§ 23. Construction of an Internal Coil Device with a High Temperature Superconductor

Ogawa, Y., Morikawa, J., Ohkuni, K., Nihei, H., Hori, D., Yamakosi, S. (The Univ. of Tokyo)
Iwakuma, M. (Kyushu Univ.)
Mito, T., Yanagi, N.

We have constructed an internal coil device with a high temperature superconductor (HTS), called Mini-RT. This is a first challenge for utilizing a HTS coil in a plasma experimental device. The major radius of the internal coil is 0.15 m and the nominal coil current is 50 kA. A schematic drawing of the internal coil is shown in Fig.1. The Ag-sheathed Bi-2223 tape with a low silver ratio of 1.57 is employed, which has a critical current I_c (77K, self-field (s.f.), 1 μV/cm criterion) of 108A. The maximum magnetic field strength at the HTS coil is 0.51 T (0.76 T) in the perpendicular (parallel) direction of the tape.

Direct excitation of the coil current with an external power supply is adopted by utilizing removable electrodes. This requires a persistent current switch (PCS) in the coil. Here the PCS is made of a bifilar coil with a 0.3wt%Mn-doped Bi-2223 tape (I_c = 52.5 A at 77 K, s.f.). The HTS coil and the PCS are covered with a copper radiation shield and multi-layer insulators. A socket-type current feed-through is equipped inside the coil and a removable electrode is inserted. The coil-lead between the HTS coil and the current feed-through is made of a 3at%Au-doped Bi-2223 tape (I_c = 62 A at 77 K, s.f.), so as to keep high thermal resistance between the HTS coil and the current feed-through. In addition, to reduce the heat load to the coil-lead, the removable electrodes are cooled by liquid nitrogen.

The HTS coil and the PCS are cooled down with cold gas helium, which is supplied to the internal coil with a cooling pipe and a check valve. Cold gas helium is supplied for the HTS coil and the PCS separately, because each temperature should be independently controlled. The internal coil is cooled down and excited at the bottom of the vacuum vessel. The coil position is precisely adjusted with a rotating stage and two-dimensionally sliding micrometers. Two electrodes and three transfer tubes are inserted into the internal coil. In addition, a multi-pin connector is inserted, and the temperatures and voltages of the HTS coil and the PCS are monitored. Cold gas helium with a flow rate of 0.5 g/s is supplied with two GM refrigerators, the total cooling power of which is 33 W at 20K. It took about 11 hours to cool the coil down to 21 K from the room temperature.

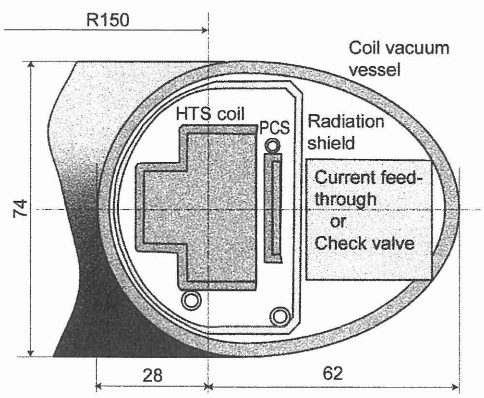

Fig. 1 A schematic drawing of the internal coil.

The excitation of the coil has been carried out. Figure 2 shows the waveforms of the currents of the coil cable and the power supply, and temperatures of the HTS coil and the PCS. Here the coil current was evaluated by measuring the magnetic field with a Hall probe. Initially the HTS coil was cooled down to 21 K, and then the PCS temperature was raised above the critical temperature (about 106 K) using a Manganin heater so as to hold the turn-off condition. In Fig.2, a persistent current (of ~80A) due to the previous excitation was quickly discharged with an increase of the PCS temperature. The coil current was supplied by the external power supply within a few minutes. When the coil current was increased up to the nominal value of 118 A, the PCS was quickly cooled down below 40 K to hold the turn-on condition. Then, the current of the power supply was decreased, and the persistent current mode was achieved. The persistent current gradually decays with a time constant of ~20 hours at the initial phase. This time constant seems to be considerably shorter than the expected value of ~200 hours which can be obtained by integrating the flux-flow resistance and the joint resistance along the coil cable. We should consider some kind of electromagnetic effect for explaining the observed unexpectedly large resistance in the coil cable.

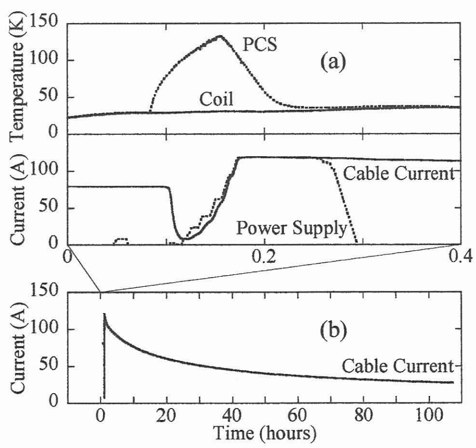

Fig. 2 Excitation test of the HTS coil; (a) the charging phase using a PCS heater and (b) the persistent current phase.