2013 DOE Bioenergy Technologies Office (BETO) Project Peer Review

Development of Applied Membrane Technology for Processing of Ethanol from Biomass

Date: May 20-23, 2013
Technology Area Review: Biochemical Conversion

Principal Investigator: Stuart Nemser, PhD
Organization: Compact Membrane Systems

Goal Statement

- Enhance the low-cost production of bioethanol
- Develop membrane system
- Demonstrate drying ethanol to fuel grade
- Demonstrate long term resistance

Quad Chart Overview

Timeline

- Project start date: 6/29/2006
- Project end date: 3/31/2013
- Percent complete: 100%

Budget

- Funding for FY06: $495,000/$123,750
- Funding for FY08: $492,000/$123,000
- Years the project has been funded / average annual funding: 6.5 years @ ~ $152,000/year

Barriers

- Barriers addressed
  - Develop EtOH/Temp. resistant components
  - Scale up system
  - Demonstrate long term performance

Partners

- Interactions/ collaborations
  - CMS working with 2 potential customers
  - All research and project management performed solely by CMS

Project Overview

- Need for production of low cost fuel-grade ethanol from renewable sources
- Drying ethanol by conventional methods: costly and energy intensive
- Enhance low-cost production by means of a novel water-ethanol separation membrane and process
- Bio-ethanol plants tend to be small
- Membrane processes are ideal for
  - ✓ Small applications
  - ✓ Removing small components
- Commercial liquid dehydration platform established

1 - Approach

- Develop membrane system that removes the minor component
- Overall technical approach:
  - ✓ Experimental
  - ✓ Scale up demonstrated prototype
  - ✓ Pilot test
  - ✓ Use of real feedstock
  - ✓ Engineering design
  - ✓ Critical path

2 - Technical Accomplishments (Summary)

- The program goals were successfully achieved.

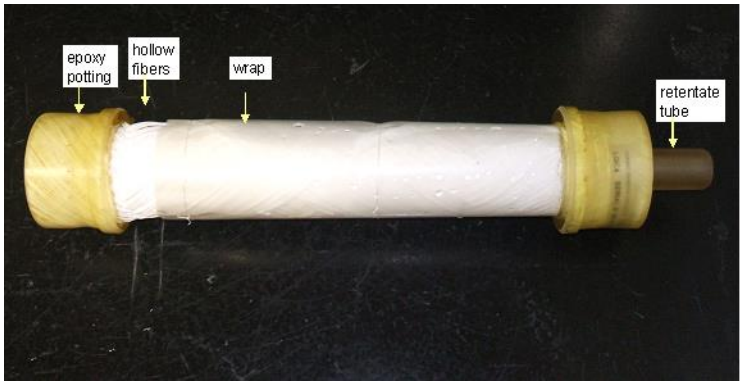
- Developed a thermally and ethanol (chemically) resistant membrane system that demonstrated:
  - ✓ Fuel grade ethanol production from wet ethanol
  - ✓ Steady operation for 50 days
  - ✓ Withstood multiple startups/shutdowns
  - ✓ Efficient operation in a wide range of water content in the ethanol

2 – Progress/Results (cont'd) Project Tasks

- ✓ Develop epoxy/potting system
- ✓ Develop hollow fiber membranes
- ✓ Scale-up/Optimize module performance
- ✓ Demonstrate stability for at least 30 days
- ✓ Demonstrate production of 99.5% ethanol

2 – Progress/Results (cont'd)
Membrane System

1. Composite hollow fiber membrane
   - Perfluorinated polymer
   - Microporous support
2. Epoxy potting system



2 – Progress/Results (cont'd)

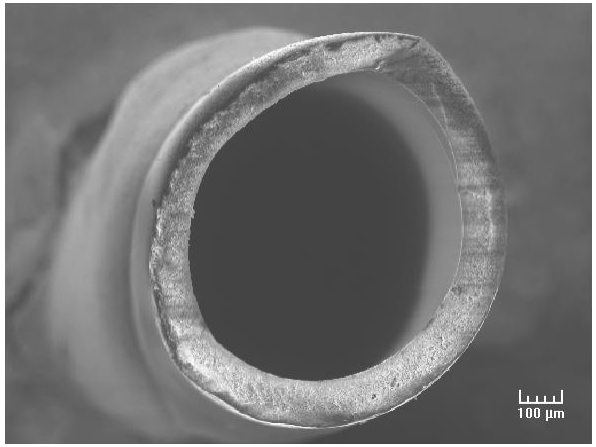
Develop epoxy/potting system

- Epoxy resistant to ethanol at 120^{o}C was demonstrated
- 1.5 year exposure test
  - ✓ Retained bonding capability
  - ✓ Retained sealing capability for ethanol vapor

