§27. Lifetime of Quasi-steady State Caused by Stepwise Heat Input to a Horizontal Wire in Subcooled He II

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Transient heat transfer coefficients for a wire in He II caused by pseudo-step heat inputs with heights that were higher than the values corresponding to the steady-state critical heat fluxes were measured for the bulk liquid temperatures ranging from 1.85, to 2.1 K at system pressures ranging from 5.465 to 101.3 kPa on 0.08 mm-dia. wire, and for the liquid temperatures ranging from 1.8 to 2.1 K for the wire diameters, D, of 0.2, 0.5, and 0.7 mm at atmospheric pressure.

The lifetimes, t_L, for the quasi-steady state heat fluxes on 0.08 mm-dia. wire were obtained by pseudo-step heat inputs with various heights for liquid temperature of 2.0 K at various pressures at the level of test wire axis, P_L, are plotted against the difference between the quasi-steady state heat flux, q_s, and the steady-state critical heat flux, q_{st}, in Fig. 1. The lifetime is significantly dependent on the liquid temperature but shows little dependence on P_L within this experimental range. The lifetime decreases with the increase in the quasi-steady heat flux, q_s. It was found that the lifetime at a value of $(q_s - q_{st})$ is longer for a larger wire diameter, though the steady-state critical heat flux is lower for a larger diameter.

The integrated values, obtained from each runs on 0.08 mm-dia. wire for the pseudo-step heat inputs for the liquid temperature of 2.0 K, are plotted on the graph of $\int_{t_{st}}^{t_B}(q - q_{st})dt$ versus $(q_s - q_{st})$ in Fig. 2. At the time t_{st}, the increasing heat flux reaches the steady-state critical heat flux, q_{st}, and at the time t_B, the lifetime for the value of q_s ends. The integrated values for all the experimental runs on a wire obtained for each liquid temperature are almost constant and independent of the step heights of the heat inputs and of the initial heat input waveform up to the step heights. The average of the integrated values for each bulk liquid temperature is about 9.8 J/m^2 for 1.85 K, 10.4 J/m^2 for 1.93 K, 12.0 J/m^2 for 2.0 K and 7.0 J/m^2 for 2.1 K on 0.08 mm-dia. wire. The integrated value is larger for thicker wires being almost proportional to $D^{2/3}$.

It is possible to evaluate the lifetimes for the ideal step heat inputs which cannot be realized experimentally. By assuming that the integrated values, $\int_0^{t_B}(q - q_{st})dt$, for the ideal step heat inputs at given liquid temperatures are the same as the integrated values, $\int_{t_{st}}^{t_B}(q - q_{st})dt$, for the same liquid temperatures obtained for various stepwise heat inputs with rising times up to Q_s, the lifetimes of the quasi-steady heat fluxes, q_s, corresponding to the ideal step heights for each liquid temperature are given by

$$t_L = [1/(q_s - q_{st})][\int_{t_{st}}^{t_B}(q - q_{st})dt]_{av.} \quad (1)$$

The curve of t_L versus $(q_s - q_{st})$ for the ideal step heat inputs for T_B of 2.0 K is shown in Fig. 1 in comparison with the corresponding experimental data for pseudo-step heat inputs. The values of t_L for the pseudo-step heat inputs are significantly lower than the evaluated values for the ideal step heat inputs for larger values of $(q_s - q_{st})$.

If one wishes to consider the impact on conductor stability of a transient heat pulse in a subcooled He II cooled superconducting magnet, the transient heat transfer caused by the ideal pulse heat inputs with the heights Q_s and the width t_w will be of interest; the transient heat transfer is in the quasi-steady state Kapitza conductance regime and a rapid rising of the surface temperature does not occur as long as the width of the pulsed heat input is equal to or shorter than the lifetime of the quasi-steady heat flux mentioned above.

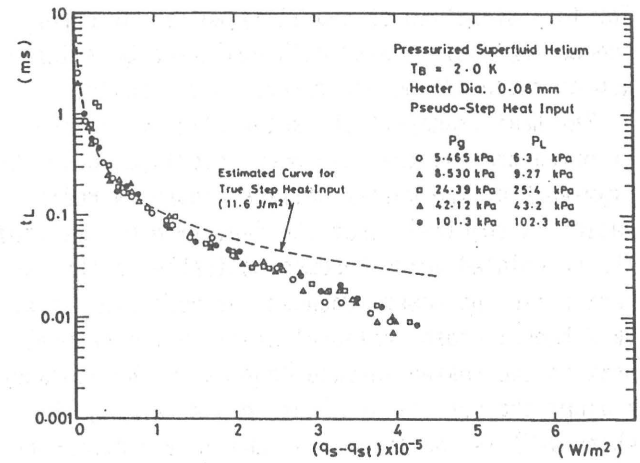

Fig.1 Lifetimes for pseudo-stepped heat inputs.

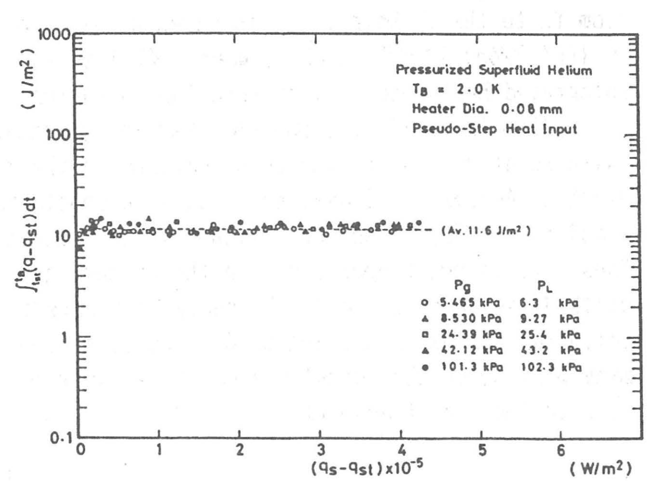

Fig.2 Integrated values of excess heat fluxes beyond q_{st} until the lifetimes end.