

## **Membrane Distillation, Membrane Crystallization and Membrane Condenser**

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Among the large variety of membrane operations, membrane contactors (MCs) represent relatively new membrane-based devices that are gaining wide consideration. Membrane contactors are systems in which microporous hydrophobic membranes are used not as selective barriers but as a tool for inter phase mass transfer operations. All traditional stripping, scrubbing, absorption and liquid–liquid extraction operations, as well as condensation, dehydration, crystallization and phase transfer catalysis, can be carried out according to this configuration. With respect to conventional membrane systems, MCs have some important advantages such as high interfacial area per volume unit, low operating temperatures and pressure, high rejection, modular design, easy scale-up, less membrane fouling and low sensitivity to concentration polarization phenomenon. Drawbacks are related to the presence of an additional mass transport resistance (the membrane itself) and to the rather limited range of the operating pressures below the breakthrough threshold. The performance of MCs strongly depends on the properties of the membranes used. In general, a high hydrophobicity (for aqueous applications) is required to prevent wetting and mixing between the different phases in contact; elevated permeability leads to high fluxes; high chemical and thermal stability are necessary to improve the membrane resistance to chemical attack and its resistance to degradation and decomposition.

Membrane distillation (MD) is an attractive separation and purification method for the preparation of fresh water and for the removal of volatile compounds. Membrane crystallization (MCR) is an extension of MD; it is a hybrid membrane separation-crystallization process where a solution becomes first saturated, then supersaturated and finally the crystals are obtained. Membrane assisted condenser is another innovative membrane operation. As membrane distillation, also membrane condenser is a membrane contactor operation. In a membrane condenser the hydrophobic microporous membranes are used for promoting water vapor condensation and recovery from waste gaseous streams (e.g., flue gas, plume, etc.). The composition of the recovered liquid water can be controlled by opportunely tuning the operating conditions.