2 – Progress/Results (cont'd)

Develop hollow fiber membranes

- Composite hollow fiber
  - Optimized microporous hollow fiber support
  - Coated CMS perfluorinated polymer on support
  - Fabricated several thousand feet of membrane
- Testing shows that the membrane meets gas tests performance specifications
- Soaking in hot ethanol does not affect performance



2 – Progress/Results (cont'd)

Scale-up/Optimize module performance

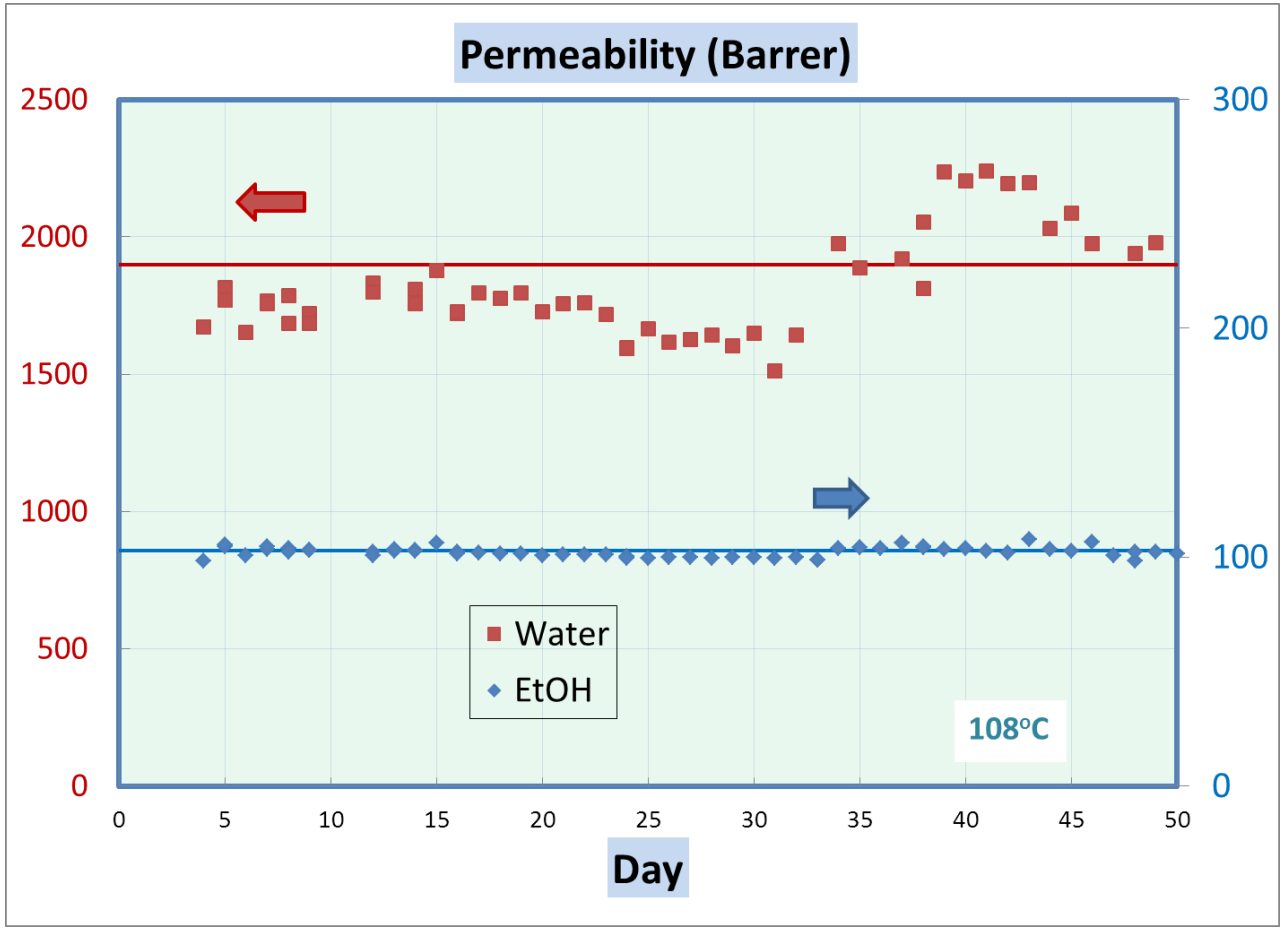
Successfully scaled up membrane module

- Scale-up factor: 150x
- Performance conserved

Area (ft^2)	H2O permeability (Barrer)	EtOH permeability (Barrer)
0.05	1500	110
7.5	1900	100

