing DP3

Fuel cartridge and power section

DP3 System with comparable battery energy




DP3 Exploded View

DP3 was a successful proof-of-concept design.

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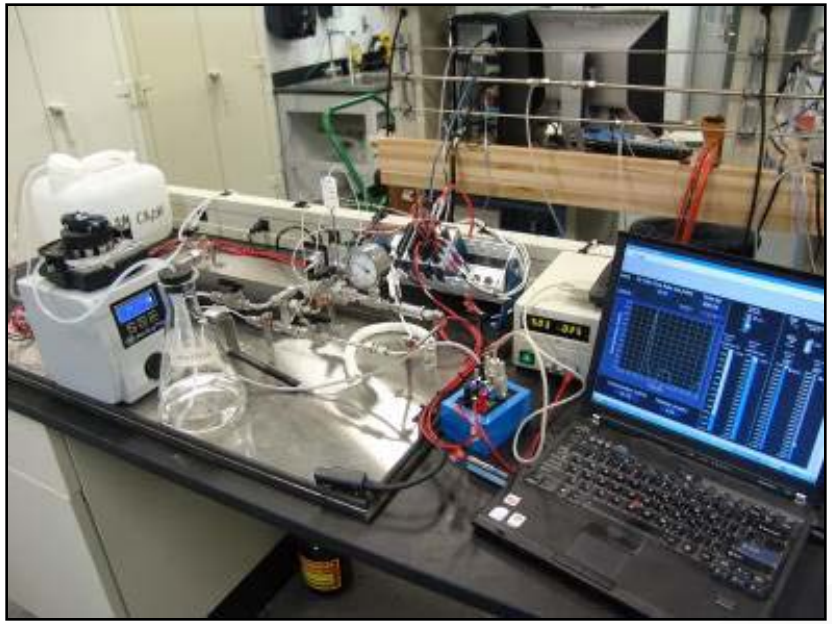
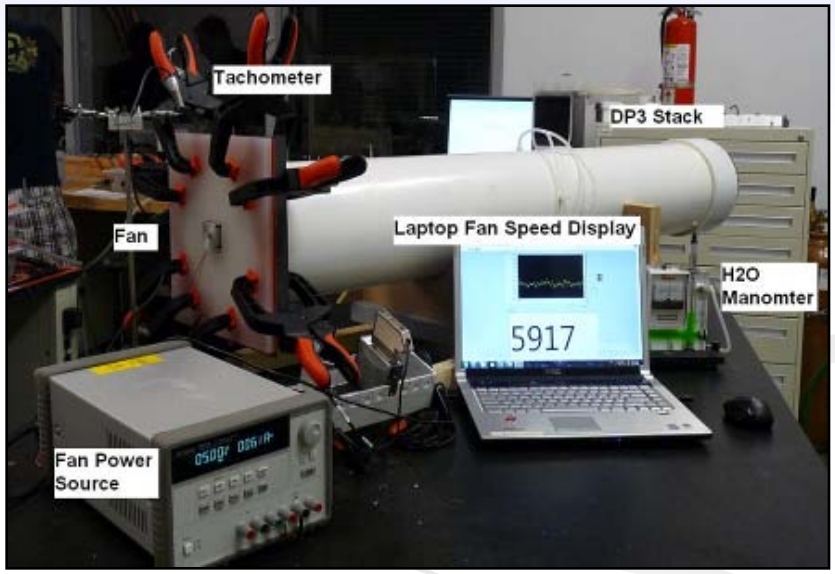
# Technical Accomplishments: Component Test Stands

**Test stands will be used for each component to insure the component design requirements are met**

**Methanol Sensor Test Stand:** Used to measure the accuracy, transient response, and robustness of various methanol concentration sensor technologies






**Cooling Fan Test Stand:** Used to measure the performance and efficiency of small-scale motor-blower combinations

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# Accomplishments: Design Requirements

| OVERVIEW | | | | | | | |
|---|---|---|---|---|---|---|---|
| **System Requirements** | | | | | | | **CDR** |
| **Power Section Requirements** | | | | | | **CDR** | |
| Fuel Cell Stack | | | | | **CDR** | | |
| MEA | | | | | | | |
| Bipolar plate | | | | | | | |
| Stack ancillaries | | | | | | | |
| Air Management | | | | | **CDR** | | |
| Thermal | | | | | | | |
| Noise / filtration | | | | | | | |
| Fuel Subsystem | | | | | **CDR** | | |
| Recirculation Pump | | | | | | | |
| Gas-Liquid Separator | | | | | | | |
| Reservoir isolation system | | | | | | | |
| Methanol conc. Sensing | | | | | | | |
| Fuel feed subystem | | | | | **CDR** | | |
| Feed pump, isolation valve | | | | | | | |
| Fluid & mechanical interface | | | | | | | |
| **Fuel Cartridge (Energy Storage)** | | | | | | **CDR** | |
| Fluid containment | | | | | | | |
| Mechanical | | | | | | | |

