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EUROPEAN ROADMAP OF PROCESS INTENSIFICATION

- TECHNOLOGY REPORT -

TECHNOLOGY: Distillation - Pervaporation

TECHNOLOGY CODE:: 2.1.5.5

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Table of contents

1. Technology

1.1 Description of technology / working principle

This report addresses the hybrid technology of Distillation-Pervaporation, where a distillation column is coupled with a membrane module to enhance its performance.

It traces the history of the technology and considers how the challenges to its more widespread adoption on an industrial scale can be met.

The report also recognises that Pervaporation is now a well proven technology in its own right and used as a stand alone uint operation in many processes.

Pervaporation is seen as offering improved performance to a distillation system in three main ways:

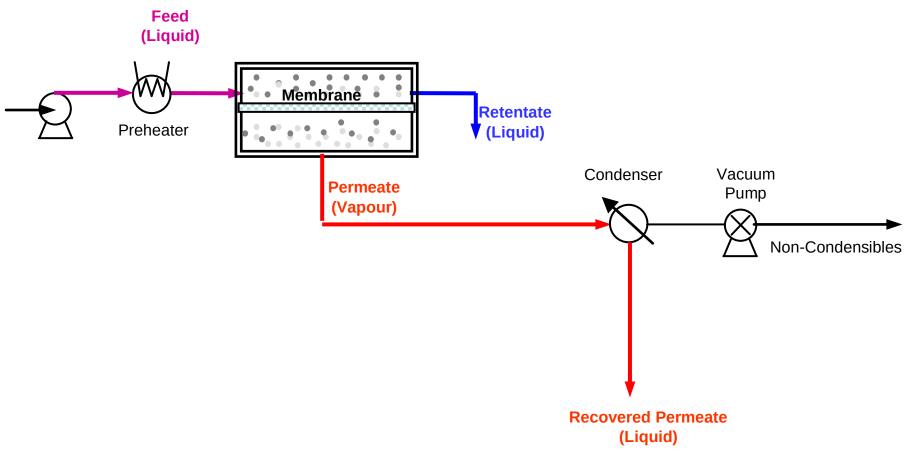
i. The breaking of an azeotrope without needing to add a "foreign" material.
ii. Increasing the capacity for the same overall energy input.
iii. Improving the quality of both bottoms and overhead product, without any increase in energy input.

The principles of Distillation are well understood but those of Pervaporation are perhaps less familiar, even though there are many stand alone industrial systems in operation.

Pervaporation is defined as a membrane based process for separating miscible liquids. In this respect it can be likened to Distillation as being an enrichment technique.

All membrane processes, such as Micro, Ultra and Nano filtration and Reverse Osmosis, involve a feed stream being separated into two outlets, a Retentate and Permeate. The Retentate is that part which is retained on the upstream side of the selective barrier that is the membrane, whilst the Permeate is that which has passed through. Pervaporation differs from these other membrane processes, in that there is a phase change either side of the membrane. Pervaporation is also unique amongst membrane processes in that the retentate leaves at a lower temperature than that of the feed. It loses sensible heat as a consequence of the evaporation of the permeate component. Some units are heated in order to assist with the permeability of target components.

For the phase transition, energy is required to drive a vacuum pump and to condense the recovered component. The downstream side is in the vapour phase. The target component of the feed mixture is absorbed by the non porous membrane, diffuses across it and evaporates as it is desorbed into a partial vacuum to become the permeate stream. A generic depiction of this is as below:



Membranes have to be selected for specific separations to have an affinity for the target permeate component. Generally, two factors determine which of the feed components are transported preferentially through the membrane:

i. The solubility of a component in the membrane matrix
ii. The diffusion rate through the membrane.

In general, for the separation of water from an aqueous solution, a polar or *Hydrophilic* membrane will be selected and conversely one with non-polar or *Hydrophobic* properties to remove a hydrocarbon. This might also be described as *Organophilic*. Separations are not always simple separations between water and organic phases but between different hydrocarbon entities, e.g. alkanes and alkenes or isomers of the same molecular formulation.

