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INNOVATIVE RESEARCH FOR A SUSTAINABLE FUTURE

Improving Biofuels Recovery Processes for Energy Efficiency and Sustainability

Introduction

Biofuels are made from living or recently living organisms. For example, ethanol can be made from fermented plant materials.

Biofuels have a number of important benefits when compared to fossil fuels. Biofuels are produced from renewable energy sources such as agricultural resources. When used in place of imported fossil fuels, biofuels can help reduce U.S. dependence on foreign oil. Biofuels can also have fewer environmental impacts than fossil fuels.

The 2007 Energy Independence and Security Act (EISA) called for increased biofuel production. The EISA also set standards for renewable fuels achieving 20, 50, and 60% reductions in greenhouse gas (GHG) emissions relative to fossil fuels.

GHG emissions from renewable fuels are primarily due to feedstock production, conversion of feedstock to fuel (upstream emissions), and fuel use. For corn-based ethanol, about 50% of the energy consumed in the production facility is due to the separation processes of distillation and adsorption used to recover and dry ethanol from fermentation broths, leading to significant upstream GHG emissions.

Method

The US EPA has proposed that pervaporation and vapor permeation, two emerging membrane technologies, can provide energy savings and reduce product recovery costs over traditional technologies, especially for smaller systems.

Pervaporation involves the selective permeation and evaporation of compounds in a liquid feed into a vapor phase. For example, an alcohol-selective membrane yields concentrated ethanol vapors from dilute solutions. A water-selective membrane yields water-enriched vapors while dehydrating the feed liquid. EPA researchers have also used pervaporation in other environmental applications (ex. the separation of chlorinated solvents and gasoline organic compounds from the water and surfactant solutions used in soil flushing).

Vapor permeation is identical to pervaporation except all process streams are vapors.

Goal

A goal of this research is to demonstrate at the pilot-scale the recovery of ethanol from the fermentation of a waste biomass. The research helps make the biofuel system as environmentally neutral, energy-efficient and sustainable as possible.

Vapor Permeation Results

EPA researchers evaluated hybrid systems which synergistically combine vapor permeation membrane systems with traditional separations such as distillation. Membrane Assisted Vapor Stripping (MAVS), a hybrid system developed at EPA (see picture and schematic), was predicted to deliver fuel-grade ethanol using 50% less energy than current separation technologies. In MAVS, the stripping column obtains high alcohol recoveries and low effluent concentrations. The vapor compressor and membrane enable the efficient recovery of latent and sensible heat from both the retentate and permeate vapor streams.

The EPA team evaluated the energy savings of MAVS through chemical process simulations and verified the predictions with experiments on a five weight percent ethanol aqueous feed stream.

Membrane Assisted Vapor Stripping unit at EPA's Test & Evaluation Facility.

Pervaporation Collaborations and Results

Through a cooperative research and development agreement, EPA and Membrane Technology & Research, Inc. (MTR) demonstrated a new method for recovering and concentrating ethanol and other organic chemicals from water. The

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approach combines pervaporation with a vapor condensation technology called dephlegmation.

An MTR pervaporation pilot unit was integrated with the EPA dephlegmator at the EPA's Test & Evaluation Facility in Cincinnati, Ohio to evaluate the ethanol recovery performance of the combined technologies. Results have been quite promising. The combined technologies concentrated a stream containing 1 to 5 weight percent ethanol to over 90 weight percent ethanol. This MTR/EPA project was funded, in part, through a Phase I Small Business Innovative Research grant to MTR from the National Science Foundation.

In collaboration with several industrial and academic partners, EPA's Pervaporation Team has demonstrated a novel pervaporation-based ethanol recovery technology which enables the economical production of ethanol from biomass readily available throughout rural areas. One project targeted whey, a byproduct of cheese production. A typical cheese facility generates enough whey to produce around 1-2 million gallons of ethanol per year (MGY). Though the capacity of one whey-to-ethanol facility is much smaller than the 50 MGY capacity of a typical corn-to-ethanol facility, the ethanol production from hundreds of cheese facilities would be substantial.

Because of the high water content of whey, it is uneconomical to transport the material to a centralized ethanol production facility. A solution to this problem is an efficient, small-scale ethanol production and recovery system that enables the production of ethanol from cheese whey and other low-volume byproduct and waste streams.

EPA collaborated with membrane producer MTR, researchers from Argonne National Laboratory, and potential end-user Kraft Foods. The recovery of ethanol from a simulated whey process stream was demonstrated at the EPA's Test & Evaluation Facility.

Current Work

The MAVS technology is being further developed through a cooperative research and development agreement with MTR. The EPA and MTR are working with several potential end-users to adapt the technology to their biofuel production processes.

References

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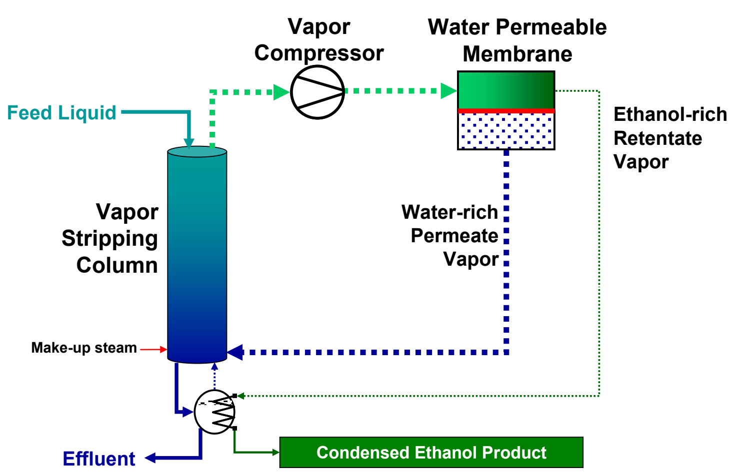

Schematic diagram of energy efficient Membrane Assisted Vapor Stripping process for alcohol recovery and dehydration.

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