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Flow of Liquid He II under Large Temperature and Pressure Gradients*

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Two previous papers from this laboratory have reported measurements of heat conduction and fountain pressure for liquid He II flowing through narrow slits ($0.3\mu < d < 3.3\mu$) for temperature differences as large as 1°K. For the lower, yet appreciable, temperature differences the linear two-fluid equations of London and Zilsel were quantitatively verified; integration over the temperature interval was required. The present paper extends the analysis of the measurements to still larger ΔT's, for which the linear equations are no longer applicable. For this purpose integrated solutions of the Gorter-Mellink nonlinear thermohydrodynamic equations, based on the concept of mutual friction, are derived with special emphasis placed on the assumptions and restrictions necessitated by the model. The integrals for heat flow and fountain pressure have been solved numerically using a high-speed computer and the results are compared with the experiments. When Vinen's values of the mutual friction parameter $A(T)$ are employed in the solutions, the comparison is quite good, except near the λ-point; it is also shown that other values of $A(T)$ are not compatible with the observations. An explanation in terms of the vortex line model is proposed for the deviations near T_λ. Despite the agreement between the vortex line theory and experiment obtained here, several as yet unresolved difficulties are associated with flow phenomena in small slits; certain aspects of these problems are discussed, most notably the criteria for the onset of the nonlinear dissipation effects.

I. INTRODUCTION

Experimental studies, designed to test the linear equations of motion for liquid He II under conditions of large temperature and pressure differences in narrow channels of carefully chosen geometry, have been reported in two previous papers (*1*, *2*) (henceforth denoted as I and II). In interpreting these measurements it was necessary to integrate the linear equations of motion over the temperature differences encompassed by the experiments. This approach proved adequate to explain observations on both fountain pressure and heat flow over a far wider range of temperature differences than could be accounted for by the

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