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Total water production capacity inversion phenomenon in multi-stage direct contact membrane distillation: A theoretical study

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Abstract

The low thermal efficiency and low water production are among the major challenges that prevent membrane distillation (MD) process from being commercialized. In an effort to design an efficient multi-stage direct contact MD (DCMD) unit through mathematical simulation, a new phenomenon that we refer to as total water production capacity inversion (WPI) has been detected. It is represented by a decrease in the total water production beyond a number of stages or a certain module length. WPI phenomenon, which was confirmed by using two different mathematical models validated experimentally, was found to take place due to the decrease in water vapor flux across the membrane as well as the increase in heat loss by conduction as the membrane length increases. Therefore, WPI should be considered as a critical MD design-criterion, especially for large scale units. Investigations conducted for a simulated multi-stage DCMD process showed that inlet feed and permeate temperatures difference, feed and permeate flow rates, and feed salinity have different effects on WPI. The number of stages (or module length at constant width) that leads to a maximum water production has been determined for different operating parameters. Decreasing inlet feed and permeate temperatures difference, or inlet feed and permeate flow rates and increasing inlet feed temperature at constant temperature difference or inlet feed salinity cause the WPI to take place at lower number of stages. Even though the feed salinity affects negligibly the