ALTERNATIVE DIPOLE MAGNETS FOR ISABELLE

Taylor, C.

1982-05-01

LBL-14215
SUMAG-62

LBL--14215

DE82 020549

ALTERNATIVE DIPOLE MAGNETS FOR ISABELLE*

C. Taylor, R. Althaus, S. Caspi, W. Gilbert, W. Hassenzahl
R. Meuser, J. Rechen, and R. Warren

May 1982

Accelerator and Fusion Research Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

---

*This work was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, High Energy Physics Division, U. S. Dept. of Energy, under Contract No. DE-AC03-76SF00098.

LBL-14215
SUMAG-62

ALTERNATIVE DIPOLE MAGNETS FOR ISABELLE

A dipole magnet, intended as a possible alternative for the ISABELLE main-ring magnet, was designed at LBL. Three layers of FNAL Doubler/Saver conductor were used. Two 1.3-m-long models were built and tested, both with and without an iron core, and in both helium I and helium II.

The training behavior, cyclic energy loss, point of quench initiation, and quench velocity were determined. A central field of 6.5 tesla was obtained in He I (4.4 K), and 7.6 tesla in He II (1.8K).

INTRODUCTION

A dipole magnet design was developed by the Lawrence Berkeley Laboratory as a possible alternative for the ISABELLE project of the Brookhaven National Laboratory. Two developmental magnets with internal cold bores of 133 mm and lengths of 1.3 m were built and have been tested in He I at 4.4 K and in He II at 1.8 K.

MAGNET CONSTRUCTION

A construction method was developed in which the magnet coil structure is assembled without the use of adhesives, in its final form, on the coil winding fixture. Following the techniques developed for 76 mm-bore diam, two-layer model coils [1], a three-layer winding was made in which each layer was wound directly over the previous layer (Fig. 1). Each layer of cable is pre-compressed using special clamps and then wound with a single layer of approximately 1.0 mm x 2.0 mm monofilament Nylon to maintain the pre-compression. Sufficient circumferential coil pre-stress is introduced during construction to prevent separation of the coils from the pole spacers under the action of the Lorentz forces induced during operation. The final pre-stress is achieved by means of a tapered collet and structural ring system, which compresses the coil assembly radially. All rings are 200 mm I.D. Aluminum alloy rings 37 mm long x 320 mm O.D. are used to support the ends, and mild steel rings 35 mm long x 490 mm O.D. are used in the straight section. For the iron-free test, all rings are 320 mm O.D. aluminum alloy.

The superconductor is a standard Fermilab 23-strand Rutherford cable that is insulated with 25 μm Kapton and 50 μm Mylar overlapping tapes. These windings have less helium ventilation than other designs which have a wrap of fiberglass around the cable. In each half of the magnet the inner and middle layer are connected electrically near the pole at one end, and wound with a single length of cable (no internal splice). The electrical lead from the outer layer is connected to the lead from the other layers in a low-field region at one end of the magnet. No effort was made to produce a high-uniformity field in these models.

MAGNET PERFORMANCE

Training Behavior in Helium I and Helium II

Two magnets were built and tested. The first magnet, D-8A, was initially tested with external aluminum-alloy structural rings. In He I (4.4 K) the first quench occurred at 4.3 tesla central field, the seventh quench at 5.0 tesla, and at the fifteenth quench the coil reached the short sample limit of 5.4 tesla. Two quenches in He II (1.8 K) raised the field to 6.3 tesla. Later the aluminum structural rings over the central straight section were replaced with iron (mild steel) structural rings. This moved the high field point from the end region into the central straight section. In He I the first quench occurred at 5.0 tesla, the eighth quench at 5.5 tesla, the sixteenth at 6.0 tesla, and the short sample limit of 6.5 tesla was reached only after training in He II. In He II, the first quench occurred at 6.5 tesla, the fourth at 7.0 tesla and 7.6 tesla was reached at the eighth quench.

Various mechanical improvements were introduced in the fabrication of the second magnet, D-8B, with the intent of making the structure more rigid and increasing the compressive pre-stress. In He I, 5.0 tesla was achieved on the first quench, 5.7 tesla on the second, 6.2 tesla on the third, and short sample, 6.5 tesla, on the eighth (Fig. 2). In He II, 7.2 tesla was reached on the first quench, 7.3 on the second, and a maximum 7.6 tesla in another run sequence at a later date. The central field was measured with Hall probes and magnetoresistence probes that were previously calibrated in our short-sample magnet.

Cyclic Energy Losses

Cyclic energy losses were measured in He II using a calorimetric method discussed in another paper in this conference.[2] Triangular current-time waveforms were used. One of the magnets with iron structural rings was cycled between 0.5 tesla and 6.5 tesla at 0.47 tesla/s rate, 25 s full period. The heat generation rate was 41 watts or 24 mJ/cycle-tesla-cc of conductor. At lower sweep rates, the specific loss rate, mJ/cycle-cc, is lower, approaching one-third of the above number at very low sweep rates.

Quench Location and Quench Velocity

Voltage taps on the inside turns of the inner coil layers were used to locate the quench-initiating site and map the quench wave propagation. Additionally, acoustic emission sensors were placed at each magnet end, and the time of arrival of the acoustic-emission signals were used to determine independently the time and location of the quench-initiating event.

