Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2019.25017

171 (2019) 1–17
December

Energy and exergy analysis of a novel multiple-effect vapor chamber distillation system for high-salinity wastewater treatment

Hamidreza Shabgard[a,*], Ramkumar Parthasarathy[a], Ben Xu[b]

[a]*School of Aerospace and Mechanical Engineering, University of Oklahoma, 865 Asp Ave., Norman, OK 73019, USA, Tel. +1-405-325-5753; email: shabgard@ou.edu (H. Shabgard), Tel. +1-405-325-1735; email: rparthasarathy@ou.edu (R. Parthasarathy)*
[b]*Department of Mechanical Engineering, The University of Texas Rio Grande Valley, Edinburg, TX 78539, USA, Tel. +1-956-665-2896; email: ben.xu@utrgv.edu*

Received 1 May 2019; Accepted 8 October 2019

ABSTRACT

A novel modular thermally-driven multiple-effect vapor chamber distillation (MVCD) system is presented for compact and portable desalination applications. The MVCD system consists of several vapor chambers connected in series with the condenser section of the upstream vapor chambers serving as the evaporator section of the following effect. A heat transfer model accounting for the major thermal resistances was developed to predict the heat transfer and distilled water production rates. A mass transfer analysis was performed to evaluate the effect of the accumulation of the non-condensable gasses within the chambers. An exergy analysis was also conducted to quantify the efficiency of the system from the viewpoint of the second law of thermodynamics. It was found that for a fixed number of effects, increasing the hot-end temperature increased the distillation rate and decreased the second law efficiency. On the other hand, increasing the number of effects at a fixed hot-end temperature resulted in increased distillation rate and second law efficiency. The increased salinity of the feed water resulted in smaller distillation rates and greater second law efficiency. For all the cases, it was found that sensible heat recovery from the discharging fluids could improve the gained output ratio (GOR) and the second law efficiency by about 10%. Quantitatively, at a hot-end temperature of 70°C, feed water salinity of 35 ppt and recovery ratio of 36%, the MVCD system with six effects and energy recovery from the discharging fluids yielded a GOR of 5.0 and a second law efficiency of 3.8%.

Keywords: Thermal desalination; Multiple-effect vapor chamber; Exergy analysis

* Corresponding author.