§2. Measurement of Residual Magnetic Field by LHD Superconducting Magnets

Imagawa, S., Takahata, K.

After only the poloidal coils of the LHD had been excited, the residual magnetic field prevented uniform glow discharging for cleaning the surface of the plasma vacuum vessel. The changes of residual magnetic field of the LHD were measured in the 7th campaign to investigate its source. Hall probes were installed at five periodic positions in the three directions on the mid-plane of the inner cylinder of the cryostat, as shown in Fig. 1. The Hall probes are high sensitive types of InSb. They were calibrated before installation within ±3 mT by a coil.

After the first excitation of the magnets, the residual magnetic field was changed by 0.2-0.25 mT at all the positions, as shown in Fig. 2. During warm-up of the magnets, the residual field was decreased as the IV coils were transited to a normal state, as shown in Fig. 3. Besides, it was slightly reduced by the transition of the helical coils. It shows that the residual field at the inner cryostat after the standard excitation was induced by the magnetization of IV coils. The amount of the residual field by the coils was 0.10-0.12 mT, which was smaller than the change by the first excitation. The difference is caused by the magnetization of the pole in the Hall probes.

The direction of residual magnetic field was same as the field during the excitation. The deviation among the five positions is within the measurement errors. The residual field was slightly decreased with a long time-constant of a few hours. It may be induced by loop currents in the cable-in-conduit conductor. After the currents were reversed, the residual field was also reversed. In the case only IS coils and OV coils were excited, the residual magnetic field is in the opposite direction during the excitation. Furthermore, the residual magnetic field after the excitation of only IV coils and OV coils is as about twice as that after standard excitations.

The magnetic field by magnetization M is given by

$$\vec{H} = -\frac{1}{4\pi} grad\left(\int \frac{\vec{M} \cdot \vec{r}}{r^3} dV \right) \qquad (1)$$

where V is the small volume of the magnetized material and r is the distance from it to the calculated point. In the assumption that a critical current density j_c is constant, the magnetization of the superconductor is given by

$$M = \frac{4}{3} j_c a^3 n \qquad (2)$$

where a and n are a radius of filaments of the conductor and the number of the filaments per unit area, respectively. The radii of OV, IS, IV, and helical coils are 13.8, 12, 15, and 47 μm. Their numbers are 3.84, 6.01, 4.80, and 0.34 $\times 10^{10}$ m^{-2}, respectively. The direction of the magnetization was set to the same as the magnetic field during the last excitation before the discharge. The calculated results for j_c of 1.2×10^{10} A/m^2 are in good agreement with the measured residual field as shown in Fig. 4.

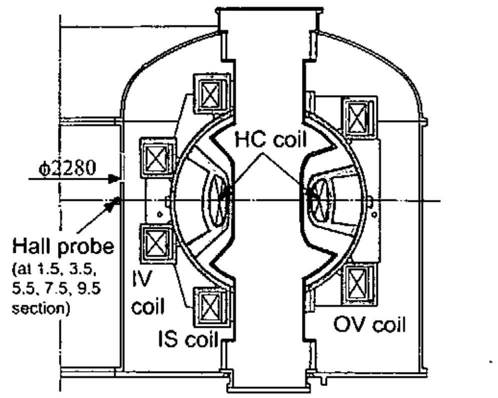

Fig. 1. Position of Hall probes on the cryostat of the LHD.

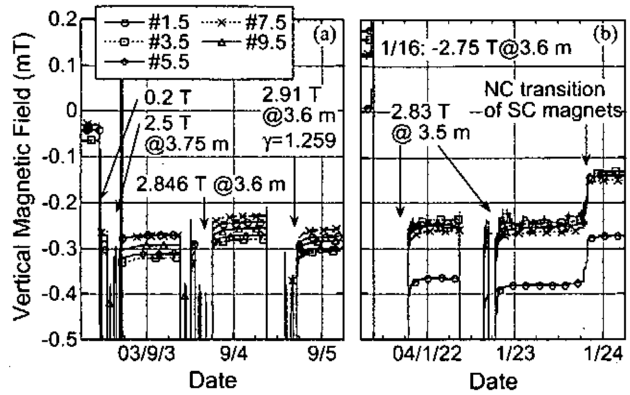

Fig. 2. Change of residual magnetic field at the inner mid-plane of the cryostat of the LHD during first excitation (a) and warm-up (b) in the 7th cooling cycle.

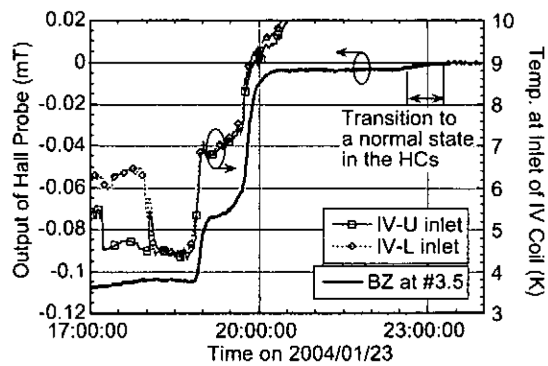

Fig. 3. Change of residual magnetic field during the transition to a normal state of superconducting magnets.

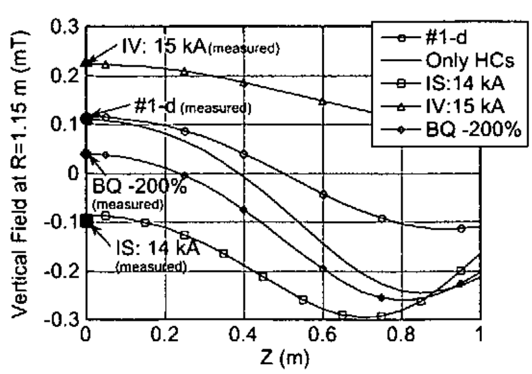

Fig. 4. Calculated residual magnetic field at the radius of 1.5 m for j_c=1.2E10 A/m^2.