

# Compact Membrane Systems (CMS) applications in solvent recovery

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## Overview

Many chemical, industrial, and pharmaceutical processes use solvents, in many stages of manufacturing: removal of intermediates, control of water- shift or side reactions, drying of final product for packaging, clean-up of machinery, and more. While some solvents are recovered and reused, others are not due to the cost or challenge in recovering them to the necessary purity. The solvent recovery process can still be expensive or cumbersome, involving multiple distillation steps and large columns for components with similar volatilities, and large quantities of heat to drive evaporation.

Compact Membrane Systems (CMS) offers a new, membrane-based separation technology that is highly effective at dehydration and separation, drying solvents to 99.5+% purity. CMS technology is particularly effective in breaking azeotropic solvent-water mixtures, situations where water is the minor component and it is dissolved and/or dispersed, and in close boiling point mixtures. CMS technology is cost effective and easy to use, enabling recovery of most solvents to very dry levels for less than \$2/gallon, with payback periods of less than 1 year.

CMS uses perfluoromembranes with exceptional chemical and thermal stability and gas transport properties, which provide performance and cost superiority to conventional alternatives that require multiple steps and heat input for evaporation.

## The Current Challenge

Organic solvents are extensively used in drug manufacturing processes, semiconductor and paint manufacture, and other industrial processes for several purposes including preparation, extraction and purification of intermediates and final products, and clean-up.

Currently, few solutions exist for drying solvents to very dry levels. For example, IPA, ethanol and THF form azeotropes (at 12 wt.%, 5 wt.% , and 5 wt.% water respectively), making further dehydration nearly impossible for conventional, distillation based technologies. In these situations, consumers regularly and repeatedly purchase virgin solvent, sending spent solvent to incineration as toxic waste. This solution is both costly and environmentally unappealing. Alternatively, manufacturers may reuse solvent that has taken on water, but pay a penalty in terms of performance.

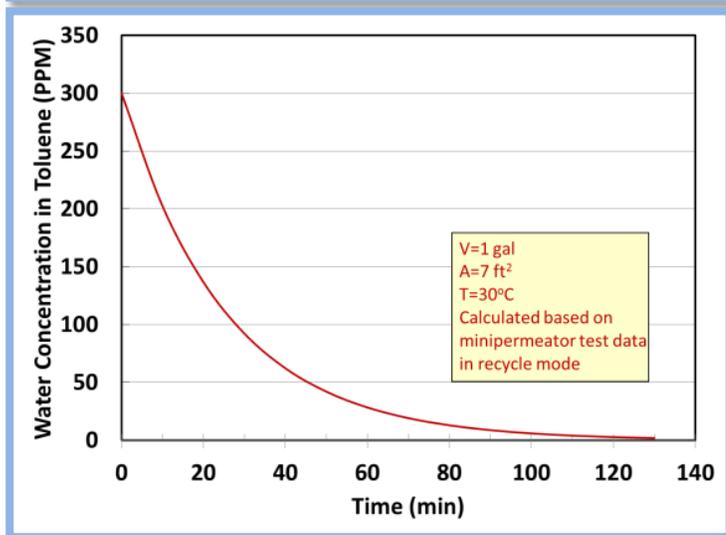
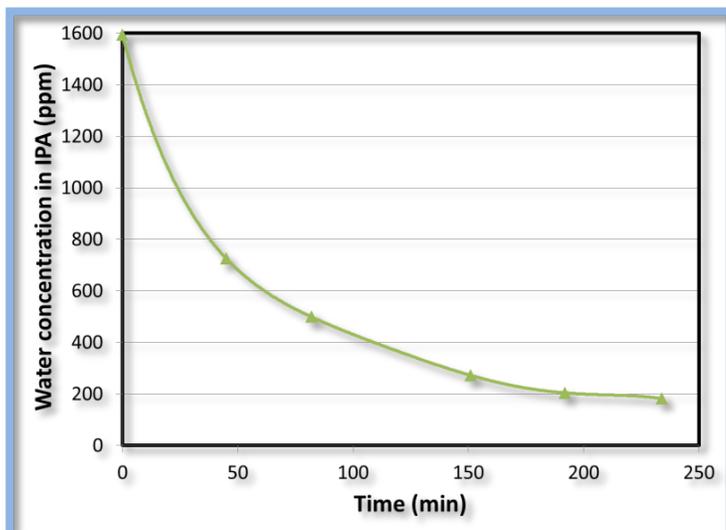
In the face of rising solvent costs, increased interest in green chemistry, and greater attention to risks in managing and transporting hazardous waste, recovering spent solvents is more critical than in the past.

## Technology Platform, Performance, and Value

Utilizing novel technologies that address the shortcomings of distillation based approaches can be an important component of reducing production and recovery costs, increasing solvent purity, reducing environmental impact, and ensuring high quality end product.