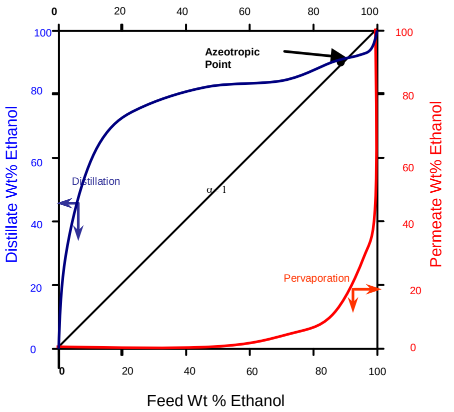
The term **PERVAPORATION** is derived from the nature of this particular type of membrane separation, in which the driving force for **PER**meation is e**VAPORATION**. It was first coined by P.A.J. Kober in 1917 [1]. In his paper he described how a liquid in a collodium bag, suspended in air, evaporated, even though the bag was non porous and tightly closed. Somewhat earlier in 1906, L. Kahlenberg reported some quantitative examples concerning the selective transport of hydrocarbon/alcohol mixtures through a thin rubber sheet [2].

However the discoveries were not really studied in any depth until the 1950s and 1960s, when much work began on membrane development

It has the place as the only membrane process primarily used to purify chemicals. Strictly however, in this context, it is coupled with its sister counterpart, Vapour Permeation. This functions very similarly, except that the feed stream is a mixed vapour.

For separation, pervaporation depends upon the difference in partial pressures across a membrane, whilst distillation is achieved because of the difference in volatilities of the components in a feed mixture. An adaptation of the familiar McCabe-Thiele diagram for the ethanol-water system, below, can be used to illustrate where the benefits of pervaporation lie. In the area of the azeotropic mixture, where distillation is very inefficient, pervaporation is extremely efficient.

To completely replace distillation with pervaporation on most large scale operations is not economically viable because of the huge membrane areas required. Membrane system costs scale up linearly with membrane area, whereas other separation systems generally scale to a volume$^{2/3}$ ratio. However, the merits of a Distillation-Pervaporation combination, using each where they are most efficient, are very clear.



McCabe-Thiele Diagram Ethanol-Water
Comparison of Pervaporation and Distillation Selectivities

In different configurations, the pervaporation step might be introduced in different locations, e.g.:

1. The feed stream to the distillation column
2. The bottoms stream
3. The condensed overheads
4. An intermediate liquid stream, from a strategic point between plates or packed sections within the column.

Each will be designed to provide an improvement to the separation of a specific component at that point in the system.

1.2 Types and “versions”

There can be a number of variants to a hybrid Distillation-Pervaporation system, with the pervaporation module or modules providing improved performance at different locations.

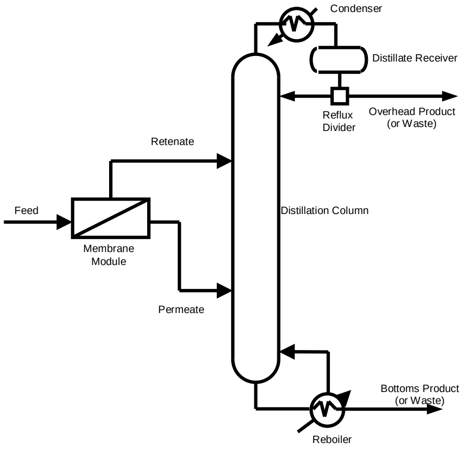
An upgrade of an existing system might see modules being inserted at more than one location.

There are opportunities in the following streams:

1. Feed
2. Overheads
3. Bottoms
4. At a mid take off point

It is convenient in analysing the performance of a hybrid system to relate the separation achieved in a pervaporation stage to an equivalent number of distillation column plates or height of packing. This analogy cannot be used where a simple distillation is met by an azeotropic mixture.

Simple illustrations of hybrid systems are shown below.



