§3. First Cool-down Performance of the LHD

Mito, T., Maekawa, R., Yamada, S., Nishimura, A., Takahata, K., Imagawa, S., Watanabe, K., Yanagi, N., Tamura, H., Iwamoto, A., Baba, T., Moriuchi, S., Oba, K., Sekiguchi, H., Ohtake, I., Satow, T., Satoh, S., Motojima, O. and LHD Group

The first cool-down test of the Large Helical Devise (LHD) and the performance of the LHD cryogenic system during the first cycle operation are described. The LHD is the first fully superconducting heliotron type experimental fusion device. The superconducting coils for the LHD consists of two helical coils (H1 and H2) and three pairs of poloidal coils (IV, IS and OV). The helical and poloidal coils are mounted on the supporting structure in the cryostat, whose total cold mass becomes 850 tons.

The LHD cryogenic system consists of the helium refrigerator/liquefier, the superconducting helical and poloidal coils, the supporting structure, the superconducting bus-lines, the cryostat, the control-valve-boxes, the cryogenic transfer-lines and the cryogenic control system (LHD-TESS).

The helium refrigerator/liquefier can support four different cooling schemes; 1) a pool boiling for the helical coils and the current leads, 2) a forced flow supercritical helium for the CICC poloidal coils, 3) a forced flow two phase helium for the supporting structure and the superconducting bus-lines, 4) a forced flow 40 K – 80 K helium gas for the 80 K radiation shields. The cooling capacities of the He refrigerator are 5.65 kW at 4.4 K, 20.6 kW from 40 K to 80 K and 650 L/h liquefaction simultaneously.

Main events during the first cool-down test are listed in Table 1. We started the main compressors in Feb. 9, 1998, and continued purifying operation of the cryogenic system until Feb. 22 to remove impurities in helium gas (such as oxygen, nitrogen, water, etc.) less than 2 ppm. The first initial cool-down of the LHD started in Feb. 23, and finished in Mar. 22. Figure 1 shows cool-down curves of the helical and poloidal coils. The coils and the supporting structure were cooled by the temperature controlled helium gas, mixing cold and warm gases in the helium refrigerator. The temperature distribution in the coils and the supporting structure was maintained less than 50 K. On Mar. 17, at 16:10 the helical coils became superconducting state and at 22:58 all poloidal coils became superconducting state when the supply gas temperature was 8.5 K and the coil outlet temperature was 9.0 K. According to the programmed refrigeration modes, the cool-down was successfully completed within 4 weeks on schedule.

After the cool-down, the excitation tests of the SC coils were successfully carried out up to 1.5 T, which was the operating plasma central field during the first cycle experiments. The long-term operation for the first cycle plasma physics experiments have continued until the middle of May. The cooling characteristics of the LHD such as temperature distributions during cool-down, heat loads in steady state were measured and confirmed almost same as the design values.

Table 1. First Cool-down Procedure of the LHD

Date	Events
2/9 – 2/22	Purification
2/9	Start of He Compressors
2/23 – 3/22	Cool-down
2/23	Start of Cool-down
2/23 – 3/8	Cool-down with LN_2 HEX
3/9 – 3/18	Cool-down with Turbines (T1 – T7)
3/9	Start of Turbines T1 to T5
3/13	Start of Turbines T6 and T7
3/17	Helical and Poloidal Coils became superconducting state
3/18	SC Bus-lines became superconducting state
3/18 – 3/22	Cool-down with LHe
3/23 - 3/28	Excitation Tests of SC Coils
3/29 – 5/15	Steady State Operation for 1st Cycle Exp.

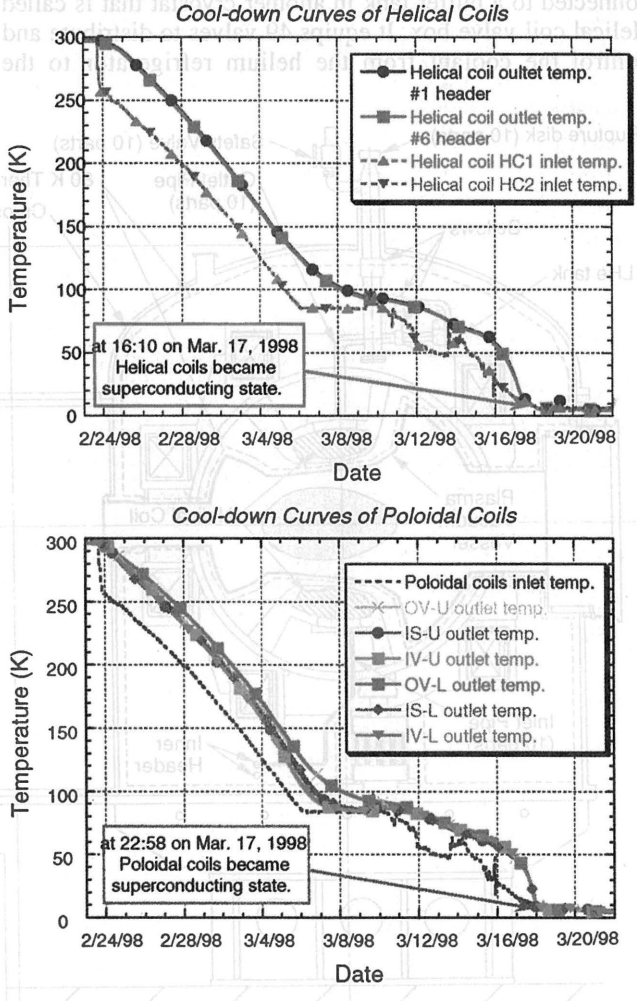

Fig. 1. Cool-down curves of the helical and poloidal coils for the LHD.