It was found that out of 21 quenches, 19 occured in the inner layer, 2 occured in the second layer, and none occured in the third or outside layer. Two quenches occured at the transition between the straight section and the curved end turns, and all others occured in the straight section at the inside turn next to the pole island. The agreement between the data from the voltage taps and from the acoustic-emission sensors is excellent. The quench propagation velocities along the cable vary from 5.8 to 22.6 m/s, increasing with quench current. The turn-toturn transfer times yield azimuthal velocities from 0.042 to 0.105 m/s.

Test Facility

Tests were conducted in our large, 400 liter, horizontal He II cryostat (Fig. 3). This apparatus has a magnet chamber 0.56 m in diameter and and 1.4 m in length. The gas-cooled current leads and the power supply are capable of 7000 A operation. Liquid helium is supplied by a refrigerator rated at 200 W at 4.2 K, or about 70 liters of liquid per hour. For operation in He II, an auxiliary vacuum pump, operating as a closed-loop, low-pressure compressor, maintains reduced pressure over a small quantity of liquid helium in a heat-exchange coil immersed in the main helium volume, accommodating a heat load of 30 W. An external quench-detection and energy-extraction system limits the energy input to the helium bath during a magnet quench to about 25 percent of the stored energy.

CONCLUSIONS

The same type of training behavior found in 76-mm-bore-diameter, 2-layer iron-free magnets [1] is found in these larger-bore, 3-layer magnets.

At the initiation of a quench, resistance usually first appears in the straight section of the inner layer next to the pole.

Considering stability and pulse losses, a three-layer design using this type of cable could be used as a 6T, 4.2 K synchrotron magnet.

ACKNOWLEDGEMENT

This work is supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, High Energy Physics Division, U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

REFERENCES

1. Taylor, C., Althaus, R., Caspi, S., Gilbert, W., Hassenzahl, W., Meuser R., Rechen, J., and Warren, R., "Design of Epoxy-Free Superconducting Dipole Magnets and Performance in Both Helium I and Pressurized Helium II", IEEE Trans. on Magnetics, vol MAG-17, no 5, Sept. 1981.

2. Caspi, S., "The Use of Calorimetry in Superfluid He II to Measure Losses in Superconducting Magnets", Paper HC-4, ICEC 9.

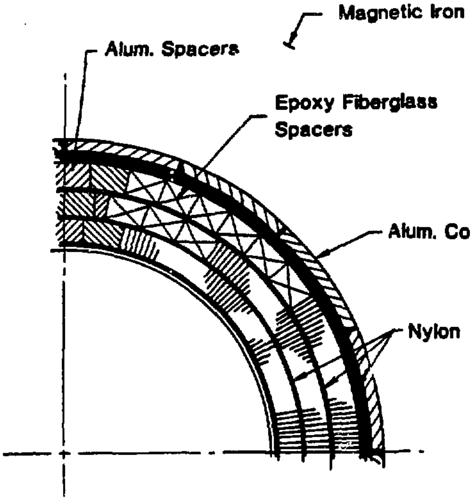

Fig. 1 Magnet cross-section.

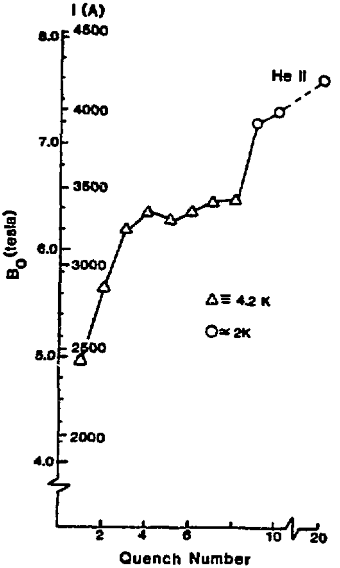

Fig. 2 Training curve for magnet D-8B.

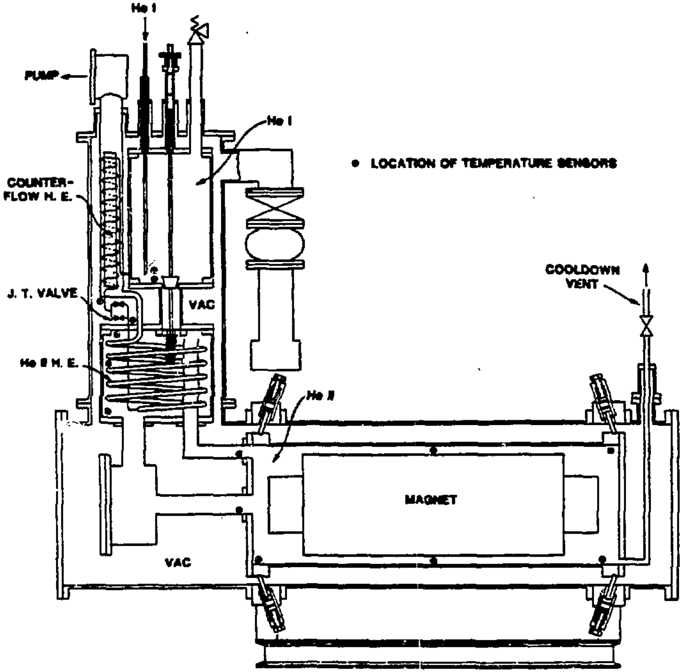

Fig. 3 Helium II cryostat for testing 1-meter magnets.