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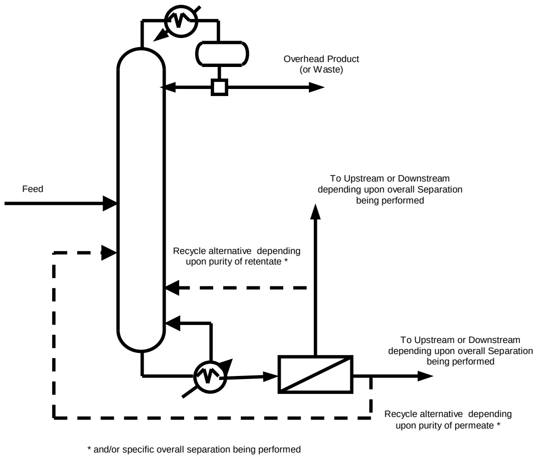

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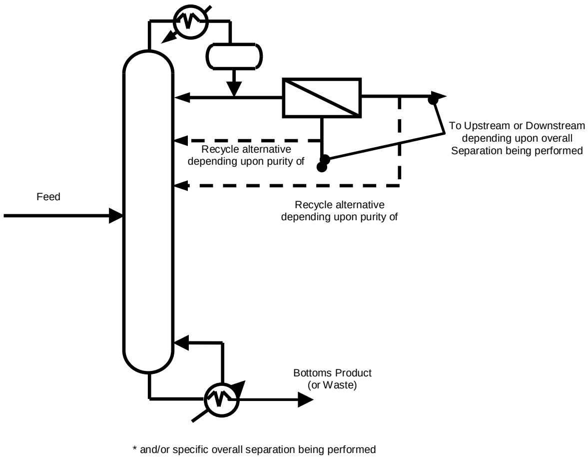

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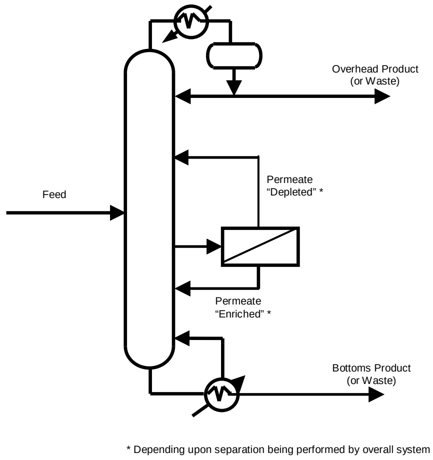

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As indicated above, Pervaporation involves a feed stream in the liquid phase. A variation of the same technique has a vapour feed but otherwise operating on the same principle. This technology is termed Vapour Permeation.

In the overhead stream either Pervaporation or Vapour Permeation might be employed.

Whilst vacuum is the predominant means of promoting the partial pressure difference between the two sides of the membrane, some systems use a sweep of an inert carrier gas across the surface of the downstream side to "capture" the desorbed component. In both cases the phase change across the membrane occurs because the partial pressure of the permeating component is lower than the corresponding saturation pressure.

In a hybrid system combined with a distillation column it can provide improved separation of the overheads vapour stream ahead of a reflux condenser.

The critical component in a membrane module is of course the membrane itself. The thin separation layer is designed to be selectively permeable by the target component. In polymeric membranes the degree of cross linking has a significant impact on quality of selectivity and capacity. Poly Vinyl Alcohol (PVA) is a widely used polymer for membranes.

Highly cross linked membrane exhibit high selectivity but low flux (Flowrate/unit surface area). With weakly cross linked membranes this combination is reversed.

Polymeric membranes have almost always been used in pervaporation as flat sheets. Configuring them as spiral does not offer any distinct advantages but hollow fibre structures can offer benefits. Compactness because of high packing density is one. Also, they require no membrane support, can be operated at very high pressures and are easier to fabricate. The major disadvantage is high pressure drop. Overall, the hollow fibre configuration offers distinct advantages over the flat sheets but the selection of a given configuration should be addressed individually, based on membrane properties and the throughput rates desired.

Polymeric membranes have temperature limitations, with 110^{O}C being an upper limit. This has an impact on the partial pressure difference that can be achieved. Ceramic membranes allow operation at 200^{O}C where, for water, the partial pressure difference is increased by a factor of 15 compared with 100^{O}C, allowing more water through the membrane in a dehydration operation. As a rule of thumb, flux rates double for every 20^{O}C increase in temperature [3].

Examples of polymer membranes are Polyvinyl chloride/ polyvinyl acetate copolymer. (PVC-PCac) composites [4].
Ceramic membranes can withstand significantly higher temperatures. Much effort has been devoted to developing these in tubular configuration.

