§2. Cooling System and Current Feeder of Helical Coils for LHD

Imagawa, S., Yanagi, N., Mito, T.

The helical coils for LHD are large scale pool-cooled superconducting coils. Against large electromagnetic forces, the conductors are packed into thick cases which are used as baths for liquid helium. Longitudinal cooling channels inside the coils are placed at both sides of each layer of the conductors and both top corners, the areas of which are 25 $mm^2 \times 2 \times 20$ layers and 306 $mm^2 \times 2$, respectively. These areas were required to vent helium bubbles generated by steady heat input. Electrical insulators between conductors are 2.0 and 3.5 mm thick, and they are settled at intervals to create transverse cooling channels. The layouts of cooling pipes and coil leads are shown in Fig. 1. The coolant is supplied from each bottom of the coils through two inlet headers and ten inlet pipes. Ten outlet pipes from the top of the coils are connected to a header tank which equips ten safety valves, ten rupture disks and two kinds of venting lines for an emergency. There are twenty parallel passes in the helical coil. The inlet headers and the header tank are connected to a buffer tank in another cryostat that is called Helical coil valve box. It equips 49 valves to distribute and control the coolant from the helium refrigerator to the helical coils, the supporting structures and 80 K thermal shields. Against the coolant content of 2.2 m^3 in the helical coils, the volume of the header and buffer tank are 2.3 and 4.0 m^3, respectively, to stabilize the liquid level control and to delay the pressure increase during an emergency. The amounts of liquid helium in both the tanks will be controlled to be 1 m^3.

The coil leads are derived from the outer mid-plane and connected electrically to the superconducting power cables, which are called SC Buslines, with S-shaped flexible leads at the bottom of the cryostat. Since the coil leads move inside by 20 mm during cooling down from 300 K to 4.4 K, the flexible leads are necessary to reduce the counter force to the terminal of the SC Busline under 200 kg. Terminals of both the coil lead and the SC Busline are copper plates with superconductors inside. The flexible lead consists of two copper plates sandwiching the terminals at the end, compacted superconducting strands buried in them, and copper pipes welded to both sides. The coil leads are in pipes and cooled by liquid helium from the header tank through each branching pipe. The coolant is bounded at the terminal by ceramic breaks. The flexible leads are cooled by two-phase helium from the SC Buslines. Since the amounts of strands are twice as the conductor of the helical coils, the cryostability will be sufficient at less than 8.5 K. The cross-section of the copper plate was designed to avoid thermal runaway. The joint resistances between the flexible lead and the terminals are estimated in the order of nΩ.

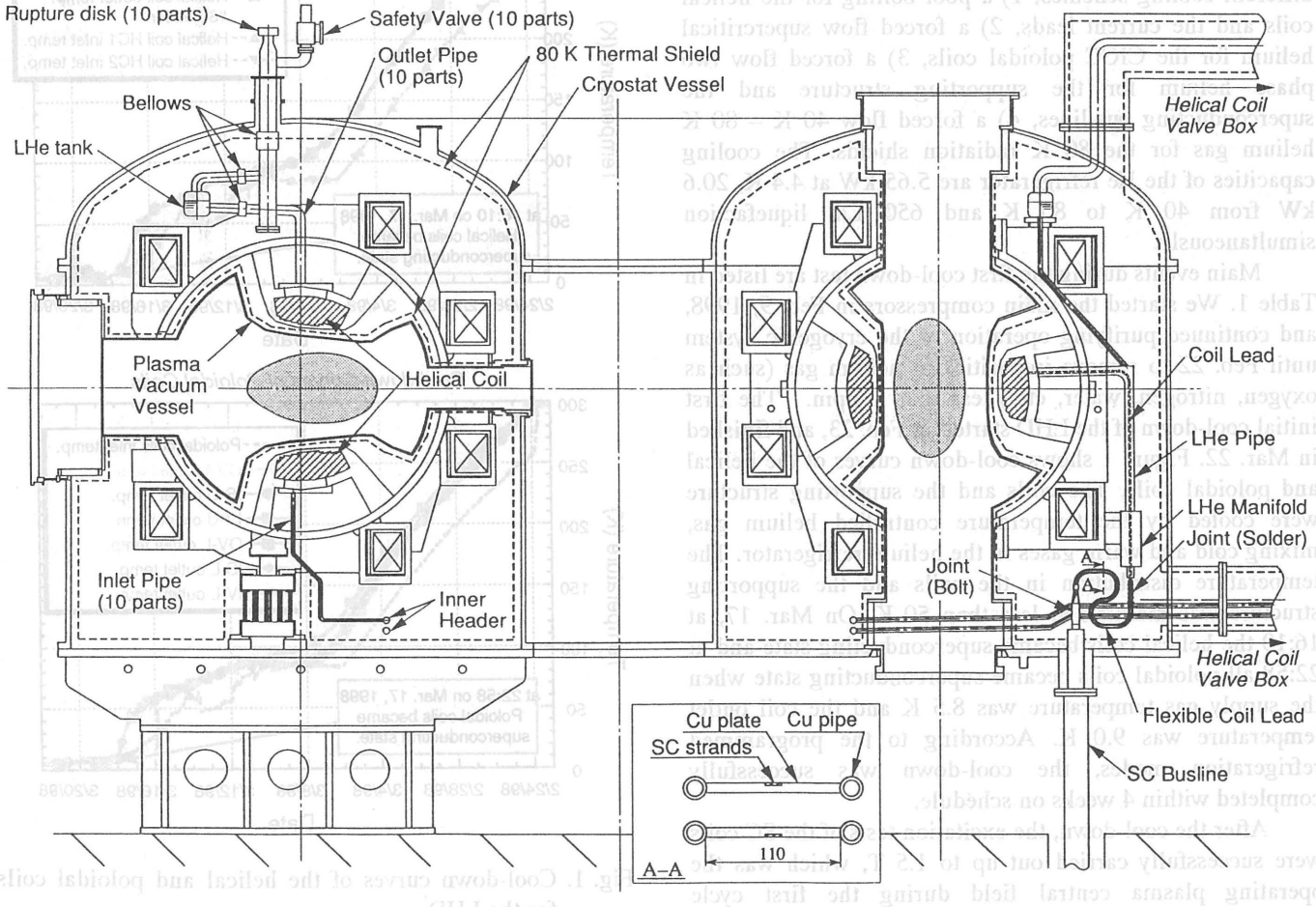

Fig. 1 Layout of cooling pipes and coil leads of helical coils