§2. Heat Leak Measurement of Cryogenic Line from Refrigerator to Both Helical Coils and Poloidal Coils in LHD

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Heat leak of cryogenic lines is important for cryogenic plants. However, the measurement is very difficult after the installation. Therefore, it is common issue for large scale cryogenic plants. In the LHD, the heat leaks of superconducting magnets such as helical coils and poloidal coils were measured after the installation, but those of the cryogenic lines have not been measured. Those were just analyzed at liquid helium temperature with FEM and measured at liquid nitrogen temperature before the instration[1]. In this study, a new method is proposed to measure heat leaks and a heat leak of a cryogenic line in the LHD is measured for the first time after the installation.

In the present measurement, the existing pressure gauges and thermometers were utilized only and the target cryogenic line was a transfer tube from the refrigerator to both the helical coils and the poloidal coils (Fig. 1). The length is 68 m and the inner volume is 0.163 m^3. The measurement method is as follows; [1] stabilize and uniform the temperature of the target cryogenic line with cryogenic helium gas, [2] close both the inlet valve and the outlet valves and seal the cryogenic helium gas, [3] measure the pressure increase of the cryogenic line. After that, the enthalpy increase was calculated from the pressure increase with HEPAK[2] and then the heat leak was estimated by,

$$Qt = m \Delta h, \qquad (1)$$

where Q is the heat leak of the cryogenic line, t is time, m is the mass of helium gas and Δh is the enthalpy difference.

Fig. 2 shows the temperature and the pressure profiles after the valves were closed, while the temperature of 80K shield was maintained approximately constant (80K supply: 82.07 K – 82.66 K, 80K return: 101.42 K – 104.79 K). It was confirmed that the pressure was uniform throughout the transfer tube. From the initial temperature and pressure in the transfer tube, the initial enthalpy and the density of the helium gas were calculated to be 56,953 J/kg and 7.449 kg/m^3, respectively. The enthalpy change of the transfer tube was calculated from the pressure increase and the density and also the heat leak was estimated from the gradient of the enthalpy. These results are shown in Fig. 3. Consequently, the initial heat leak was 58.1 W at 8.53 K and it was reasonable as compared with the previous analytical result, which was about 67 W at 4.4 K.

In this study, the heat leak of the transfer tube from the refrigerator to both the helical coils and the poloidal coils was measured for the first time after the installation by the proposed measurement method. As a result, the reasonable heat leak was obtained and the proof of concept of the method was demonstrated. In addition, it was implied that the thermal insulation of the transfer tube was not deteriorated.

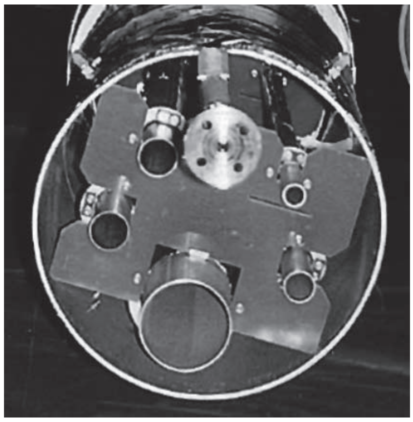

Fig. 1. Photograph of the cross section of the target cryogenic line

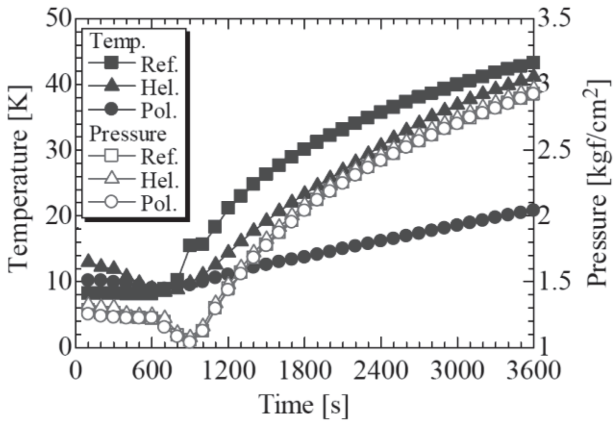

Fig. 2. Temperature and pressure profiles in the transfer tube after the inlet and outlet valves were closed.

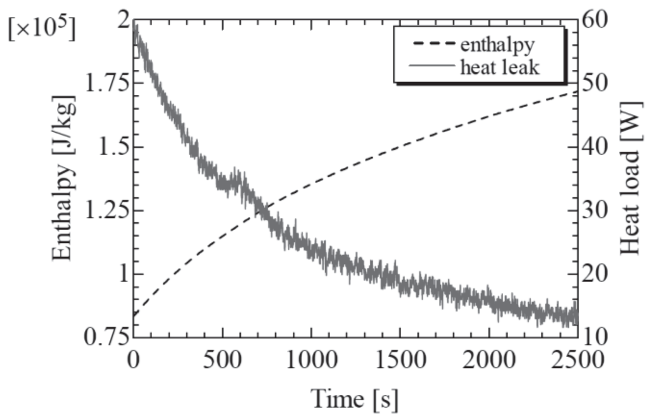

Fig. 3. Enthalpy change calculated with HEPAK and estimated heat leak.

1) Ushijima, I. et al.: NIPPON SANSO GIHOU **14** (1995) 1.
2) HEPAK version 3.4, Arp, V., copyright by CRYODATA.