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Pressure drop and heat transfer characteristics of boiling nitrogen in square pipe flow

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Japan Aerospace Exploration Agency has been promoting the research and development of the hypersonic aircraft that can cruise at Mach 5 speed. The engine is equipped with a heat exchanger which uses liquid hydrogen fuel as a coolant for decreasing temperature of incoming air during hypersonic flight.
The objective of the study was to elucidate the pressure drop and heat transfer coefficient of boiling nitrogen flow in a horizontal square pipe instead of using liquid hydrogen. The test section consisted of a heat transfer pipe with a heated length of 800 mm and a side length of 12 mm, a flow visualization pipe and two different capacitance-type void-fraction meters. The heat fluxes were 5, 10 and 20 kW/m2.
In the experiment, seven types of flow patterns were observed such as bubbly, plug and slug flows. The correlation between the measured void fraction and the quality was compared with the homogeneous and separation flow models for the choosing of pressure drop models.
Experimental pressure drops were compared with the predicted values using the homogeneous and separation flow models. The Butterworth model showed good agreement with the experimental values within ±30%.
Local heat transfer coefficients were measured at three locations on the top, side and bottom of the pipe wall. Differences in heat transfer among three locations were obtained. The Gunger-Winterton equation showed good agreement with the experimental values within the accuracy of -20 to +30% regardless of any locations of the pipe wall.

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