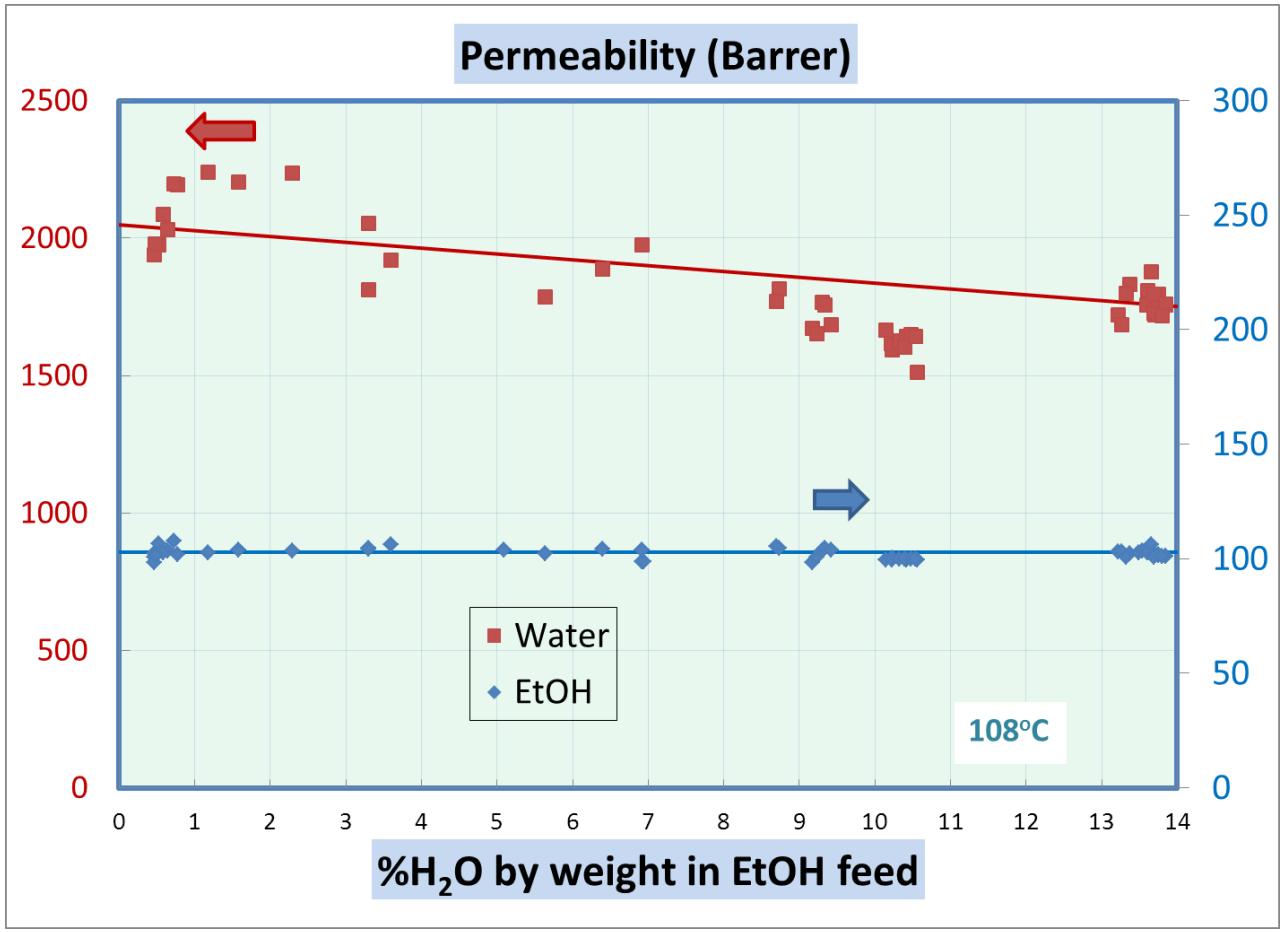
2 – Progress/Results (cont'd)

Demonstrated stability for at least 30 days



2 – Progress/Results (cont'd)