Compact Membrane Systems' (CMS) membrane-based technology is efficient and cost-effective at dehydrating and recovering a number of solvents to very high levels of purity. CMS membranes can perform a valuable service: offering a cost effective way to conduct difficult separations and/or as a finishing step after distillation to enhance purity to high levels. Using mass transfer principles, CMS membranes can reduce water to below 10 ppm in immiscible solvent-water systems (e.g. xylene, hexane, toluene) without the use of entrainers to break multiple distillation steps. In miscible solvent-water systems (e.g. IPA, EtOH, THF) the membranes can decrease water content to below 500 ppm.

CMS technology can achieve high levels of purity and recovery, with processing costs of less than \$2/gallon (and often less than \$1/gallon) and payback periods less than 1 year. Systems are easy to use and can be adapted to different applications, to meet customer need for specific purity and recovery levels. Example results for IPA and toluene drying processes, at right, show substantial reductions in water content.



CMS technology has proven effective at drying the following solvents:

Common Pharmaceutical and Industrial Solvents		
Solvent	Normal Boiling Points (°C)	CMS technology effective?
p-Xylene	139	y
Ethylbenzene	136	y
Chlorobenzene	131	y
Toluene	111	y
N-Hexane	68	y
Cyclohexane	81	y
N-Butyl Alcohol	118	y
Isopropyl Alcohol	82	y
THF	66	y
Methyl Tert-Butyl Ether	55	y
Methyl Isobutyl Ketone	117	y
Dichloromethane	40	n
Chloroform	61	n
EtOH	78	y
Acetonitrile	82	n
Methanol	65	n
Boiling Points and Solubilities were obtained from <a href="http://macro.lsu.edu/HowTo/solvents.htm">http://macro.lsu.edu/HowTo/solvents.htm</a> *20 C, **25 C		

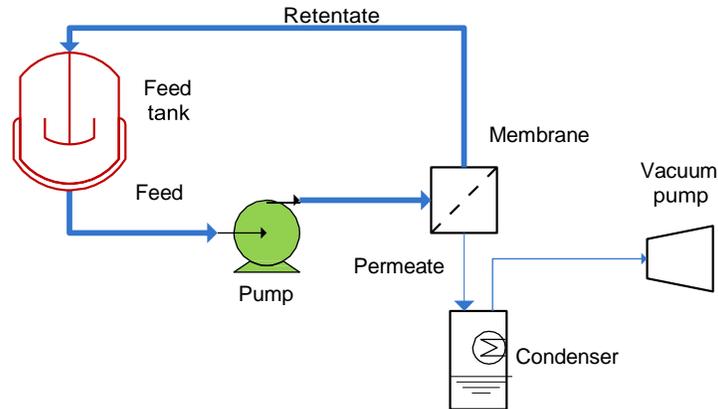
## How it works

CMS membrane systems are chemically and thermally resistant and suitable for a range of dehydration applications, including oil, solvents, and other chemicals. CMS membranes are most effective where water is the minor component and processed volumes are less than 5000 gallons per day. They can remove even small quantities of water, to provide product that is 99.9+% free of water and other components. CMS membrane modules can be used in harsh environments as they are chemically and thermally resistant. Since CMS membranes have the ability to dewater azeotropic solvents like alcohols, they are a cost effective alternative to distillation, and other technologies, in fine chemicals, custom chemicals, and pharmaceutical applications.

CMS technology works by pervaporation, an energy efficient combination of membrane permeation and evaporation. Pervaporation involves the separation of two or more components across a membrane by differing rates of diffusion through a thin polymer film and an evaporative phase change comparable to a simple flash step<sup>ii</sup>.

Pervaporation works efficiently in batch recycle mode as shown in the diagram below. A vapor pressure gradient is used to allow one component to preferentially permeate across the membrane. A vacuum applied to the permeate side is coupled with the immediate condensation of the permeated vapors. Pervaporation is typically suited to separating a minor component of a liquid mixture, thus high selectivity through the membrane is essential.

The liquid feed to the membrane is heated once to operating temperature and doesn't have to be cooled until the dehydration is completed. The only heating required during the process is that needed for the evaporation of the permeate and for making up the heat losses from the system to maintain the feed at operation temperature.



## About Compact Membrane Systems (CMS)

CMS is an advanced materials company, turning chemistry into sustainability with superior products for advanced chemical separations. CMS perfluoropolymers are compatible with a wide range of chemicals, are resistant to surface fouling, and perform well at high temperature.

The CMS platform is in commercial use in a range of applications and industries, showing long term performance over thousands of weeks of continuous use in power generation, nuclear power plants, marine vessels, wind turbines, mines, paper mills, and more.

CMS has a strong patent portfolio that includes 15 issued patents, and seven pending applications. The portfolio includes composition of matter patents as well as CMS perfluoromembrane patents for removing small molecules from liquids.

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<sup>i</sup> EPA-HQ-RCRA-2010-0742

<sup>ii</sup> <http://www.cheresources.com/content/articles/separation-technology/pervaporation-an-overview>