§18. Heat Transfer from a Large Copper Plate to Liquid Helium

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For the cryogenic stabilization of the pool-cooled superconducting magnets, heat transfer characteristics from the surface of superconductors to liquid helium are very important. They change according to heat surface orientation, treatment, area or cooling channel width. The heat transfer characteristics from the larger surface are required to analyze the stability of the large superconductor exactly. In the large scale superconducting magnets, cooling channels are formed by spacers and conductors (channel-cooled).

We measured the dependence of the heat transfer from a large copper plate to liquid helium on the heat surface orientation and also investigated the effect of a cooling channel for the heat transfer. During the measurement, we kept the pressure of liquid helium constant at 101.3 kPa. We used a polished copper plate with 18 mm wide, 76 mm length and 7.5 mm thickness to simulate large scale superconductors, like LHD conductor. The surface roughness was less than 10 μm. The schematic illustration of the sample is shown in Fig.1. The heat surface orientation was varied from 0° (horizontal, heat surface upward), through 90° (vertical), to 180°(horizontal, downward) with the interval of 15°. The channel width can be adjusted to be 2 or 3 mm. Both ends of the channel were opened.

Figure 2 shows the dependence of the critical and the minimum heat fluxes on the heat surface orientation, in which Q_{CHF} and Q_{MHF} respectively indicate the critical and the minimum heat fluxes. We found that the critical heat flux depends on the heat surface orientation for both with and without the channel. The critical heat flux becomes maximum around 30° of the heat surface orientation. At angles above 30°, the critical heat flux decreases with the increasing angle. The critical heat fluxes reported by D.N. Lyon[1] are also shown in Fig.2. In his experiment, the critical heat flux becomes maximum at 0° and decreases monotonously with the increasing angle. Our results are lower than Lyon's, and the critical heat flux in his experiment decreases slowly with the increasing angle compared to that in our experiment. It is thought that the deference between our results and Lyon's is due to deference of the area of the heat surface. On the other hand, the minimum heat flux has less dependence on the heat surface orientation.

The channel tends to degrade the heat transfer at all surface orientations, especially at 0°. At 0°, the critical heat fluxes with the channel become 21 % (channel width 2 mm) and 40 % (channel width 3 mm) compared to that without the channel. Between 0° and 30°, the critical heat flux improves rapidly as the surface angle increases. As the channel width increases, the critical heat flux improves. It is thought that cooling of the surface improves because it becomes easy for helium vapor to flow out of the channel with increasing the channel width.

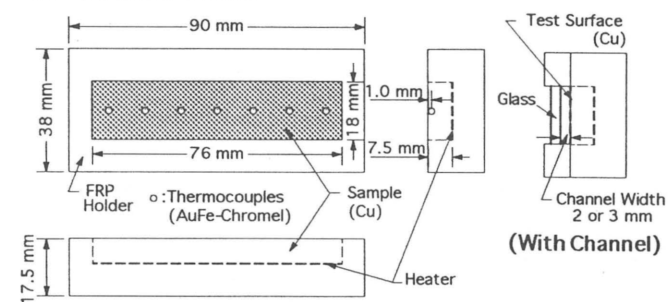

Figure 1 Schematic illustration of the sample for heat transfer measurement

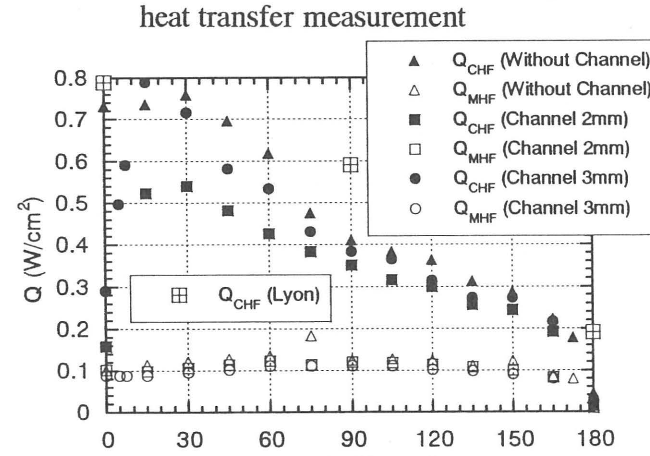

Figure 2 Dependence of critical and minimum heat fluxes on heat surface orientation

Reference

1) Lyon, D.N., : Adv. Cryo. Eng. 10 (1965) 371