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Theory of isobaric pressure exchanger for desalination

Chiang C. Mei[a,*], Ying-Hung Liu[b], Adrian W-K. Law[c]

[a]*Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA 02139*
Tel. +1 617 253 2994; Fax: +1 617 253 6300; email: ccmei@mit.edu
[b]*Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, MA, USA 02139*
[c]*School of Civil and Environmental Engineering, Nanyang Technological University, Singapore*

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ABSTRACT

A theory is developed to predict the time of sustained operation of a rotary pressure exchanger used for energy recovery in seawater reverse osmosis system. Based on past experiments for oscillating pipe flows, it is found that the existing plug flow velocity in the ducts is not high enough to induce turbulence in the wall boundary layer. Modeling the time series of the flow velocity in the inviscid core as a periodic series of rectangular pulses, the structure of the laminar momentum boundary layer is first derived. The mass boundary layer induced by the oscillating velocity is then solved in order to obtain the slow diffusion of the averaged brine concentration along the duct. With the result the effective longitudinal diffusivity (dispersivity) is found explicitly for arbitrary Schmidt number. The dispersivity is found to be small due to the small viscosity and mass diffusivity in the very thin boundary layers, however it is still augmented to hundreds times of the molecular diffusivity. For a range of duct and rotor dimensions and rotor frequencies, the time needed for the mixing zone to spread to the ends of the duct is predicted for large Schmidt number appropriate for salt in water. After transient mixing is over, a certain amount of salt leaks steadily into the fresh seawater reentering the membrane. However the leakage is shown to be small due to the small dispersivity.

Keywords: Pressure exchanger; SWRO system; Energy recovery; Boundary-layer theory; Convective diffusion; Taylor dispersion

*Corresponding author.