Demonstrate production of 99.5% ethanol



3 - Relevance

- ✓ This program has developed a more cost effective and energy efficient method of drying ethanol than conventional method
- ✓ The proposed method can be used in biofuel plants for final drying of product
- ✓ Implementation should facilitate production of fuels from biomass and promote energy independence
- ✓ Commercial liquid dehydration platform established
- ✓ Economic evaluation
  - ✓ Ethanol lower capital cost
  - ✓ Biodiesel better at up to 2M GPY

4 - Critical Success Factors

- ✓ Successful implementation of ethanol from cellulosic sources
- ✓ Pilot demonstration at ethanol plant
- ✓ Successful field demonstration
- ✓ Overcoming industry risk-aversion

5. Future Work by CMS

Field demonstrations

Market development and Commercialization

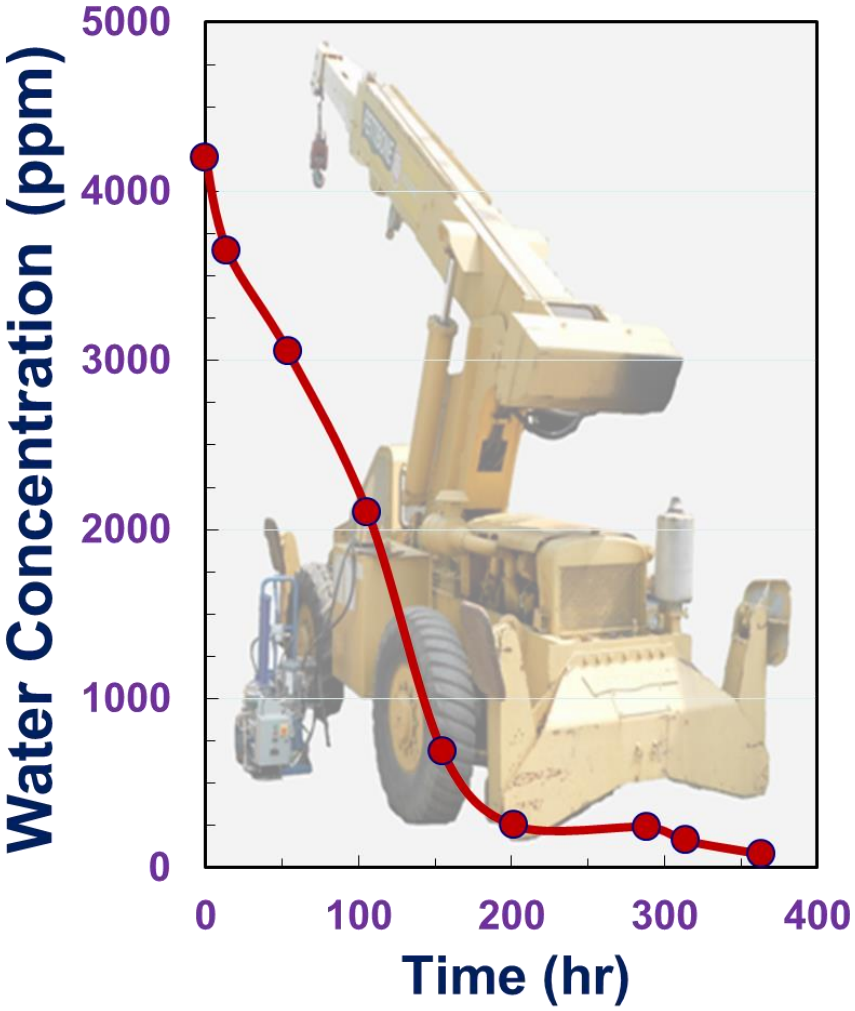
Summary

Developed membrane system
for drying ethanol and demonstrated:

1) Ethanol and high temperature (up to 120^{o}C) resistant components
2) Drying ethanol to fuel grade
3) Long term stability
4) Stable performance over wide range of water content (<0.05%)
5) Rugged: withstood dozens of startup/shutdown cycles