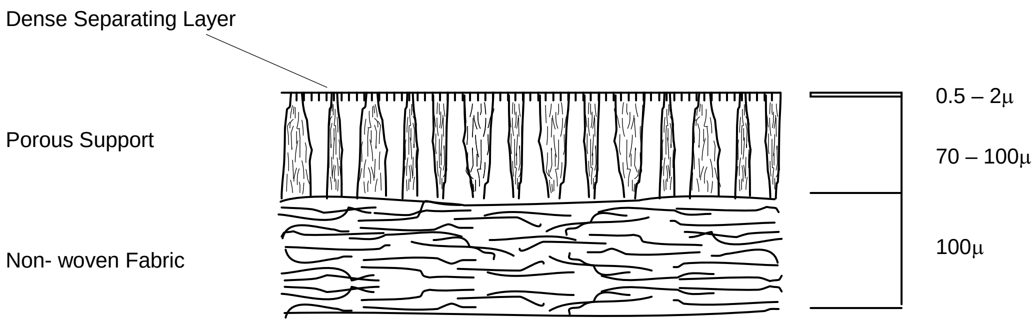
Zeolites, which are aluminosilicate members of the family of microporous solids in widespread use as molecular sieves, are suitable in aqueous and organic solvent environments. They have pore sizes of approximately 4Å and allow the passage of water molecules and are used for organic separations. . Zeolites can withstand significantly higher temperatures than polymers (>200^{O}C) but their achilles heel is sensitivity to even weak acids. Below pH 6 the zeolite layer is irreversibly leached from the ceramic substrate.

A wide range of microporous Silicon Dioxide membranes have been developed. These are compatible with both strong acids and alkalis and also organic solvents. They can also withstand temperatures up to 240^{O}C.

Other types of membrane have up to 30% Silicon Dioxide particles dispersed in a polymer matrix.

As though reverting back to the work of Kahlenberg in 1906, highlighted above, elastomers, such as nitrile rubber, are also used as membranes

Typical membrane structure:



There are many assessments in the literature of different membrane types but an analysis of the use of the technology for its potential in making dramatic energy savings in industry calls for more research into membrane development [5].

1.3 Potency for Process Intensification: possible benefits

Separation processes account for 40-70% of the capital and operating costs in industry. Distillation is a very energy intensive process and consumes about 40% of the energy used in the chemical and petroleum refinery industries and about 95% of that for separation. Whilst distillation is flexible and of low capital cost relative to other separation technologies its thermodynamic efficiency is only of the order of 10% [5].

A view has been expressed that almost every column in operation today could be retrofitted with pervaporation with attractive environmental and economic benefits. At some scales this can also mean total replacement.

Table 1: Documented and expected benefits resulting from technology application

Benefit	Magnitude	Remarks
Reduced energy consumption for the same feed rate capacity and separation as a stand alone distillation system	Overall reduction of 25 -40% in energy consumption for same separation of target components.	Reboiling heat and overhead condenser cooling loads reduced.
Improved quality of overhead and bottoms products	As an example, for a C_4 – C_7 feed mixture, composed of 23% n-Pentane and 50% iso-Pentane, with object of recovering iso-Pentane in overheads and n-pentane in bottoms. In overheads purity of iso-pentane increased by 1.8% (93.7 to 95.4), n-Pentane reduced by 1.7% (2.5 to 0.8) Bottoms n–Pentane purity raised by 2.9% (44.9 to 46.2), iso-Pentane content reduced by 50% (1% to 0.5%)	Introduction of pervaporation stage has the equivalent effect of increasing the number of plates or height of packing in a distillation column
Breaks azeotrope.	Simple distillation cannot achieve	Avoids need for introduction of "foreign" component for extractive distillation that presents possible risk of contamination and/or need to remove downstream.

One set of published [6] comparative operational costs per unit weight of product for dewatering of Iso-Propyl Alcohol costs, relative to a base of 100, is:

	500kg/hr	2000kg/r
Distillation alone	100	70
Pervaporation alone	105	70
Distillation-Pervaporation	75	40

Another, in comparing extractive distillation for breaking an azeotrope, shows an operating cost advantage for Distillation-Pervaporation of 60:100 so the benefits are appreciable.

