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Development of a Membrane Distillation module for solar energy seawater desalination

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ABSTRACT

Membrane Distillation (MD) processes are gaining growing interest among novel desalination technologies, in particular for small scale applications also coupled with non-conventional energy sources. In the present work an original laboratory scale planar geometry Membrane Distillation unit was designed, built and tested for future coupling with solar energy. Though conceptually simple, the original geometry was developed in order to allow for multi-stage arrangement, compactness, internal heat recovery and possible integration with a polymeric heat exchanger for final brine heating by means of solar energy or waste heat. The laboratory scale unit was tested in order to investigate the effect of operating conditions, i.e. hot feed temperature and flow rate, on the process performance, with particular attention paid to parameters relevant to the design of the system coupled with solar energy. Also the effect of different airgap configurations was investigated, namely (i) free airgap, (ii) permeate-gap and (iii) partial vacuum airgap arrangements.

In parallel, a simplified predictive model based on heat and mass balance and transport equations was implemented and validated against experimental data collected. The validated model was used to simulate the behavior of multi-stage units based on the planar geometry investigated in the present work for the purpose of a simplified economic analysis of the system and for the conceptual design of the solar energy powered MD unit to be installed at Università di Palermo, where further testing will be performed.

Keywords: Membrane Distillation; Flat membrane; Modelling; Multistage unit; Economics; Solar energy; System integration

1. Introduction and literature review

MD is a thermally driven process, which uses a hydrophobic and micro-porous membrane for the separation of vapour from aqueous solution. The driving force for the process is the trans-membrane vapour pressure difference, depending also on the temperature difference across the membrane. The vapour formed due to the vapour/liquid equilibrium at the membrane surface permeates through membrane pores, while the aqueous solution flowing parallel to the membrane cannot pass because of the high hydrophobicity of membranes adopted in MD.

Literature reports a number of applications for the MD process, such as the separation of non-volatile components like ions, colloids or macromolecules from water, and the removal of volatile organic compounds from dilute aqueous solutions. Indeed, MD process is suitable for both high purity water production and concentration of aqueous solutions (El-Bourawi et al., 2006).

Early patents about MD systems date back to the 1960s, while the terminology used in describing MD processes was standardised during the 1980s. According to Lawson and Lloyd (1997) a membrane operation can be labelled as "Membrane Distillation" when all the following conditions are achieved:

- the membrane should be porous;
- the membrane should not be wetted by the process liquids;
- no capillary condensation should take place inside the pore of the membrane;

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