Fluid Mixture Separation Technologies for Cost Reduction and Process Improvement

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FLUID MIXTURE SEPARATION TECHNOLOGIES FOR COST REDUCTION AND PROCESS IMPROVEMENT

Foreword

This book presents an assessment and evaluation of fluid mixture separation technologies in the oil and gas, chemical, and paper industries. These technologies are also pertinent for other industries. Significant cost reductions and the potential for process improvement are possible with the adoption of selected separation technologies as replacements for currently employed practices. Areas for further research and development are specified also.

Significant energy savings are possible if these technologies are implemented. In addition, the technologies may offer benefits such as lower operating temperatures (and less product decomposition), increased throughputs, better turndown capabilities, increased process reliability, and improved process safety.

The processes evaluated and assessed for fluid mixture separation are distillation with high-efficiency mass transfer devices, membrane separations, adsorption/desorption, extraction, and crystallization. The evaluations include a review of concepts and theory, the state of the art, potential applications, and research suggestions. This book should prove to be an excellent overview of these replacement technologies.

The information in the book is from *Assessment of Potential Energy Savings in Fluid Separation Technologies: Technology Review and Recommended Research Areas;* prepared by Jose L. Bravo, James R. Fair, Jimmy L. Humphrey, Chris L. Martin, Albert F. Seibert, and Sudhir Joshi of the University of Texas at Austin; for the U.S. Department of Energy; December 1984.

The table of contents is organized in such a way as to serve as a subject index and provides easy access to the information contained in the book.

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Contents and Subject Index

Excecutive Summary

The main objective of the Assessment of Potential Energy Savings in Fluid Separation Technologies was to review and evaluate fluid mixtures separation technologies in the oil and gas, chemical, and paper industries that would show significant energy savings if implemented in place of current practices. As a result of such review and evaluation, several separation technologies were identified as having the best potential for short- to medium-term application. These technologies are shown in Table ES-1. Finally, a number of research areas in these technologies were identified. Developments in these areas would in turn improve the potential of the technology for industry. Table ES-2 shows general research areas that have to be addressed to improve the applicability of the five technologies discussed in this report. A detailed analysis of these areas as they apply to each individual technology comprises the bulk of the report.

An evaluation procedure was devised for this project to aid in the identification of fluid mixture separation technologies that showed the most potential for application. The methodology followed for this evaluation, as well as the screening criteria and grading characteristics used, is described in detail in the Project Overview section of the report.

The evaluation process was undertaken by a team of six chemical engineers with diverse backgrounds and experience. All decisions concerning the application of screening criteria and the selection of the grading characteristics and corresponding weight factors were arrived at by a consensus of all the members of the evaluation team. The grading of each technology was done individually by each member of the team. The total scores produced by individuals differed, as was expected, from one another, but the ranking order of the technologies was almost identical from one team member to another. Averaging of the total scores produced a ranking that agreed with the individual rankings.

At this point in the project, a decision was made to study in more detail the highest ranking technologies. The ones selected for further study were the seven with the highest scores plus liquid/liquid extraction. To avoid duplication, these technologies were condensed into five: distillation with high-efficiency mass transfer devices, membrane separations (including gas and liquid permeation as well as pervaporation), adsorption, extraction (including liquid/liquid and supercritical extraction), and crystallization.

The current energy use of the last four technologies was estimated. The results of this baseline assessment show that at present more than 95% of the energy used in the oil, chemical, and paper industries for separation processes is expended in distillation. All the other technologies combined account for less than 5%. The most important applications of these alternative technologies are summarized in Table ES-3.

The next step in the project was to review the state of the art of research for each of the five areas of technology chosen. This was done to determine what research frontiers are of importance in a particular technology and which topics should be addressed if the technology is to have an improved probability of application with the inherent energy savings. Tables ES-4 through ES-8 summarize the most important research areas for each of these technologies.

As a corollary to this project, it can be concluded that two avenues exist for the reduction of energy consumption in separation processes at a national level: improvements on the energy efficiency in distillation and the replacement of distillation with less energy-intensive technologies.

It should also be recognized that industry would be much more interested in adopting energy saving technologies if such techniques provided other benefits in addition to a reduction in energy use. Such benefits might include lower operating temperatures (and less product decomposition), increased throughputs, better turn-down capabilities, increased process reliability, and improved process safety. In many cases, energy savings alone would not make a process modification attractive to industry. Nevertheless, if energy savings are accompanied by one or more of these other features, the chances of implementating the less energy-intensive separation technology are greatly enhanced.

Table ES-1

FLUID MIXTURE SEPARATION TECHNOLOGIES WITH BEST POTENTIAL FOR SHORT- TO MEDIUM-TERM APPLICATION

Distillation with high-efficiency mass transfer devices
Membrane separations (gas and liquid mixtures)
Adsorption
Extraction (liquid/liquid and supercritical)
Crystallization

Table ES-2

GENERAL RESEARCH AREAS IN FLUID MIXTURE SEPARATION TECHNOLOGIES

- Generalized theory development
- Expansion of data base
- Development of mass, heat, and momentum transfer models
- Study of physicochemical effects at phase boundaries
- Screening and testing for new applications
- Development of process design and scale-up techniques

Table ES-3

VARIOUS SEPARATION TECHNOLOGIES AND THEIR ENERGY CONSUMPTION

Technology	Most Common Applications	Yearly Consumption (quads)
Adsorption	n-paraffins	0.0018
	p-xylene	0.0113[a]
Liquid/liquid extraction	BTX	0.049[b]
	lube oil refining	0.021[b]
Crystallization	p-xylene	0.0468[a]
	lube oil dewaxing	0.007
Supercritical extraction	ROSE®	0.0011
Gas permeation	H_2/NH_3	0.00026 potential
	H_2/refinery gas	0.00001 potential
Liquid permeation	desalination	0.02[c]
	Total	0.158 quads/yr

[a] Includes energy used in isomerization.

[b] Most of this energy is used in separating solvents and solutes by distillation.

[c] Worldwide.

Table ES-4

DISTILLATION WITH HIGH-EFFICIENCY MASS TRANSFER DEVICES:

RESEARCH AREAS

1. Expand data base
2. Develop generalized models for mass, momentum, and heat transfer
3. Perform parametric studies to improve devices
4. Develop manufacturing techniques for devices

Table ES-5

MEMBRANE SEPARATIONS: RESEARCH AREAS

1. Generalized theory and expanded data base
2. Membrane materials science
3. Process engineering: membrane process design
4. Membrane manufacturing techniques
5. Membrane modules
6. Applications research (demonstrations)
7. Molecular sieve membranes

Table ES-6

ADSORPTION: RESEARCH AREAS

1. Equilibrium data and models

2. Design and analysis models

3. Process engineering: adsorption process design

4. Applications research

5. Molecular sieve membranes

Table ES-7

EXTRACTION: RESEARCH AREAS

SUPERCRITICAL EXTRACTION

1. Equilibrium and phase behavior
2. Entrainers and co-solvents
3. Generalized theory and models
4. Materials science
5. Applications research

LIQUID/LIQUID EXTRACTION

1. Entrainers and co-solvents
2. Generalized theory and models
3. Applications research

Table ES-8

CRYSTALLIZATION: RESEARCH AREAS

1.	Equilibrium and crystal formation kinetics
2.	Heat and mass transfer models
3.	Liquid occlusion mechanisms
4.	Process design
5.	Materials science
6.	Applications research