SUPERCONDUCTING COMPENSATOR MAGNETS
TO BE
USED WITH THE HRS SPECTROMETER
AT THE
SLAC PEP FACILITY

MASTER

by

L.G. Hyman, J.F. Sheppard, and R.F. Smith

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SUPERCONDUCTING COMPENSATOR MAGNETS TO BE USED WITH THE HRS SPECTROMETER AT THE SLAC PEP FACILITY*

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Abstract

The first of a pair of identical superconducting compensator solenoids required for the High Resolution Spectrometer Facility (HRS) at the Stanford e^+e^- Colliding Beam Storage Ring Accelerator (PEP) has been tested. The magnet provides a 2.0 T field in a room temperature bore 19.0 cm in diameter. The magnet winding length is 1.65 m and a cold iron yoke reduces the fringe fields 30 cm outside the cryostat to less than 10 gauss. The pool-boiling helium cryostat with liquid nitrogen cooled thermal radiation shield will be supplied with cryogens from the Spectrometer Facility refrigeration system.

Introduction

The installation of the Argonne 12-foot Bubble Chamber superconducting magnet at the PEP machine at Stanford Linear Accelerator Center as a solenoidal particle detector magnet has required the construction of two superconducting compensating solenoids to complete the new HRS Facility. The first of these identical compensator magnets (Fig. 1) has been completed and successfully tested. Each magnet must provide one-half the ampere-turns of the HRS main magnet and have a

solenoidal geometry with a warm bore 19.0 cm in diameter. The fringe field was required to be reduced as much as practical to minimize interference with other nearby equipment. The specification of the axial dimension of the magnet involved a tradeoff between a longer magnet preferred by the storage ring designers and a shorter magnet preferred by the storage ring users who seek maximum space along the colliding beams for experimental equipment. A batch-fill pool-cooled cryostat was specified for compatibility with the refrigeration system of the HRS main solenoid. The magnet iron yoke was designed with a "guard ring" structure at each end which reduces the fringe field axially beyond the coil by approximately 20%. Care was used to position the cold iron yoke concentrically around the coil so that the fringe fields at the ends of the magnet remained radially symmetric insofar as possible. Stray dipole fields, if sufficiently large, can profoundly effect the performance of the PEP storage rings. Room temperature dipole windings are provided in the warm bore of the compensator to cancel up to 100 gauss-meters of dipole fields due to misalignments.

Conductor

A conventional monolith of multifilamentary NbTi in copper was used for the compensator magnet. The copper to superconductor ratio was 5.25 to 1.0. Formvar was applied to the bare conductor for electrical insulation. The characteristics of the conductor are presented in Table I.

Table I

Compensator Conductor Characteristics

Material	NbTi Multifilament in Copper
Bare Dimensions	0.102 x 0.203 cm
Filament Size	36 microns
Number of Filaments	264
Copper:NbTi Ratio	5.25:1.0
Critical Current (3T, 4.2K)	550 A
Insulation	0.005 cm Formvar

Winding Design

The conductor was helically wound onto the stainless steel bore tube which was insulated with a 0.010 cm thick layer of mylar overwrapped with a double layer of 0.013 cm thick mylar tape. Pickets consisting of narrow mylar ribbons 0.036 cm thick and 0.635 cm wide were laid axially on the insulated bore tube with 0.635 cm spacing. These pickets formed longitudinal

Fig. 1 Compensator Solenoid for the HRS Facility

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vent channels between the bore tube and the first layer of conductor which was wound onto the pickets. As each layer of conductor was added to the coil, an interlayer sheet of mylar 0.010 cm thick was wrapped onto the layer to provide additional interlayer electrical insulation. A set of pickets made from epoxy-glass sheet was laid axially on the coil after the last layer was completed. These pickets were 0.159 x 0.318 cm in section and provided ventilation between the coil and the stainless steel banding which was wound onto the pickets. Three layers of banding each 0.13 cm thick provided coil support against the magnetic hoop forces. The conductor was wound with pretension and the banding with 335N pretension. No epoxy of any type was used during coil winding. The ends of the coil were electrically insulated from the bore tube flanges by an epoxy-glass spacer 0.635 cm thick. The calculated cumulative axial compressive stress on the midplane of the coil is 1.6×10^7 Pa.

Safety calculations made with a version of the Rutherford program QUENCH¹ using credible values of the adiabatic quench propagation velocity indicated that peak temperatures during a quench would not exceed 125 K and that the coil internal voltage (coil resistive voltage subtracted from the local inductive voltage) does not exceed 100 V. No protection resistor is required for quench safety.

The coil parameters are given in Table II.

Table II

Compensator Magnet Parameters

Winding Length	165.74 cm
Winding ID	25.15 cm
Winding OD	26.19 cm
Number of Layers	6
Number of Turns	4536
Peak Conductor Field	1.9 tesla
Operating Current	550 amperes
Iron Yoke ID	28.0 cm
Iron Yoke OD	40.6 cm
Cryostat OD	71 cm
Cryostat Length	2.00 m

Cryostat Design

The winding bore tube forms the inner diameter of the helium vessel, with added

cylindrical sleeves welded to the ID of the bore tube end flanges to carry the inner vessel axially beyond the reentrant ends of the cold iron yoke which itself is precisely and rigidly clamped to the bore tube end flanges. Flanges welded to the sleeves form the ends of the helium vessel and a cylindrical sleeve welded to the OD of the flanges completes the outer diameter of the helium vessel. The acentric mounting of the magnet with respect to the helium vessel permits a helium ullage above the coils of 130%. The ends and the OD of the helium vessel are insulated with 10 layers of superinsulation and the 1200 kg cold mass is suspended from the vacuum vessel with epoxy-glass tension links. A convection-cooled copper thermal radiation shield covered with 50 layers of superinsulation surrounds the ends and OD of the helium vessel. The ID of the helium vessel is screened from 300 K radiation by 100 layers of superinsulation. The vertical tower on the cryostat contains a 20 l liquid nitrogen reservoir and all electrical and cryogenic penetrations. The cryostat is designed to permit the cold mass to be precooled with liquid nitrogen.

System Performance

The magnet coil was operated in a vertical dewar without the iron yoke. The magnet reached the short sample limit, 610 amperes, on the third quench. Following installation of the iron yoke and completion of the cryostat the entire system was tested. The helium compensation of the cryostat with no current but cold gas flow in the current leads was found to correspond to a total heat flux to the cold mass of 4 W. This was observed to decrease to about 3 W as the helium level decreased in the cryostat. The magnet was energized and the first quench occurred at 522 amperes. On the fifth quench the short sample limit (for the load line with the iron yoke) of 590 amperes was reached. This represents a "loss of memory" of the magnet, perhaps due to the thermal cycle between the two testing periods. The magnet operates stably at 550 amperes (93% of short sample) and this will correspond to operation of the HRS main solenoid at 2000 amperes.

References

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