1.4 Stage of development

Whilst there has been much research carried out on a range of separations and work done on membrane development by suppliers, industry has been generally slow in adopting the technology. Europe and Japan have been more active than the US. This may be because historically there was not much priority given to membrane development in the US but perhaps also a reflection of Europe's and Japan's acceptance of Kyoto protocols and environmental emission limits. However the system should fit nicely into the US policy of reducing emissions by implementing new technologies.

The advent of biofuels is creating renewed interest in Distillation-Pervaporation. and GEA Wiegand has been successful in providing a plant for Verbio in Nordbrandenburger, Germany. This was commissioned in 2005.

If membrane suppliers can develop more robust and reliable membranes much of the reluctance to invest in the technology might disappear.

2. Applications

2.1 Existing technology (currently used)

The different types of separation that have been demonstrated by the hybrid technology under consideration here are:

- Dehydration of alcohols
- Separation of isomers of similar molecular entities, e.g. n-propanol and iso-propanol
- Concentration of aqueous solutions

Distillation alone is the technology conventionally used to perform these separations.

This is in both continuous and batch operations. Distillation columns might have valve trays, bubble caps or perforated plates for contacting rising vapours and falling liquids.

Alternatively, they might be packed towers with sections of structured packing or randomly filled with, e.g. Raschig rings, Berl saddles, Pall rings.

Batch applications can be associated with reactors where solvents need to be separated at some point in the cycle from the system mass.

2.2 Known commercial applications

Dehydration of solvents is the most widespread use of Distillation-Pervaporation, where the ability to break azeotropes without the introduction of a third component is of great benefit. Ethanol and Iso-proponal are the two most extensively processed using hybrid installations.

Despite the discovery of pervaporation in the early 1900s, the first full scale plant did not come into operation until1982 in Brazil. This was because it was not until the 1960's that any serious work on the development of membranes was carried out.

In the petroleum refinery industry the technology is used to separate isotopes of olefins and paraffins. It quite dramatically reduces the number of theoretical plates that would otherwise be needed in a distillation column.

Table 2. Industrial-scale applications of the Technology (existing and under realization)

Sector	Company - Process/Product name/type	Short characteristic of application	Production capacity/ Pant size	Year of application	Reported effects
Sugar Industry	Brazil [7]	Recovery of ethanol from mash with 5-7% ethanol.	≈ 50,000 litres/day	1982	Raised to 80-85% by distillation, then to 96% by pervaporation
Sugar Industry	Philippines [7]	As above	As above	1980s	
Sugar Industry	Betheniville, Marne, France	Dehydration of ethanol produced from sugar beet...	150,000 litres of refined alcohol per day	1988	94% ethanol /water reduced to 2000ppm water

Between 1984 and 1996, 63 systems involving Pervaporation were industrialized. It is not known how many of these use Distillation-Pervaporation as hybrid systems. Much of the information comes from brochures by Sulzer-Chemtech, who, initially as Gesellschaft für Trenntechnik (GFT), have supplied 90% of the commercial scale systems.

It is reported [8] that there are 62 units dehydrating organic solvents made up of:

22 for Ethanol
16 for Iso-Propanol
12 Multifunctional
4 Esters
4 Ethers
3 Solvent Mixtures
1 Triethylamine

These are located in Europe, South East Asia, Canada and the USA, with Germany featuring the most. There are believed to be more installations in China and Japan but these are not well reported.

The only instance of an application other than dehydration of organic solvents is the recovery and recycling of tetrachloroethylene in a dry cleaning operation.

