Enhanced Separation Efficiency in Olefin/Paraffin Distillation

Improved Energy Efficiency in Refineries Through Hollow Fiber Technology

Petroleum refining and chemicals manufacturing are two of the most energy-intensive industries. The energy consumption by these two industrial sectors for separations in distillation processes is significant. Conventional distillation processes are thermally driven and have low energy efficiencies.[1] Distillation alone consumes 2,400 trillion Btu/yr, representing over 10% of the energy consumed by the entire manufacturing sector.[2] While non-thermal processes are being developed, anything that can be done in the near-term to improve the separation efficiency of existing equipment will have a significant impact.

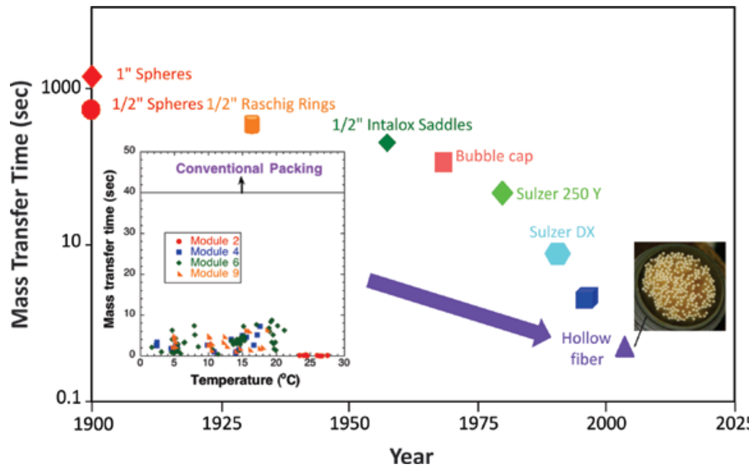
While incremental improvements in petroleum distillation provide only a marginal increase in performance, each percent saving in the net energy use of this sector can amount to the energy savings of 10 trillion Btu and CO_2 emission savings of 0.2 million tons per year.[3]

To achieve these energy savings, researchers will replace the conventional packing materials used in distillation columns for olefin/paraffin separations with hollow fibers. Appreciable increases in the separation efficiency are expected, resulting in significant energy savings.

The technology will be initially applied to olefin/paraffin distillation, which together with ethylene, propylene, n-butane, and isobutane, are the largest commodity chemicals in the U.S., and major building blocks for petrochemical industries.

Benefits for Our Industry and Our Nation

The use of hollow fibers in distillation columns can help refineries decrease operating costs, reduce greenhouse gas emissions through reduced heating costs, and help expand U.S. refining capacity through improvements to existing sites, without large scale capital investment. This cost effective increase in refining capacity can significantly increase market competitiveness and promote job growth in the U.S. hydrocarbon processing sectors. The energy benefits associated with this technology will be significant. Every year, 500 trillion Btu are consumed in the distillation of liquefied petroleum gases and olefins alone.[4] Potential savings from moderate improvements in distillation efficiency are estimated at 10–50 trillion Btu and up to 0.5 million tons of CO_2 per year.[5]



The data presented in this plot is based on E. L. Cussler's paper in *J. of Chem. Tech. and Biotech.*, 78, 98-102, 2003) and the papers of D. Yang, et al. in *J. of Membrane Science*, 279 (2006) 61–69 and 304 (2007) 88–101.

The enhancement of separation efficiency of different packing materials over the past century

Photo was taken by D. Yang.

Applications in Our Nation's Industry

Improvements in hydrocarbon-light gas separation processes represent the largest area for potential cost reductions for the entire hydrocarbon industry that includes natural gas processing, oil refining, and petrochemicals. In addition to its application in refining, this technology is applicable to several other markets, including commodity chemicals manufacturing, such as vacuum distillation and industrial gas separations.

Project Description

The main objective of this research effort is to develop technologies to enhance separation efficiencies by replacing the conventional packing materials with hollow fiber membranes, which have a high specific area and separated channels for both liquid and vapor phases. This new type of packing materials can result in high separation efficiency and high capacity.

The project team will evaluate the effects of reflux ratio on separation efficiency and optimize system operation for maximum efficiency without flooding events. The reflux ratio is the proportion of compound distilled off to the proportion left in the distillation column. Ultimately, the team will evaluate the possibility of scaling up the technology for commercialization.