Additional Slides

Additional Slides



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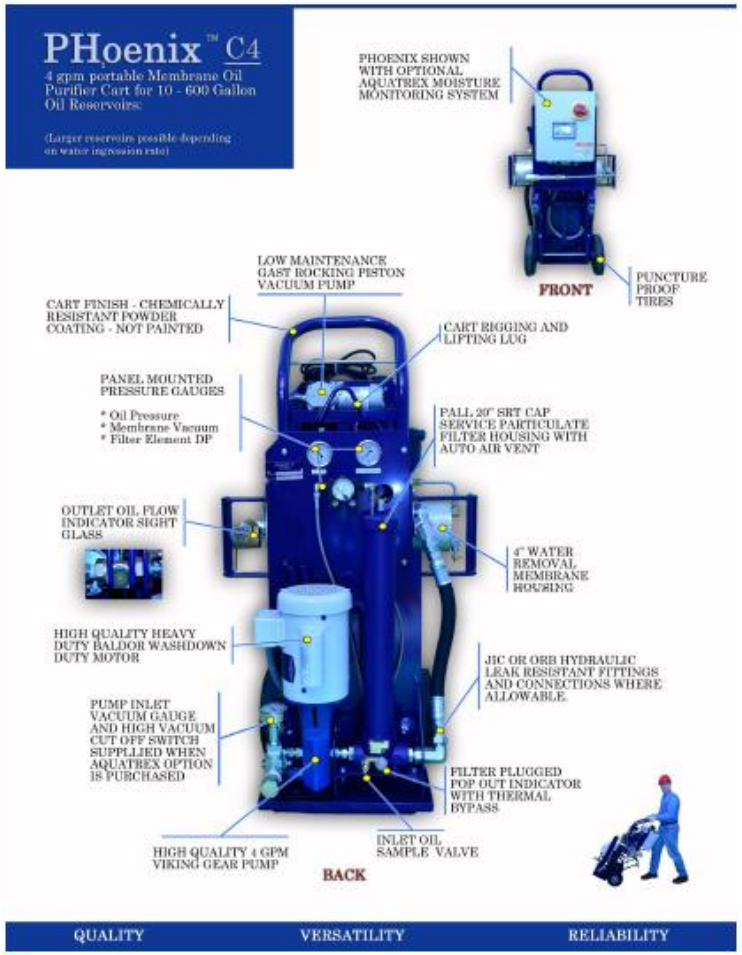


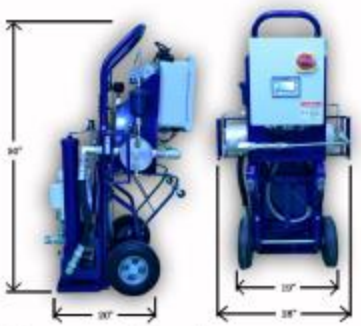
PHoenix™ C4

Specifications

Flow Rate: 4 gpm constant
Inlet/Outlet Connections: 1" Male JIC
Available Voltage: 110 V or 220V
Max Amp Draw: 10 Amps
Fluid Pump Motor: 1/2 HP Washdown
Dry Weight: 250 Lbs
Inlet Pressure Range : -10 hg - 10 psig
Max Outlet Pressure: 45 psig
Maximum Oil Viscocity: 3000 Cst
Minimum Oil Viscocity: 10 Cst
Maximum Operating Temp: 190 F
Minimum Operating Ambient: 33F
Maximum Free Water Removal: 2-3 Gallons/Day
(Depending on Water Content, Oil Temp and Oil Type)

Oil Type: Low Volatile Mineral Based
Phosphate Ester Optional

Recommended Oil Reservoir Size: 10 - 600 gallons
(Larger Possible depending on water ingression rate)



Dimensions

Spare Parts	Qty	Part Number
Vent Filter	1	FS-05-25
V Seal Kit	2	K757
219 Filter	1	UE219++20Z
Optional 319	1	UE319++20Z

Filter Micron add to ++ in Part Number

AZ 1 Micron
AP 3 Micron
AN 7 Micron
AS 12 Micron

Ordering Information

PHX-C4 | Table 1 Voltage | Table 2 Aquatrex | Table 3 Housing | Table 4 Oil Type

Table 1: Voltage Options

A	110 V 60Hz - SP Standard
B	220 V 60Hz - SP Optional

Table 2: Aquatrex Moisture Monitoring

C	Without Aquatrex
D	With Aquatrex

Table 3: Filter Housing Option

E	20" Pall UR219 7 Micron
F	20" Pall UR319 7 Micron

Table 4: Oil Type

G	Mineral Based Only
H	Phosphate Ester

Publications, Presentations, and Commercialization

- U.S. Patent application (US20120283489), “Removal of Water from Fluids”, has been allowed
- CMS working with two potential users to demonstrate/implement CMS technology in their commercial operations
- Market development study commissioned by CMS is under way
- Commercial liquid dehydration platform established