Direct Contact Membrane Distillation: Harnessing a Vapor Pressure Differential in a Low Energy Water Purification Process

Introduction:

Membrane Distillation (MD) is an emerging membrane technology that allows for a phase-change based separation process. A porous hydrophobic membrane separates feed and effluent streams, allowing for the passage of vapor but not liquid or solid phase components. Flux across the membrane is driven by a vapor pressure differential, created by a low grade thermal gradient between feed and distillate sides [1]. The low operating temperature and pressures, high theoretical/experimental contaminant rejection rates, and reduced energy requirements make MD a promising technology for the future of water treatment.

Background:

The simplest configuration of MD is Direct Contact Membrane Distillation (DCMD) which puts the feed and distillate streams in direct contact with the membrane (as opposed to alternative configurations such as Air Gap Membrane Distillation, Vacuum Enhanced Distillation, etc). This simple configuration has been favored for its higher rates of flux, although it suffers from higher thermal losses from conductive transfer than the other typical configurations [1][2]. While the required thermal gradient is small (20-30°C, generally) supplying it is a non-trivial portion of the operating expenses for any MD system [3].

![Figure 1: Bench Scale DCMD layout.](4]

In a typical bench scale DCMD system and in many industrial systems, the thermal gradient is supplied directly via a heater and a chiller (see figure 1.) However, recent studies
have examined alternative sources of heat to reduce the overall cost of MD operations, including solar and waste heat [2, 3].

Solution:

A bench scale DCMD system was assembled in the boiler room of a recreational facility (Lombardi Recreational Facility, UNR campus, NV). In place of the standard heater, a coiled loop heat exchanger was designed and installed directly in the boiler exhaust flue, capturing a small fraction of the waste heat available in the water heating/air conditioning system. This heat exchanger was coupled into the DCMD system, and the bench scale model was run for several weeks.

System performance was measured as flux (volume of water produced/time*membrane area) and tracked for the duration of the experiment, showing a strong correlation to the times when the boiler system was actively running. However, enough extra heat was captured to effectively heat feed tank during these active times to well within the range desired for operation of MD systems. Average flux over the course of the experiment was lower, but comparable to the flux rates measured in the lab using a standard heater.

Conclusion:

Significant amounts of waste heat are available in numerous industrial processes, however this waste heat is rarely a constant. This experiment demonstrates that waste heat can be used to provide the driving force behind MD processes, in spite of this inconsistency. Refinements to the system, including better insulation in storage tanks, larger and better heat exchangers, and process control to maintain a narrower feed temperature range (possibly by supplementing the feed heat provided with a standard heater) can significantly reduce the power requirements of an MD system, and thus the overall cost, making MD even more economically efficient.

Works Cited:

