

### §3. Cooling Performance of the Subcooling System for the LHD Helical Coils

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The cooling system of the LHD helical coils has been upgraded to generate higher magnetic fields for improving the performance of plasma experiments. In the upgraded system, the cryogen from the existing cooling system is cooled by an additional heat exchanger to generate subcooled helium of 3.0 K. In addition, heaters were attached to the outlet pipes of the helical coils to increase the mass flow of the cooling system with maintaining the liquid level as shown in Fig. 1. As the result of the upgrade, the design requirements in which the mass flow of the subcooled helium and the inlet temperature of the helical coils are respectively 50g/s and 3.2K was fulfilled. In this study, cooling tests of the system were carried out under various conditions in order to understand the performance of the cooling system.

Fig. 2 shows the temperatures of the inlet, outlet and coil case for each subcool cryostat temperature at the mass flow rate of 50g/s. As shown in Fig.2, the temperatures vary linearly for the cryostat temperature. The temperature of the coil case is higher than that of the outlet, because the coil case is considerably affected by heat radiation from the plasma vacuum vessel. In addition, the outlet temperature is lower than the saturated helium temperature of 4.3K@120kPa, the helical coils can thus be cooled by the subcooled helium in the case that the cryostat temperature is below 3.6K at least.

The coil excitation test was conducted under the rated operation of the cooling system in which the inlet temperature is 3.2K, and the mass flow is 50g/s. In the test, the helical coils were excited up to 11.25 kA at the ramp rate of 3.5 A/s, and the current value was hold during 60 s, the coils were finally demagnetized up to 0A. The current wave form and the temperatures of the inlet, outlet and coil case during the test are shown in Fig. 3. The inlet temperature was always stable in the excitation and demagnetization, on the other hand, the outlet and coil case temperatures changed gradually. The outlet temperature increased up to about 0.2 K by the effect of AC loss. Consequently, we expect that the increase of the average coil temperature would be at least 0.1 K when the coils are excited up to 11.25K at the ramp rate of 3.5 A/s. In the 10<sup>th</sup> cycle, the coil excitation above 11.0 kA was

carried out with taking into account the test result.

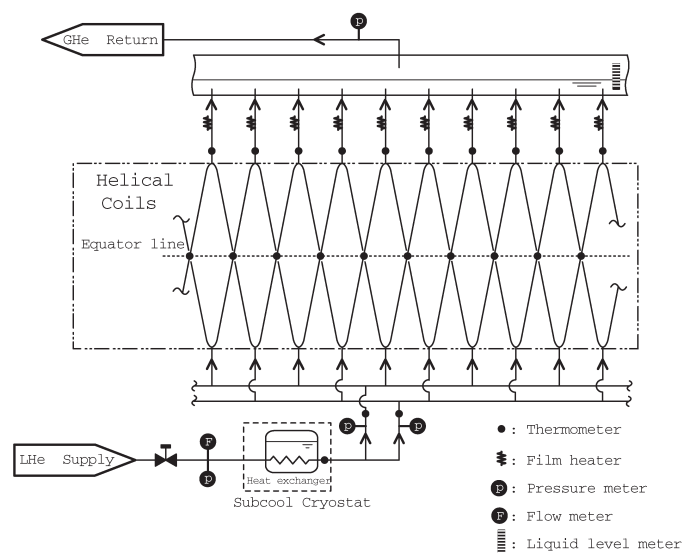


Fig. 1. Flow diagram of the subcooling system.

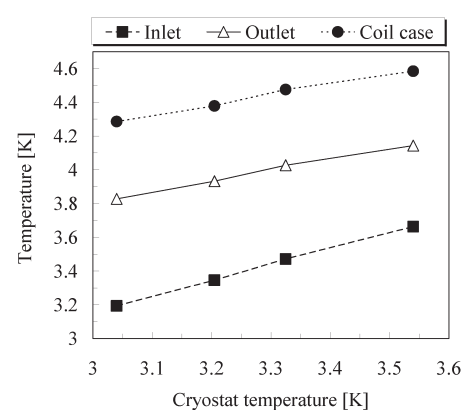


Fig. 2. Inlet, outlet and coil case temperatures for each subcool cryostat temperature at the mass flow of 50g/s.

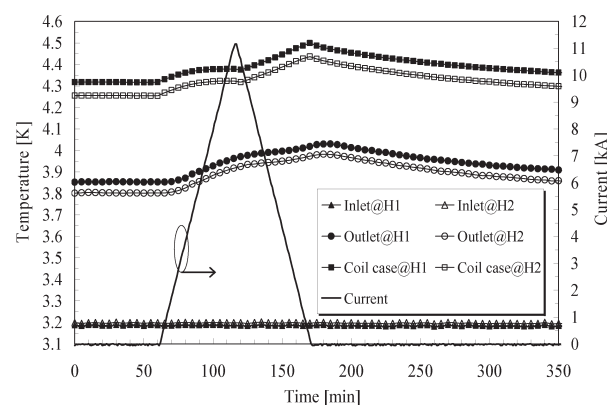


Fig. 3. Temperatures of the inlet, outlet and coil case during excitation and demagnetization. H1 and H2 mean the system of the helical coil 1 and helical coil 2.

#### Reference

- 1) T. Obana, et al.: Abstracts of CSJ Conference, Vol. 76 (2007) p.203