Performance Analysis of the Tube-in-Tube Heat Exchanger in Dilution Refrigerators under Small Flowrates

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Dilution refrigeration is widely used in the frontier research fields of condensed-matter physics, astronomical observation, and quantum computing. Heat exchangers are the critical components affecting its performance. They are significant to the normal operation and thermodynamic efficiency of the whole system, especially in the condensation-pump dilution refrigerators with the small driving force. At present, there are few reports on the comprehensive analysis and quantitative calculation of heat exchanger, especially under small flowrates. This paper focuses on the continuous tube-in-tube heat exchanger in dilution refrigerators, establishes the theoretical and numerical models, and uses MATLAB to calculate the optimum dimensions and thermal performances under small flowrate conditions. It is found that the Kapitza thermal resistance between the dilute liquid and the wall is the most critical factor and the axial liquid heat conduction and viscous heating should not be ignored. In the design and optimization of the heat exchanger, the heat transfer area of the dilute fluid should be increased as much as possible while restraining the axial liquid thermal conduction and viscous heating to reduce the entropy generation. This study provides a comprehensive design method of the heat exchanger and lays a foundation for further design of dilution refrigerators.