SUPERCONDUCTING HELMHOLZ COIL

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Abstract

A superconducting Helmholz coil and a superconducting shielding tube have been built and preliminarily tested. This program is aimed to study the technical problem for windings of cable, current lead, cryostat, cooling etc.

1. Superconducting Helmholz Coil

The Helmholz coil is of 14 cm bore and of 1.6×2.5 mm^2 multifilament NbTi alloy superconductor embedded in a copper matrix. Designed field strength at Helmholz coil center is 50 kG at 750 A excitation. The specifications of superconducting coil are listed in table 1 and the coil assembly is shown in fig. 1.

Table 1. Specification of superconducting Helmholz coil

Bore diameter	140 mm
Number of turns	748/coil
Muximum current	750 A
Current density	187.5 A/mm^2 at 750 A
Coil gap	45 mm as Helmholz coil adjustable between 40 mm and 60 mm
Field strength at center	50 kG at 750 A
Stored energy	74 kJ at 750 A

The cable was wound up tightly to an FRP bobbin with radial grooves for cooling channel. After winding, the coil was hardened with epoxy resin in a dry furnace. The space factor of the conductor of the coil finished is approximately 0.88. Two coils are assembled with a stainless steel cylinder and tightened up by end plates. The gap between the coils are adjusted by stainless steel spacers. These structures also have cooling channels. The weight of coil assembly is about 75 kg.

Vapor cooled current leads are made of OFHC copper tubes covered with a stainless steel sheath. The vapor flows inside these tubes. The current density of the lead is 18 A/mm^2 at 750A.

The cryostat, 66 cm in diameter and 100 cm in height, is made of stainless steel vessel, copper radiation shields and LHe vessel made of SUS304L. It has 8.5 cm diameter warm bore coaxial with the Helmholz coil. The outside and the bottom of the LHe vessel are shielded by LN_2 cooled copper plates whereas the bore is by superinsulator from the warm bore of the cryostat. Three layers of polystyrene is placed on the shield plates to avoid thermal convection above the vessel. The estimated heat load at LHe temperature is about 4 W with no current.

The magnet was assembled with the gap between coils adjusted to be 5 cm and installed to the cryostat. A series of coils were connected to a power supply with the external current leads of 200 mm^2. The magnet was cooled down with LN_2 of 60 liters. The resistance of the magnet decreased from 4.4 Ω at room temperature to 0.8 Ω at 80°K. Then the LN_2 was removed and LHe was introduced from a dewar through a transfer tube. In about two hours, the coils became a superconducting state and the LHe starts to stay. The boiled-off gas was drawn out through current leads and a top flange of the cryostat. With 40 liters of LHe, the magnet was fully immersed and another 15 liters was appended.

First the magnet was excited with an excitation rate of 100A/5min. Up to 400 A excitation, which corresponds 26 kG at the center, the axial and radial field distributions on and off axes were measured at every 100 A by Hall probes calibrated with a conventional magnet. In this run, the current reached to 550 A and then decreased with a rate of 100A/3min. Refilling with LHe, excitation up to 650 A was made. The field strength at the center of the coil was measured at every 100 A by a search coil with a mirror integrator. Examples of the measured fields are shown in fig. 2. These results are consistent with the calculation. The measured boil-off rate of LHe is about 3.5 ℓ/H with no current and 8 ℓ/H with 650 A excitation, respectively. These figures have a space to be improved to account a gas enthalpy.

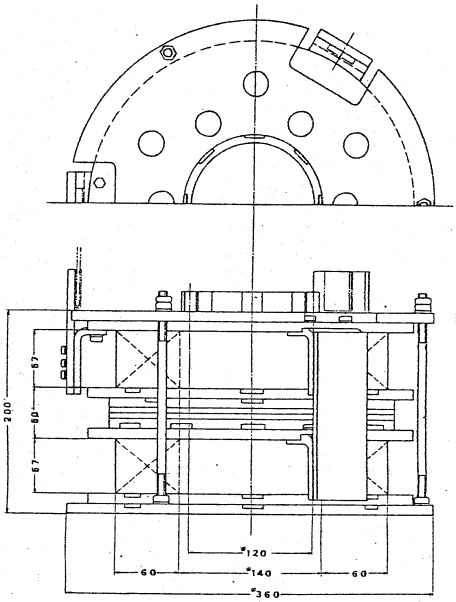

Fig. 1. Superconducting Helmholz coil assembly.

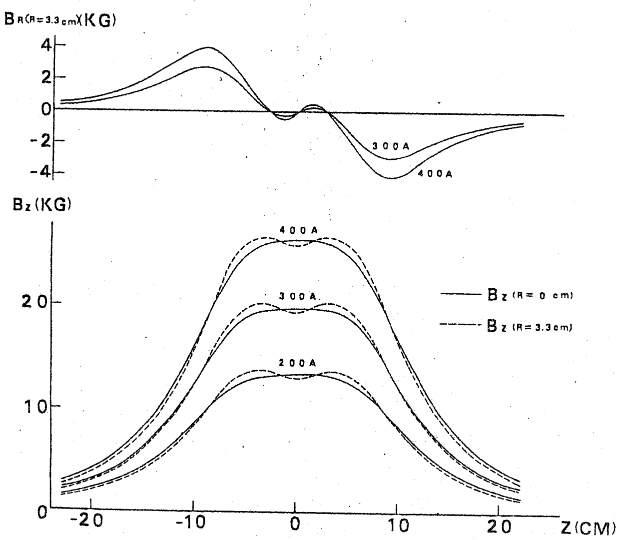

Fig. 2. Field distribution measured by Hall probe.

2. Superconducting Shielding Tube

A superconducting tube which shields the external magnetic field was made. The inner and outer diameter of the tube is 26 mm and 46 mm, respectively. The tube, made from 10 mm width and 0.14 mm thick V_3Ga tape sandwiched by soldered OFHC Cu (20 µm thick) sheets, was impregnated with wood's metal.

The test has indicated that:
(1) The shielding tube has worked well at the external field up to 9 kG. (2) Over 9 kG the flux jump has been observed and the magnetic flux at 9 kG has been trapped in the superconducting tube. (3) The trapped flux has not disappeared unless the temperature of the tube has risen up to the super-to-normal transition temperature.