Analysis

- CDRs are 75% complete at time of submission for merit review

Robust engineering design and development process.

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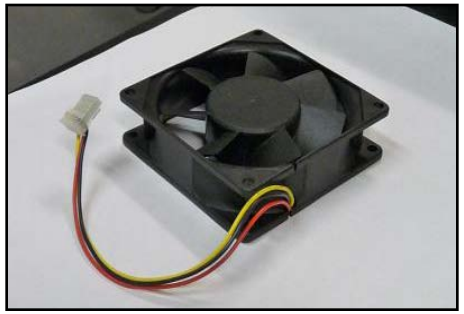
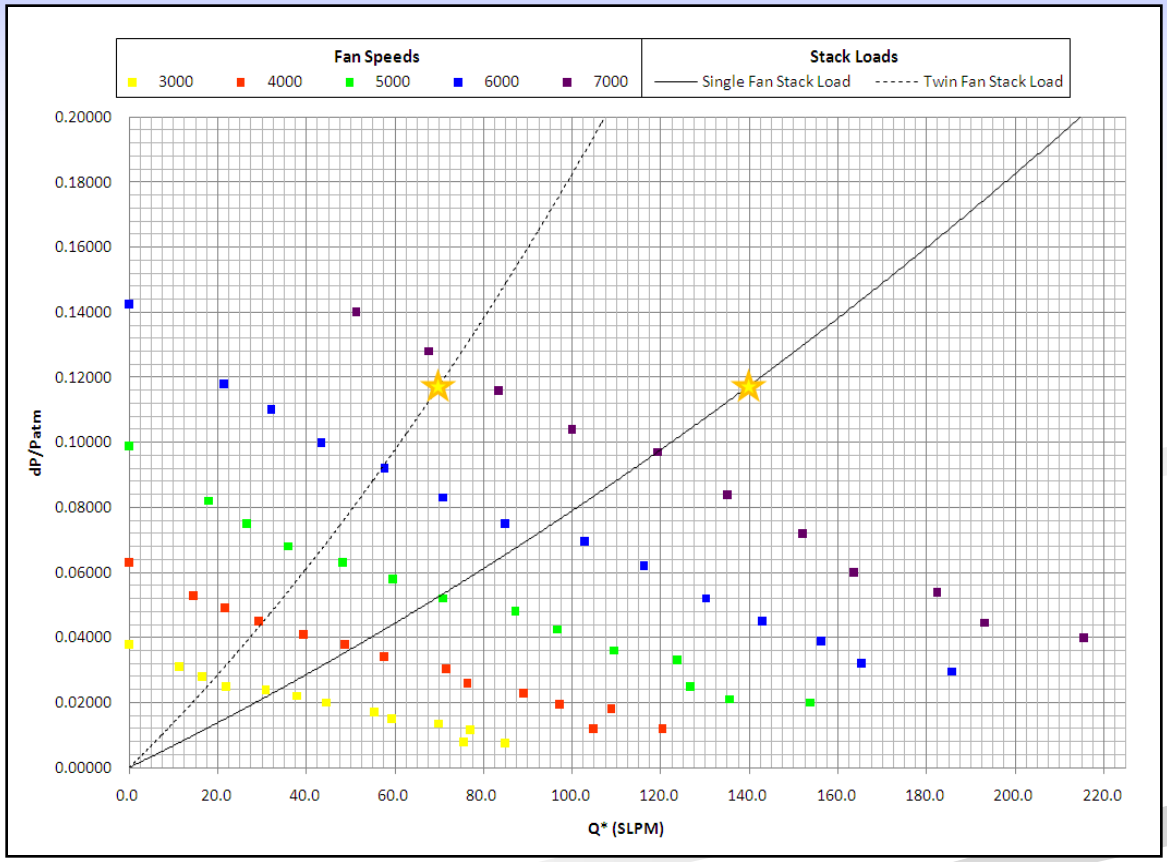
# Accomplishments: Fan Test Results

| Fan | Peak Efficiency |
|---|---|
| Adda AD4505HX-K90 | 5.2 |
| Sunon GB0545AFV1-8 | 6.0 |
| OLC CFR3B5H | 2.0 |
| Sunon KDE1204PKVX | 4.3 |
| Y.S.Tech YW0401000-5BH | 3.0 |






A dual fan configuration meets the design requirements.

