Membrane Technology A Contribution to the Protection of the Environment

By Chris Ashton
SIHI Pumps UK

Solvent recovery is an important process as vaporous solvent emissions degrade slowly in the atmosphere and represent a potential risk to man and the environment. International and local clean air regulations have therefore been passed which lay down maximum emission limits. While environmental factors are naturally a crucial consideration behind such measures, they also bring financial benefits through the recovery and recycling of valuable materials.

Membrane technology is ideal for the solvent recovery process due to their high efficiency levels, long service life, where no regeneration is necessary, and their compact design. The recovered substances are neither modified nor contaminated and are suitable for all concentration ranges, and their compact design.

A leading chemical manufacturer uses solvent recovery technology installed by Sterling Fluid Systems. They incorporate membrane units into their existing plant machinery to minimise the levels of dangerous substances that are emitted, particularly acetone. In order for the company to comply with current Government legislation it is imperative they introduce such solvent recovery methods.

Membrane processes involving gas/vapour permeation or pervaporation have shown various successes. The development of a practical, cost effective membrane for separation purposes has been difficult to produce, particularly when considered against the costs of the traditional separation methods. Recent advances in this field coupled together with the ever-growing need to conserve energy and minimise health hazards, mean membrane separation technology has become a

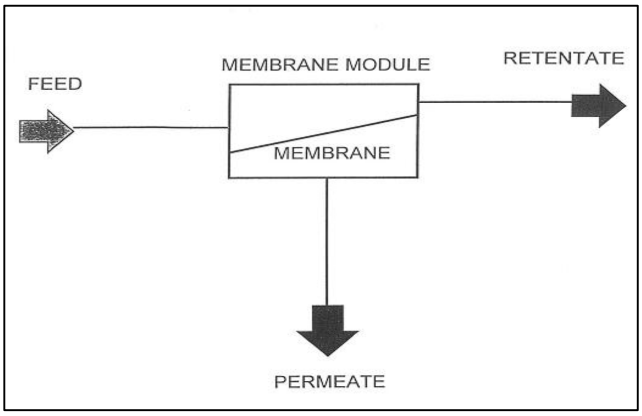

Figure 1. An example of how a membrane system works.

commercial viability.

A membrane can be considered in general terms as a barrier, against which the molecules exert a resistance. Therefore for the substance to transport or exchange itself through the membrane, it requires a motive force. These forces fall into three major categories (i) differential pressure i.e. gas permeation, reverse osmosis; (ii) differential concentration i.e. pervaporation; and (iii) electrical potential difference i.e. electro-dialysis. This method of transportation is also dependent upon the type of membrane used. Membranes can be divided into various distinguishing types.

Pore-type membrane

This type of membrane can be considered as a sieve on a microscopic scale. It contains minute holes or pores through which the substance will successfully pass through. The separation effect for this membrane type is dependent upon the size of molecule.

Solubility membrane

Solubility membranes consist of a homogenous polymer film. Here the molecule dissolves into the polymer and thereby diffuses itself through the film (solubility diffusion membrane). These types of membranes are commonly used in pervaporation, gas permeation and reverse osmosis.

For these membranes to be economical and competitive, it's necessary for the membranes to display such qualities as high permeability, high selectivity, chemical resistance, mechanical durability, component stability, longevity, low production costs and being simple to operate.

It is therefore not surprising that multipurpose membranes have been developed to meet the sophisticated requirements shown previously. Consequently membranes are typically manufactured from various polymers, ceramics or glass, and are available in the form of flat membranes or hollow fibre/thread membrane.

Modular membranes

To use membrane separation on a large scale, it is necessary to have a large membrane surface. Most membrane separation plants are produced in a modular fashion using many membranes in both the hollow fibre and flat form, which are then usually installed in some kind of pressure vessel.

A typical selection of modules available include plate, coil, tube and hollow fibre modules. In the plate module, the membrane is attached to a support plate, which are then stacked together to form the module. It is necessary however to separate each of the plates by using a non-porous wall. The coil module consists of one or more flat membranes which are coiled in a spiral form and installed in a suitably prepared pressure vessel. The tube and hollow fibre modules are designed similar to a tube style heat exchanger. Many tubular membranes are glued together and assembled as a tube bundle and subsequently installed in a pressure vessel. Some hollow fibre modules rely on the module being tightly packed with the fibre.

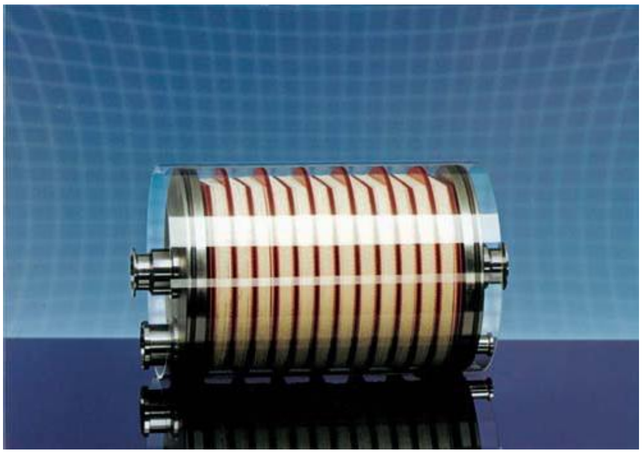

Figure 2. An example of a membrane.

Gas/vapour permeation

When considering the gas/vapour permeation process it is necessary that all the components of the mixture or product must be either gas or vapour.

The main force used for the substance transportation is the pressure created over the membrane. This is achieved by maintaining the permeate chamber in a state of vacuum or by using pressurised feedstocks. The transport system employed is the solvent diffusion model, which in practice is a three-step system. Step one involves the absorption of gases into the polymer on the high pressure side i.e. feedstock side; step two is the diffusion of the dissolved gases through the membrane; and step three is the desorption on the low pressure side i.e. permeate side.

The quantity of substance transported through the membrane is proportional to the pressure difference and the membrane surface area. This proportional factor is referred to as the membrane's permeability factor.

The permeability of any membrane depends upon the following the membrane, the substance to be transported, the temperature, and especially for organic substances the pressure relationship.

Pervaporation

Pervaporation is a low pressure membrane process in which the permeating component of the feedstock undergoes a phase change from liquid to vapour as it passes through the membrane. Pervaporation is an effective method for the separation of azeiotropic mixtures i.e. constant boiling mixtures, or narrow branded boiling components.

A good example where the pervaporation method has been commercially successful is in the concentration of Bio-alcohol for use as an alternative fuel. When using a distillation process the maximum concentration possible is nearly 96%.

An explanation of the pervaporation process is the dissolvability of one product being higher than another. The dissolved product is then transported through the membrane by diffusion, however the diffusion has no or very little effect on the separation process.

The main force for the substance transportation is the pressure between the saturated vapour pressure of the liquid component feedstock and the partial pressure of the vaporised permeate.

Figure 3. An example of a solvent recovery system.

In general terms it can be said that pervaporation is very efficient when the selective removal of minor quantities from liquid mixtures is required, or for the separation of azeotropic mixtures. However, pervaporation is not a cheap process as energy is always required for the vaporisation and condensation phases.

More Information:

SIHI Pumps Asia
25 International Business Park
#01-02 German Centre
609916 Singapore

Telephone: +65 6562 8300
Email: info.singapore@sihipumpsasia.com
Website: http://www.sihipumpsasia.com