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%

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

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

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
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
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°C was demonstrated

• 1.5 year exposure test
  ✓ Retained bonding capability
  ✓ Retained sealing capability for ethanol vapor
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
Successfully scaled up membrane module

- Scale-up factor: 150x
- Performance conserved

<table>
<thead>
<tr>
<th>Area (ft²)</th>
<th>H₂O permeability (Barrer)</th>
<th>EtOH permeability (Barrer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>1500</td>
<td>110</td>
</tr>
<tr>
<td>7.5</td>
<td>1900</td>
<td>100</td>
</tr>
</tbody>
</table>
Demonstrated stability for at least 30 days
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°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
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