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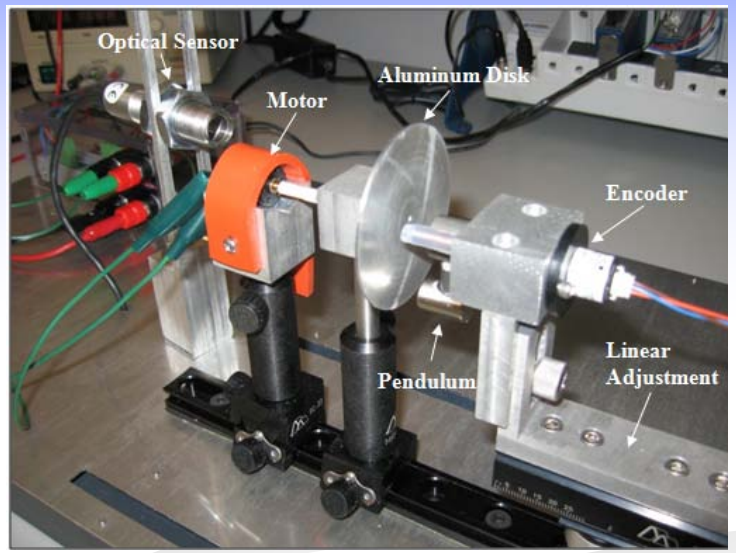
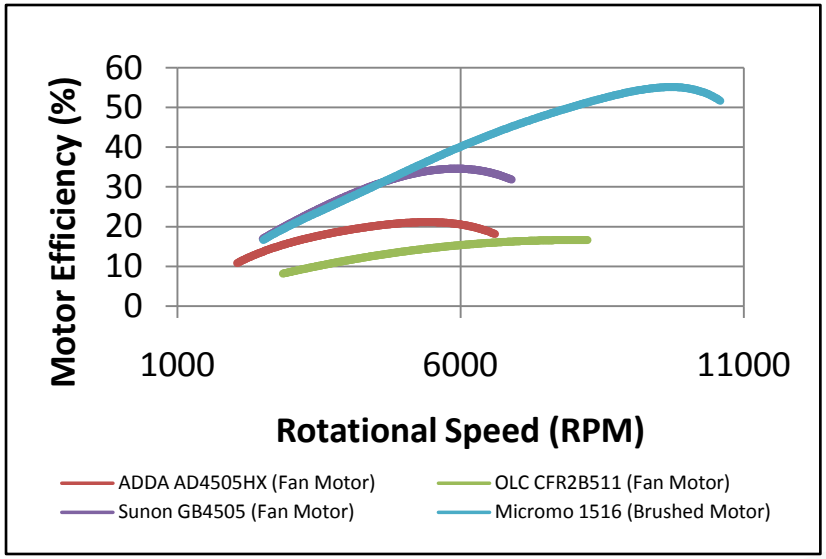
# Accomplishments: Fan Test Results

| Component | Power Budget (mW) |
|---|---|
| Methanol Injection Pump | 50 |
| Fuel Supply Solenoid Valve | 100 |
| Anode Recirculation Pump | 1000 |
| **Cooling/Oxidant Fans** | **2000** |
| Methanol Sensor | 200 |




Testing showed motor-fan assembly efficiency typically 2-6%. Small motor dynamometer was developed to separate motor and fan efficiencies

Important to minimize the parasitic load to meet efficiency and run-time goals.

