

## PERVAPORATION

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### Summary

Pervaporation is a membrane process used to separate liquid mixtures. The process offers the possibility of separating solutions, mixtures of components with close boiling points, or azeotropes that are difficult to separate by distillation or other means.

Treatment of volatile organic compounds (VOCs) containing water by pervaporation, the focus of this article, is at the early industrial stage; the first plants were installed in 1996. Applications exist in pollution control and aroma and flavor recovery from wastewater in the food industry. The most competitive conventional technology is stream stripping. Pervaporation appears to be the preferred process for relatively small volume streams ( $<10\text{-}20$  gallons  $\text{min}^{-1}$ ) and streams where the VOC to be recovered is thermally labile (e.g. flavor compounds).

Experience with these plants show the process is dominated by concentration polarization effects. Pervaporation membranes are often 1000 times more permeable to VOCs than to water, so the layer of solution next to the membrane surface becomes depleted of VOC, lowering the flux and the selectivity of the membrane. Concentration polarization effects can be controlled but not eliminated by appropriate module and process design.

Current pervaporation membranes are generally composite structures consisting of a thin rubbery layer of selective membrane material supported on a microporous support.

The membranes are usually formulated into plate-and-frame or spiral-wound membrane modules. These membranes are very selective for hydrophobic organics such as chlorinated solvents, aromatics and esters but better membranes are required for hydrophilic organics such as ethanol, methanol, and acetic acid.

## 1. Introduction

Pervaporation is a membrane process used to separate liquid mixtures. A schematic diagram of the process is shown in Figure 1. The feed liquid contacts one side of a membrane, which selectively permeates one of the components. The permeate, enriched in this component, is removed as a vapor from the other side of the membrane. The driving force for the process is the low pressure generated by cooling and condensing the permeate vapor. The separation achieved is proportional to the rate of permeation of the components of the mixture through the membrane. Pervaporation, therefore, offers the possibility of separating solutions, mixtures of components with close boiling points, or azeotropes that are difficult to separate by distillation or other means.

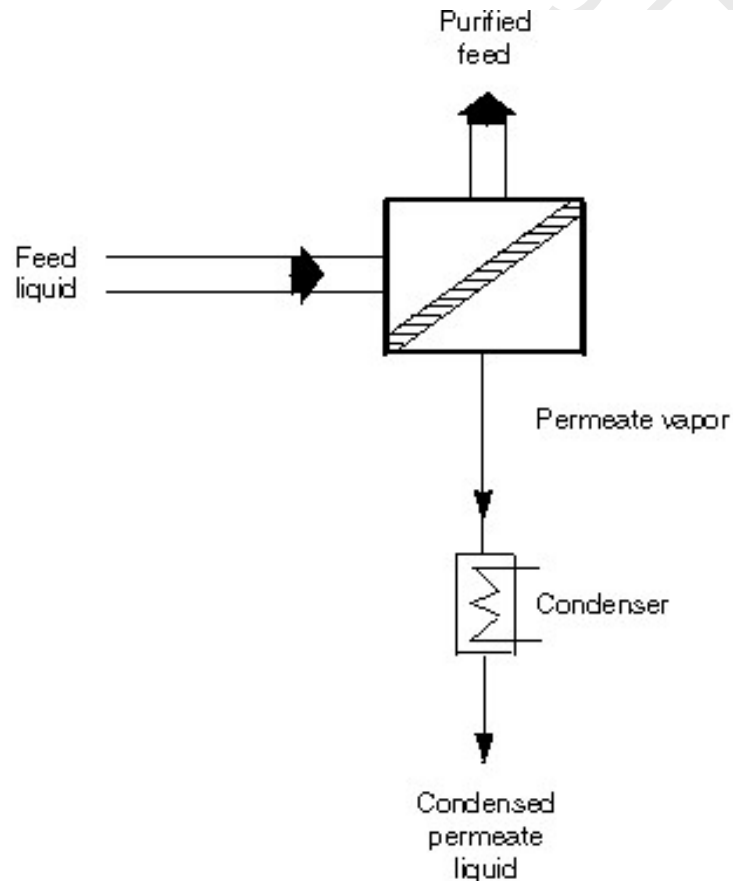


Figure 1. In the pervaporation process, a liquid contacts the membrane, which preferentially permeates one of the components as a vapor. The permeate is cooled and condensed, spontaneously generating a vacuum that drives the process.

The first systematic work on pervaporation was done by Binning et al. at American Oil in the 1950s (Binning et al. 1961). The process was not commercialized at that time and

remained a mild academic curiosity until 1982, when GFT (Gesellschaft für Trenntechnik GmbH, Germany) installed the first commercial pervaporation plant (Ballweg et al. 1982, Tusel and Brüscke 1985). The plant separated water from concentrated alcohol solutions; GFT has since installed more than 100 such plants. The ethanol feed to the membrane generally contains about 10 per cent water. The pervaporation process removes the water as the permeate, producing pure ethanol with less than 1 per cent water. All the problems of azeotropic distillation are avoided.

Spurred on by this success, a great deal of effort is being made to apply pervaporation to other difficult separations. Exxon, for example, has pursued the separation of hydrocarbon mixtures containing aromatics and aliphatics, a major separation problem in refineries (Schucker et al. 1991-1995). This article focuses on another application of pervaporation - the separation of dissolved volatile organic compounds (VOCs) from water (Burn et al. 1985, Wijmans et al. 1988, Blume et al. 1990, Bøddeker et al. 1990, Hollein et al. 1993). The first commercial pervaporation plants for VOC recovery and removal were installed in 1996.

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