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Fundamental characteristics of heat transfer in downflow reboilers/condensers

The paper presents a theoretical model of flow and heat transfer for the evaporation of the laminar flow saturated falling liquid oxygen film and the condensation of saturated nitrogen vapor, which is applied to the downflow reboilers/condensers in air separation units. The model also takes into account the heat conduction through the thin plate between two fluids. The film thicknesses, the local heat transfer coefficients on both the oxygen and nitrogen side, as well as the whole heat transfer coefficient are obtained under given conditions by solving the model with a numerical method. The effects of the heat transfer length on the film thicknesses, the heat transfer coefficients and the circulation ratio of oxygen are also analyzed in detail. Under given operating conditions, the total heat transfer rate ranges from 1472-812 W m-2 K-1 with the channel length varying from 0m to 6m; the average heat transfer rate is 922 W m-2 K-1. Due to the greater latent heat, the film thickness of the liquid oxygen varies more significantly than that of the liquid nitrogen. Furthermore, the thermal conduction resistance of the plate is the main thermal resistance in the heat transfer process, and accounts for 86-77% of the total thermal resistance. In addition, the circulation ratio of liquid oxygen significantly decreases as the channel length increases and reaches a value of 4.75 when the channel length is 6m. Therefore, reboilers/condensers should be designed with an appropriate channel length to ensure the operation safety. The analytical results could provide a theoretical guidance for the design and safe operation of reboilers/condensers in actual project.

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