Barriers

- Need to evaluate the effects of reflux ratio on the separation efficiency and the column capacity
- Unknown operational stability under temperature and pressure fluctuations and changeable reflux ratio
- Unknown optimal module design that results in the best separation efficiency without flooding the column

- Need for membranes that can be used at higher temperatures without losing mechanical integrity

Pathways

Researchers plan to design hollow fiber modules, which can be operated at loadings 2–10 times greater than that used in their preliminary work. The team will also build an experimental apparatus to conduct distillation experiments under a wide temperature and pressure range. Systematic experiments will be carried out under various reflux ratios. Project partners will quantify the separation efficiency and operational stability of various module designs, hollow fiber materials, and operating conditions.

Milestones

This project started in September 2008.

- Construct an experimental apparatus that allows separation efficiency, and energy balance measurement necessary for evaluating the energy consuming in the distillation processes of a typical oil refinery (Completed)
- Quantify the separation efficiency and energy balance for the selected energy intensive distillation processes (Completed)
- Examine operating parameters for the separations of highest economic attractiveness and develop fundamental understanding to determine the optimum design for a pilot scale demonstration
- Identify opportunities for development of new hollow fiber materials for extreme operation conditions that could further improve the economics (Completed)

Commercialization

Los Alamos National laboratory (LANL) and Chevron have a well established co-operative research and development relationship called the “Alliance for Advanced Energy Security.” The Alliance has been in place for the last four years and has successfully commercialized many technologies.

In commercialization of these previous technologies, the Alliance has engaged third-parties as needed to build the basic technology into a full commercial product. Some of these third parties have become the commercial suppliers of the new product to the end users. Once this project is successfully completed, Chevron plans to use the engineering data generated from this project to design and construct a larger scale unit that can be tested and operated in one of their refineries. The unit would be designed to operate with real, multi-component plant feeds.

Project Partners

Los Alamos National Laboratory
Los Alamos, NM
Principal Investigator: Dali Yang
E-Mail: dyang@lanl.gov

Chevron Products Company
Richmond, CA

Morrison Consulting, Inc.
El Rito, NM

Spectrum Laboratories, Inc.
Rancho Dominguez, CA

For additional information, please contact

Dr. Bhima Sastri
Technology Manager
U.S. Department of Energy
Industrial Technologies Program
Phone: (202) 586-2561
E-mail: bhima.sastri@ee.doe.gov

(endnotes)

1. Peter Angelini et al., Materials for Separation Technologies: Energy and Emission Reduction Opportunities, produced by BCS Incorporated, Columbia, MD and Oak Ridge National Laboratory, Oak Ridge, TN (Washington, DC: U.S. Department of Energy, May 4, 2005), http://www1.eere.energy.gov/industry/imf/pdfs/separationsreport.pdf.
2. Angelini, Materials for Separation Technologies; Richard B. Chapas and Jeffery A. Colwell, Industrial Technologies Program Research Plan for Energy-Intensive Process Industries, PNNL-17075, produced by Battelle Memorial Institute (Washington, DC: U.S. Department of Energy, October 2007), http://www1.eere.energy.gov/industry/pdfs/itp_research_plan.pdf.
3. Angelini, Materials for Separation Technologies.
4. Angelini, Materials for Separation Technologies; Chapas, Industrial Technologies Program Research Plan.
5. Dali Yang et al., “Hollow Fibers as Structured Packing for Olefin/Paraffin Distillation,” (presentation, 8th World Congress of Chemical Engineering, Montreal, Canada, 2009); Dali Yang et al., “Light Hydrocarbon Distillation Using Hollow Fibers as Structured Packings,” Journal of Membrane Science 362, no. 1–2 (October 2010): 86–96.

Bibliography

Yang, D., D.J. Devlin, and R.S. Barbero, “Effect of Hollow Fiber Morphology and Compatibility on Propane/Propylene Separation,” Journal of Membrane Science 304, no. 1–2 (2007):88–101.

Zhan, Goulian and E.L. Cussler, “Distillation in Hollow Fibers,” AIChe Journal 49, no. 9 (September 2003):2344–2351, doi:10.1002/aic.690490910.

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

EERE Information Center
1-877-EERE-INFO (1-877-337-3463)
eere.energy.gov/informationcenter

DOE/EE-0456 • May 2011

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.