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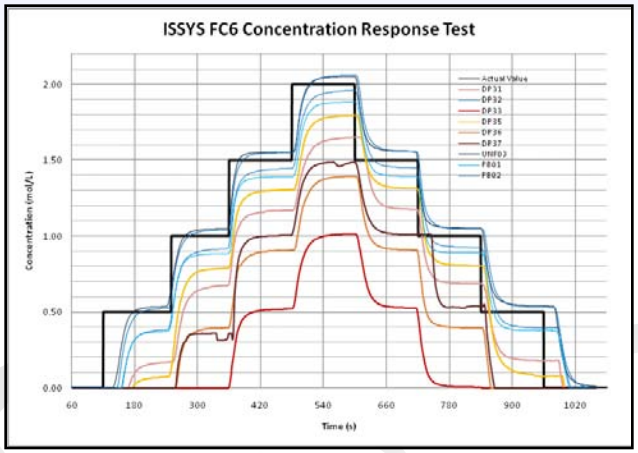
# Methanol Concentration Sensor Testing

Siargo FSC-2000 and ISSYS sensors.

## ISSYS FC6 MEMS Sensor

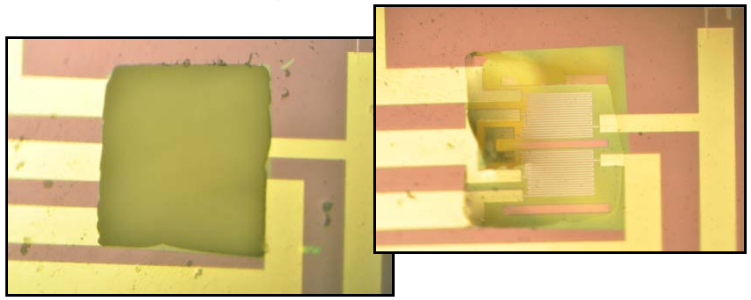
**(Density → Concentration)**




ISSYS FC6 sensitive to mechanical shock and accuracy drift.

## Siargo FSC-2000 MEMS Sensor

**(Thermal Conductivity → Concentration)**



Siargo FSC-2000 susceptible to stress cracking due to thin sensor membrane

No current methanol concentration sensor meets the CDR. Other sensing technologies must be investigated (Viscosity, Crossover $CO_2$, Acoustic Wave, etc.)

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# Hydrogen Safety Plan

- **All laboratories are outfitted with gas detection systems to alarm researchers in the event of a hydrogen leak.**

- **The hydrogen safety plan has been submitted and is under review.**

**Hydrogen Sensor Probe:** The small hydrogen detector is installed at several remote locations providing gas detection at levels greater than 100 ppm.

**KnowzNet Gas Detection System:** The 8 channel gas detection system works in conjunction with the hydrogen sensor probes in order to provide gas monitoring and alerts at various locations.

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# Collaborations

- University of Florida (Academic)
  - Dr. Bill Lear leads the effort to develop critical components including the fuel pump, the recirculation pump, and the $CO_2$ removal membrane
  - Dr. Oscar Crissale leads the effort to develop the overall control strategy
- The DOE funded project (UNF Prime) *New MEA Materials for Improved DMFC Performance, Durability, and Cost* includes the following collaborators:
  - University of Florida (Academic): Focus on manufacturability and advanced catalysis
  - Johnson Matthey (Industry): Integration of commercial processes into the MEA manufacturing
  - Northeastern University (Academic): Advanced catalysis focused on ultra-stable ruthenium catalyst

The University of North Florida (Prime) and the University of Florida also collaborate on a U.S. Army CERDEC funded project to develop a militarized version of the DMFC laptop power supply

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# Proposed Future Work

- Remaining FY2010:
  - Complete design requirements and DFMEAs (UNF)
  - Complete component development (UNF, UF)
  - Brassboard (unpackaged) system testing (UNF)

  - KEY Milestone: Demonstrate component performance meets requirements

- FY2011:
  - Complete development of advanced control strategies (UF)
  - Integrate components and sub-systems into packaged unit (UNF)
  - Extensive system testing including performance, robustness, and lifetime (UNF, UF)

  - KEY Milestone: Compare system attributes (power density, expected lifetime, etc.) versus DOE requirements.

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# Project Summary

- **Project Relevance:** The novel passive water recovery MEA technology allows for simplified balance-of-plant which results in a DMFC power supply approaching the DOE 2010 Technical targets
- **Approach:** Cascade-down design requirements to each component resulting in a robust design. Integrate the balance-of-plant with the optimized passive water recovery MEA
- **Technical Accomplishments:** Design requirements completed and initial component development underway
- **Collaborations:** Technical expertise at UF focused on component development and robust control system.
- **Proposed Future Work:** Complete component development in 2010. System integration and testing (including advanced MEA) in 2011