§2. Dependence of Critical Heat Flux in Liquid Helium on Heat Transfer Surface Length

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The heat transfer characteristics depend on the surface orientation because of various buoyancy effects for the free convection. The channel heat transfer also depends on the buoyancy effect for the convection. In the view point of the free convection, various surface areas give some effects on heat transfer. If surface area is varied, quantity of bubbles generated from the area is changed. Convection of liquid helium around the surface is influenced by a various quantity of bubbles. Especially, at high heat flux region in nucleate boiling, a large quantity of the vapor may affect free convection. It is thought that various areas of heat transfer surfaces lead the different characteristics. In this study, a factor of surface length to change the buoyancy effect were noted. Heat transfer from copper plates with various surface lengths in liquid helium was measured. Dependence of the heat transfer characteristics, which were the critical heat flux on the surface length was discussed.

The schematic illustration of the sample is shown in Fig.1. Four types of the samples were used, which are (a)18 mm (in width) x 10 mm (in length), (b)18 mm x 18 mm, (c)18 mm x 40 mm and (d)18 mm x 76 mm, and all copper blocks have 7.5 mm in thickness. Surfaces were polished to be less than 10 μm in roughness. The surface was heated uniformly by a thermofoil heater. Temperature difference between the surface and liquid helium was measured with AuFe-Chromel thermocouples which were mounted 1 mm below the surface. The bath temperature. During measurements, the bath temperature, which was monitored by a germanium resistance thermometer, was kept at 4.22 K in the atmospheric pressure. The surface orientation was 90° (vertical).

Figures 2(a) and (b) show the assumption for the sample length dependence at 90°. There is the boundary which separates liquid helium bath into two areas, as shown in Fig.2(a). The assumed heat transfer is similar to the channel heat transfer. We can define the quality (the mass ratio of vapor to liquid plus vapor mass) inside the boundary. We estimate the sample length dependence of the critical heat flux based on the concept of channel heat transfer. The channel width was decided as shown in Fig.2(b) and the channel length, L was equal to the surface length. In the defined channel, flow velocity and quality are uniform, and the quality to remain the nucleate boiling state is limited. It is called the critical quality. The critical quality ranges from 0.26 to 0.33.[1]) Vapor filled in the channel causes the degraded critical heat flux. In the channel, mass of vapor generated from the surface and released from the channel can be estimated. The quality in the channel can be calculated, and then the critical heat flux can be estimated. Figure 3 shows the calculated critical heat flux compared with those from our experimental result. The calculated critical heat flux with 0.26 of the critical quality almost agrees with the measured critical heat flux. It follows from a comparison between the measured and the calculated critical heat fluxes that the length dependence of the critical heat flux is due to the critical quality.

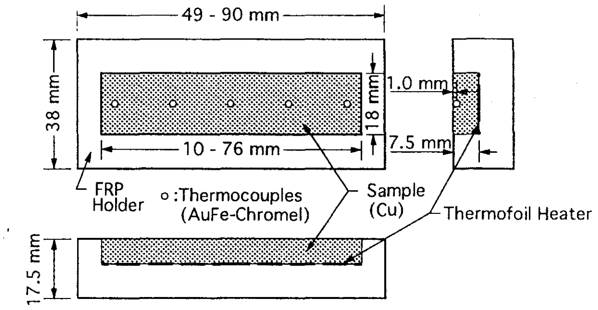

Fig.1. The schematic illustration of the sample

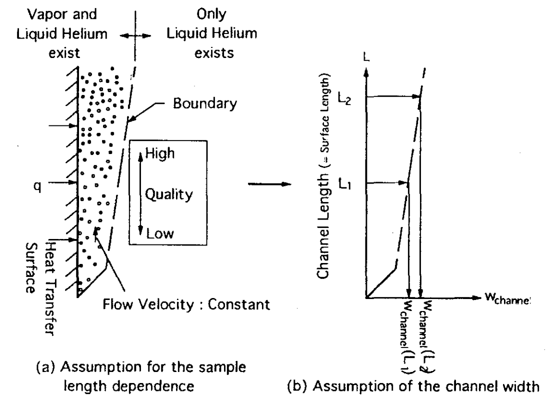

Fig.2. Assumption for the sample length dependence at 90°

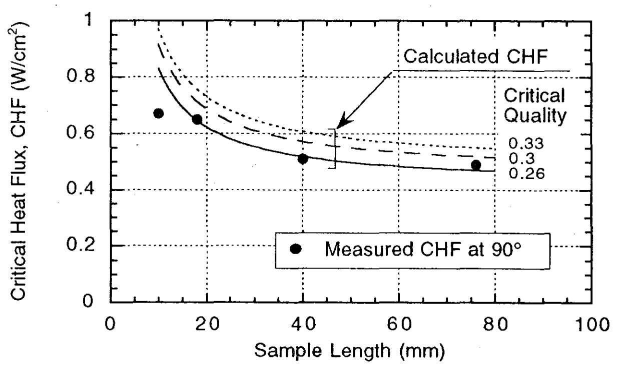

Fig.3. Comparison between the measured and the calculated critical heat fluxes

Reference

1) Steven W. Van Sciver, "Helium Cryogenics", Plenum Press, New York (1986), p.199.