2.3 Known demonstration projects

Table 3. Demonstration projects related to the technology (existing and under realization)

Sector	Who is carrying out the project	Short characteristic of application investigated, including product name/type	Aimed year of application	Reported effects
Organic Chemicals	Air Products and Chemicals Inc.	Separation of Methanol from Methyl-tertiary-Butyl Ether (MTBE)	2001	
Petrochemicals	Institut Français du Pétrole	Extraction of Ethyl-tertiary-Butyl Ether (ETBE) from alcohol/ether/hydrocarbon mixtures.		Distillation-Pervaporation hybrid showed 10-30% energy savings over azeotropic distillation.
Petrochemicals	Sponsored by Texaco	Breaking azeotrope with Methanol/ Di-Methyl Carbonate		Although membrane replacement costs high, operating costs 40% of azeotropic distillation

2.4 Potential applications discussed in literature

The following applications for Distillation-Pervaporation hybrid systems have emerged from a quite extensive review of the literature. It has to be said that many of these are reviews from University and R&D projects, rather than full scale industrial plants.

Dehydration of Alcohols that form azeotropes
Ethanol, Iso-Propanol

Olefin/Paraffin Separations
Ethylene/Ethane, Propylene/Propane, Styrene/Ethyl Benzene

Isomer Separations
p-xylene/mixed xylenes, n-paraffins from iso-paraffins

Miscellaneous Hydrocarbons
Cumene/Phenol

Recovery of dilute organics from water
Acetone
Ethylene Glycol

Liquid Air Fractionation
Oxygen/Nitrogen

Natural Gas Dehydration
Extracted LNG

Waste water concentration

3. What are the development and application issues?

3.1 Technology development issues

Table 4. Technology development issues

Issue	Description	How and by whom should be addressed?
Selectivity of membranes	Refinement , of fabrication processes needed to reduce defects, durability and improve erosion and corrosion resistance	Membrane producers and users
Temperature limitations of membranes	To date polymeric membranes have been confined to low temperature applications. Ceramics have the potential but there has been little development for high temperature applications. Composite polymer/ceramic membranes that withstand chemical and physical environments for distillation conditions would have attractions.	Membrane producers/end users.
Low cost membranes	Hollow fibre configurations provide high surface area at relatively lower cost.	
Fouling of membranes	Materials of low porosity inevitably suffer from fouling	Vibrating membranes an option. Module suppliers
Module construction	Engineering attention need to the whole module, not just the membrane in terms of corrosion resistance, pressure drop, reliability	Module suppliers.
Recognition of the concept of global warming.	Petroleum refining and chemical producing industries are mature, highly capital intensive. These factors are deterrents to the implementation of economic, large-scale, non-conventional, energy saving technologies.	A challenge not just to these industries but to us all.

3.2 Challenges in developing processes based on the technology

Table 5. Challenges in developing processes based on the technology

Challenge	Description	How and by whom should the challenge be addressed?
Improved Distillation performance	New structured packings offer HETP advantages and this might make users less inclined to consider Distillation-Pervaporation	Packing suppliers/end users. Pilot scale trials.
Proving of hybrid processes	Computer models have shown promise for applications but these need to be demonstrated in practice	Manufacturer's pilot plant in conjunction with membrane producers.
Biofuels	New plants commissioned in recent years use molecular sieves for ethanol dehydration.	Process developers should compare the energy and performance benefits of Distillation-Pervaporation

4. Where can information be found?

4.1 Key publications

Table 6. Key publications on the technology

Publication	Publication type (research paper/review/book/ report)	Remarks
Handbook of Industrial Membrane Technology	Book	Crest Publishing Latest Edition 2007 ISBN 8124205078
Membrane Separation Systems: Recent Developments and Future Directions - Richard William Baker	Book	Published by William Andrew Inc ISBN 0815512708Discusses developments and future directions in the field of membrane separation systems. Describes research needed to bring energy-saving membrane separation processes to technical and commercial readiness for commercial acceptance within the next 5 to 20 years. Pays particular attention to identifying currently emerging innovative processes.
Petroleum Refining: Separation Processes (Institut Français Du Pétrole Publications) By Pierre Trambouze	Book	Published by Editions Technip ISBN 2710807610
Separation Process Technology, Authors – Humphrey & Keller	Book	Published by McGraw Hill. Guidance on cost effective separation systems for the chemical, petroleum, pharmaceutical, food, and paper industries ISBN 0070311730
Separation Science and Technology	Journal 16 issues per year	Published by Taylor and Francis. ISSN 0149-6395
Journal of Membrane Science	Journal 40 issues per year	Published by Elsevier. ISSN: 0376-7388
Separation and Purification Technology	Journal 18 issues per year	Elsevier. ISSN: 1383-5866
Hydrocarbon Processing	Monthly Journal	Gulf Publishing. ISSN 0018-8190
Chemical Engineering Progress	Monthly Journal	ISSN 0360-7275
Industrial and Engineering Chemistry	Monthly Journal	Published by American Chemical Society ISSN 1226-086X.

