Advanced Water Removal via Membrane Solvent Extraction

Reduction in energy and water use for the ethanol industry

Ethanol is the leading biofuel in the U.S. with 13 Billion gallons produced in 2010.[1] Distillation is the industry standard for separating water from ethanol and is an energy intensive process, accounting for a significant portion of the total energy usage in an ethanol plant. Existing distillation systems also require high volumes of cooling water, resulting in about four gallons of water used for every gallon of ethanol produced.[2]

A novel membrane solvent extraction (MSE) technology is being developed to augment distillation and substantially decrease the energy and water consumption in ethanol production. This patented low-energy separation process uses a porous membrane to separate ethanol from the fermentation broth using an extraction solvent.

By separating the majority of the water from the pure ethanol product at low temperatures, the MSE process reduces the thermal heating and cooling loads and can operate using waste energy streams available within the plant.

In addition to water and energy savings, MSE can continuously remove ethanol from the fermentation process thereby accelerating fermentation and increasing throughput without the installation of additional tankage. MSE technology is an excellent fit for second generation (cellulosic) ethanol production because acceleration of fermentation and separation of the low concentration ethanol is crucial to commercializing cellulosic biomass as a feedstock.

Benefits for Our Industry and Our Nation

The MSE process increases the efficiency of the ethanol industry by reducing the energy requirements of separating ethanol and water on an industrial scale. Also, the reduction in cooling requirements that MSE allows decreases the need for cooling water, thereby improving the environmental impact of the industry.

By reducing energy and water inputs, MSE reduces the cost of producing ethanol from corn or next generation (cellulosic) feedstocks, making ethanol more cost-competitive with imported fossil fuels. By allowing greater throughput at existing ethanol facilities without additional fermentation tanks, MSE increases utilization of installed capital equipment, which allows for rapid expansion of the ethanol industry.

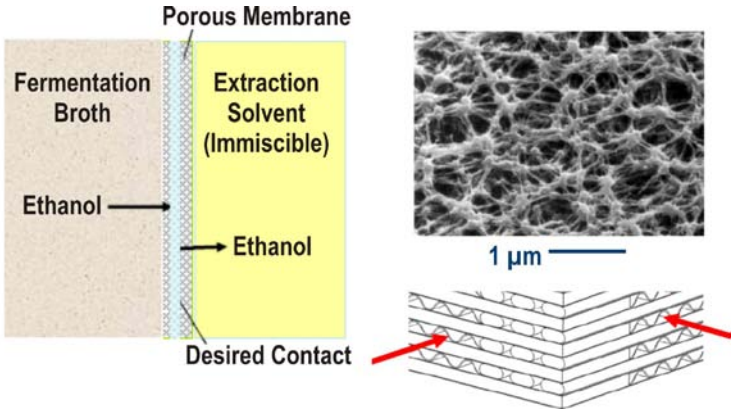

Fig1. Left – Schematic of separation of fermentation broth and a high-boiling extraction solvent using MSE. Right – Close up of microporous-membrane. By stacking layers of the membrane and incorporating integral channels, a high surface area for separation can be obtained.

Image courtesy of 3M.

Applications in Our Nation's Industry

MSE is applicable for wet-mill and dry-mill corn-based fermentation, as well as future cellulosic based fermentation. The MSE product/process can be retrofitted to an existing plant or can be a part of the basic design for newly constructed plants.

Project Description

3M has developed a membrane solvent-extraction (MSE) technology that shows promise to substantially decrease energy and water consumption in ethanol production. This project will focus on further concept and technology development and verification at the pilot scale.

Barriers

- MSE has been demonstrated at the lab-scale. Significant work is needed to complete the technology development and testing at the prototype/pilot scale.
- While the application of MSE for ethanol-water separation is a promising new technology, models based on data from a prototype scale installation must be evaluated to verify that MSE will be cost-competitive with existing separation techniques.

Pathways

The project team used a bench-top system to optimize membrane module construction and extraction solvent. A prototype process including fermentation, MSE, and distillation with fully functional controls instrumentation will be operated in order to develop data for commercial validation.

A significant effort will be placed on predictive modeling and simulation to determine the energy and water savings of the MSE technology in potential production plant systems.

An important component of this research effort is to assess and develop the extractive fermentation process to maximize the operational advantages and water savings.

Milestones

This project started in September 2008.

- Demonstration of concept feasibility at bench scale (Completed)
- Development and testing of MSE module assembly process
- Development and testing of prototype scale MSE process
- Development of models and informational databases
- Predictive modeling and simulation of process equipment performance
- Evaluation of system scalability and end-user acceptability (at pilot scale)

Commercialization

In order to successfully commercialize MSE, 3M realizes that it must demonstrate technical capability and operational scale to its potential customers. 3M will begin with a small demonstration and add plants one at a time. The company also intends to build out the capability to handle multiple customers at the same time, including smaller or independent ethanol plants.

3M has already filed patent protection for the MSE module and process. To encourage market acceptance, 3M wishes to consider as public domain the base integration design of MSE into an ethanol plant. 3M has also publicly disclosed its base MSE design. This disclosure will permit other ethanol producers or design firms to improve the base design and to custom-fit MSE into their own proprietary processes.

Project Partners

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(endnotes)

1 Renewable Fuels Association home page, 2011, www.ethanolrfa.org.

2 "Current Outlook, Profitability, and Weather Information," Iowa State University, University Extension, accessed May 17, 2011, www.extension.iastate.edu/agdm/info/outlook.html

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