

## Wetting Progression and Liquid Flux during Membrane Distillation

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Membrane distillation (MD) is a desalination process being considered for high-salinity feed-streams or in systems with on-site low-grade (“waste”) heat. MD is driven by the vapor pressure difference between the warmer feed and cooler distillate streams that are separated by a hydrophobic membrane. Critical to the MD process is inhibition of pore wetting so that, ideally, there is only flux of water vapor, and no liquid flux of the feed solution through the membrane. This talk summarizes a multi-year project focused on developing a comprehensive mechanistic understanding of wetting resistance and liquid progression in distillation membranes. In the first study, membrane hydrophobicity was found to significantly decrease after 100 days of operation; despite this, distillate conductivity remained low. It was hypothesized that internal (pore wall) and/or distillate surface hydrophobicity contribute uniquely to wetting resistance when surface hydrophilization occurs during long-term operation. After attempts to measure internal contact angle using an extended Washburn method proved inconsistent, we developed a method to measure the fibril contact angle as a surrogate for internal contact angle for PTFE membranes. Fibril contact angle was determined based on measured fibril roughness, intrinsic contact angle, and wetting state. Comparison of measured and theoretical liquid-entry-pressure values showed that *in situ* wetting resistance is best represented not by intrinsic or measured surface contact angles, but by the fibril contact angle. In the next study, we introduced the concept of liquid-entry-pressure distribution and used it to characterize membrane wetting resistance. We found that reducing pore size is equally as, or more effective than, increasing contact angle to resist pore wetting, especially for scaling-induced wetting. We also found that pore size has a greater effect on liquid flux than vapor flux; membranes with smaller pore size had relatively low liquid flux, whereas membranes with larger pore size had significantly higher liquid flux, in addition to vapor flux, despite high hydrophobicity. Finally, we demonstrated trade-offs between vapor and liquid flux due to changes in pore size and membrane thickness, which is not typically considered to affect wetting resistance. The results of these studies challenged past emphasis on increasing hydrophobicity alone to improve the wetting resistance of MD membranes. Our current study focuses on characterizing the wetting front and liquid progression through MD membranes. Using electrochemical impedance spectroscopy, we have found that PTFE membranes operate in an internally wetted state without pore breakthrough; fibril hydrophobicity at the pore walls likely maintains air in the pores and provides internal resistance, even when significant liquid penetration occurs. We have also identified solution chemistries and operational conditions that result in different depths of wetting penetration. Next we will elucidate the roles of operating pressure, salinity, and fouling/scaling on wetting resistance based on rates of liquid penetration and wetting states defined by depths of liquid progression. Our ultimate goal is to mechanistically depict the entire wetting process and consider implications for wetting prediction and improved wetting resistance through membrane or process modification.