Table 6 cont.

Publication	Publication type (research paper/review/book/ report)	Remarks
Design And Performance Of Two-Phase Flow Pervaporation And Hybrid Distillation Processes	Doctorship thesis by Javier Fontalvo Alzate under the guidance of Professor. C.J. van Duijn. February 2006	Eindhoven Technical University
Hybrid Separations/Distillation Technology	Report	Study Paper for US Department of Energy by University of Texas 2005
Reduction Of Energy Consumption In The Process Industry By Pervaporation With Inorganic Membranes: Techno-Economical Feasibility Study	Report	European Commission Project. Carried out jointly by the Netherlands Energy Research Foundation (ECN), Institut Français du Pétrole (IFP), Akzo Nobel and RWTH Aachen.

4.2 Relevant patents and patent holders

Table 7. Relevant patents

Patent	Patent holder	Remarks, including names/types of products targeted by the patent
US 5,108,549 28th April 1982	Axel Wenzlaff, Dieter Behling, Karl W Böddeeker,	Method of separating and recovering components via pervaporization
US 5,670,05123rd September 1997	Ingo Pinnau, Lora Toy, Carlos Casillas	Olefin membrane separation process
US 5,723,639 3rd March 1998	Rathin Datta, Shih-Perng Tsai	Esterification of Fermentation Derived Acids via Pervaporation
US 5,849,195 15th December 1998	Peter Haenel, Erika Schwerdtner, Harald Helmrich	Composite membrane manufacturing and use
EP 1 375 462 2nd January 2004	Willi Hofen, Helmut Gehrke, Bärbel Kolbe, Dieter Wilken, Carsten Gehlen, Percy Kampels	Alternative systems for dewatering 1-methoxy-2-propanol and 2-methoxy-1-propanol in aqueous solution.
US 2004/0182786 23rd September 2004	Craig Colling, George Huff Jr, Stephen Pietsch	Purification of fluid compounds utilizing a distillation-membrane separation process
US 2004/0236159 25 November 2004 US 7,141,707 28 November 2006	Andreas Beckmann, Dieter Reusch, Franz-Felix Kuppinger	Separation of 2-Butanol from Tert-Butanol /Water Mixtures
US 6,849,161 1st February 2005	Jean-Philippe Ricard	Concentration of aqueous solution of Hydrazine
US 2005/0283037 22nd December 2005	Patrick Briot, Arnaud Baudot, Vincent Coupard, Alain Methivier	Process for improving Gasoline Cuts and Conversion into Gas Oils.
US 2006/0281960 14th December 2006	Elsa Jolimaitre Laurent Bournay, Arnaud Baudot	Four different configurations for the separation of at least one n-Paraffin from a hydrocarbon feedstock.
World International Property Organization WO/2006/029971 23rd March 2006	Gérard Debailleul	Method for producing green fuel.
World International Property Organization WO/2006/040064 20th April 2006	Reinhard Wagener, Michael Haubs, Juergen Lignau, Matthias Göring, Michael Hoffmockel	Method for producing and dewatering cyclic formals.

4.3 Institutes/companies working on the technology

Table 8. Institutes and companies working on the technology

Institute/Company	Country	Remarks
Chemical Engineering Dept. Universidad Nacional del Sur.	Argentina	Optimisation of azeortropic distillation columns combined with pervaporation membranes.
University of the Basque Country, Department of Chemical Engineering	Bilbao, Spain	Membrane processes.
Membrane Technology and Research, Inc.	California US	Development and production of membrane separation systems for the petrochemical, natural gas and refining industries.
Technical University of Denmark.	Denmark	Membrane distillation and pervaporation studies.
Ibmem-Ing-Büro für Membrantechnik	Germany	Development, manufacture and testing of ceramic membranes
Membrane Research Laboratory Szent István University, Budapest	Hungary	Membrane distillation and/or pervaporation
Chemical Engineering Dept. Budapest University of Technology and Economics	Hungary	Optimisation of hybrid ethanol dehydration systems.
University of Bologna	Italy	Membrane distillation, Pervaporation
Netherlands Energy Research Corporation (ECN)	Petten, Netherlands	Develop high-level knowledge and technology for a sustainable energy system and transfers it to the market
Szczecin University of Technology	Poland	Membrane distillation process applied for – deionisation of water for power generation,
Institute of Science and Engineering of Material Surfaces (Technical University of Lisbon)	Portugal	Hybridization of Pervaporation and Distillation for solvent recovery.
Department of Chemical Engineering, UMIST	Manchester, UK	Optimal Design of Membrane/Distillation Column Hybrid Processes

5. Stakeholders

5.1 Suppliers and developers

Table 9. Supplier and developers

Institute/Company	Country	Remarks
Mikropur	Czech Republic	
DSS - Danish Separation Systems A/S (Part of Alfa Laval)	Denmark	
Buss-SMS-Canzler GmbH	Butzbach, Germany	Claim to have innovative modules.
GEA Wiegand	Ettlingen . Germany	Designers and Suppliers of complete biofuel separation and purification plants
GKSS	Geesthacht, Germany	Research into use of membranes for Pervaporation and vapour permeation for separation of azeotropic and close-boiling mixtures
Sulzer Chemtech	Neunkirchen, Germany	This company supplies structured packing for distillation columns and membranes for pervaporation. Flat plate and Spiral Wound membranes. Suppliers of the first Distillation-Pervaporation system in Europe (Then as GFT)
Pervatech BV	MC Enter, Netherlands	Core activity is production and sales of tubular ceramic pervaporation membranes, modules and industrial systems.
ECO Ceramics BV	JP Velsen – Noord, Netherlands	Development and production company for solutions based on porous ceramics.
Kühni	Allsschwill, Switzerland	Commercialises systems based upon modules developed by CM-Celfa Membrantrenntechnik
CM-Celfa Membrantrenntechnik	Seewen-Schwyz, Switzerland	See above
CeraMem Corporation	Waltham, Massachesetts, USA	Ceramic membrane modules

5.2 End users

In the petroleum industry, where the scale of operation for the potential use of Distillation-Pervaporation is the highest several major operators have carried out pilot scale trials. Exxon has done work in several European plants on treating mixtures of aromatics and aliphatic hydrocarbons. Unfortunately it did not proceed further with full scale industrialization owing to a too low a return on investment.

Texaco did work on the breaking of the dimethyl carbonate/methanol azeotrope but it too has not taken the final step into full scale production.

In the processing of hydrocarbon feed stocks, there is potential for improving gasoline cuts and the conversion to gas oils. Pervaporation following an upstream distillation step separates branched molecular olefins from straight chains. Branched olefins provide an improved octane number in gasoline. The straight chained olefins are then further processed for improving the cetane number in gas oil (diesel)

Grace Davison has developed a new high-performance post distillation pervaporation process for removing sulphur from gasoline. The driver for this has been the regulatory requirement for sulphur limits to fall from 80 to 30 ppm. A 300 barrel per day plant is in operation by Conoco-Phillips in New Jersey.

Vebio arecurrently operating the most modern biofuel refining plant in Europe. The technology was supplied by GEA Wiegand [9] who are showing great interest in incorporating Distillation/Pervaporation into the process.

6. Expert's brief final judgment on the technology

The main conclusion drawn from the studies carried out to produce this report is that the technology shows considerable promise in terms of its potential in significantly reducing energy consumption in liquid separations. This also extends to improving the quality of products from some separations.

A disappointment is that it has not yet been exploited on anything like a big enough scale despite these benefits being apparent for at least 25 years.

The draw back is clearly the lack of will to introduce the technology into the mature industries of petroleum refining and chemical processing.

Up to now energy savings alone have not been enough to persuade the big players to invest. New industries such as biofuel purification could see a more enthusiastic approach to benefits of the technology. The scale here could see the benefits of Pervaporation being realised in a hybrid combination with Distillation or as a stand alone unit operation.

References

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