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Author
Hassenzahl, W.

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STABILITY IN ACCELERATOR DIPOLES IN He I AND He II

W. Hassenzahl, W. Gilbert, C. Taylor, S. Caspi, J. Rechen, and R. Meuser
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Introduction

Several epoxy-free magnets of 76 and 130 mm diameter have been constructed and tested at Lawrence Berkeley Laboratory /1,2,3/. This report describes results of tests at 1.8 and 4.4 K on two recently completed magnets and presents some earlier data on heater induced quenches also at 1.8 and 4.4 K.

The epoxy-free magnets constructed have been quite similar but each has certain unique characteristics as described in Table I. All the coils are made of 23 strand Rutherford cable, of approximately the FNAL size, which is insulated with both kapton and mylar. (The coil D-7D had a small quantity of epoxy on the mylar insulation). The terms used to describe the conductor in Table I refer to the coating on the individual strands. The zebra conductor is made of wires coated with either Stabrite or Ebanol (copper oxide). The copper nickel (CuNi) conductor for D-7G is made of strands of wire having the same configuration as the wire in the Brookhaven Isabelle braid. In addition to a CuNi outer jacket, this wire has fewer but larger (18 μm vs. 10 μm diam.) filaments than the conductors in the other coils constructed in this program. All the coils fabricated in this program, except D-7G, reached 95% of short sample in 7 or fewer quenches.

Table I

Characteristics of LBL Dipole Magnets

Magnet Designation	Inner Diameter (mm)	No. of layers	Conductor	Compressive Preload (MPa)	Compressive Preload (psi)
D-7A	76	2	Stabrite	35	(5000)
D-7B	76	2	Zebra	35	(5000)
D-7C	76	2	Stabrite	104	(15000)
D-7D	76	2	Stabrite	104	(15000)
D-7G	76	2	CuNi shell	104	(15000)
D-8A	130	3	Stabrite	43	(6300)
D-8B	130	3	Zebra	41	(6000)

Tests of D-8B

The testing of D-8B consisted of studying the training behavior of the coil, monitoring the energy deposited in the coil before and during transitions, and measuring cyclic losses. The training of D-8A and D-8B are shown in Fig. 1. Both coils reached about 95% of the 4.4 K short sample in 6 quenches. After the initial set of tests shown in Fig. 1, D-8B was warmed to room temperature, partially disassembled and reassembled with much higher compressive load. Many of the quenches in D-8B during a second test sequence were monitored on a new data acquisition system with a sampling rate of 20 kHz and exhibited a precursor pulse in the inner layer of the coil. These pulses, which we assume are due to conductor motion, lasted from 0.2 to 1.0 msec and had voltages up to 1.4 V. The energy released during these precursor pulses is given in Table II.

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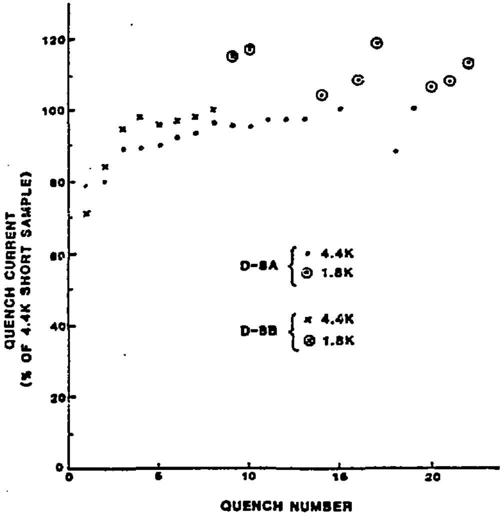

Fig. 1 Quench performance of D-8A and D-8B 130 mm bore accelerator dipole model coils

All the coils listed in Table I are thought to be quite well constrained in the straight sections, but are relatively loose at the ends. Thus it is possible to have all or part of an end move. The large, 9.8 J precursor pulse associated with quench number 34 corresponds to a change in area, at 6 T, of about 3.6 x 10^{-3} m^2. A motion of 0.36 mm would be required if this change were due to the collective movement at one end of the coil of all 67 turns in the inner layer. The ends of the coils had moved outward during the tests; however, no accurate measurements were made before the tests so the extent of the motion could not be determined.

Table II

Energy release during quench producing disturbance in dipole magnet D-8B

Quench Number	Current (A)	Temperature (K)	Energy (J)
28	3650	1.7	4.5
31	4075	1.7	6.8
32	4194	1.9	5.1
34	4100	1.8	9.8
43	2910	4.4	0.03
45	2878	4.4	0.11

Table II shows a large difference in the precursor energy for quenches at 1.8 and 4.4 K. Even though the quench currents correspond to about the same fraction of critical current, the quenches at 1.8 K were triggered by events with 40 to 200 times as much energy as those that preceeded the 4.4 K quenches. This observation is not as relevant as it may appear to be because the data acquisition system did not trigger on non-quench inducing signals thus we cannot determine the actual disturbance spectrum.

Tests of D-7G

The training behavior of D-7G and D-7B are shown in Fig. 2. The training of D-7G is very slow as compared to D-7B and all the other coils and is characteristic of the very unstable conductor. Similar training was observed in short sample tests of this conductor at Brookhaven /4/. The cause of the poor stability of this conductor is not known; however, both the copper nickel shell and the large filaments are suspect. Tests of coil D-7G are still in progress, but we have not yet seen the large precursor pulses in D-7G that were observed in D-8B. This absence may be due to the inherent instability of the conductor, smaller disturbances are required to cause quenches, or to the fact that the coil is very well clamped, and cannot move.

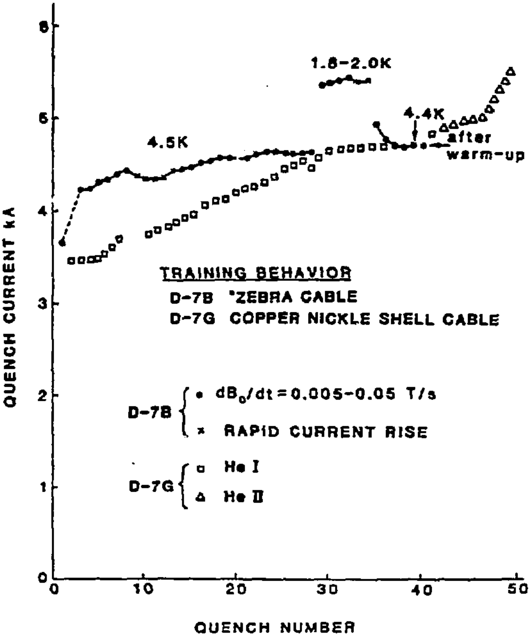

Fig. 2 Quench performance of D-7B and D-7G 76 mm bore accelerator dipole model coils

Heater Tests

Electrical heaters having a length of 5 cm were built into the D7A magnet in the high-field region between the center island and the first conductor turn. For heat pulses longer than about 250 ms, the quench current depended on the power delivered to the heater, whereas for shorter times it depended on the energy. Table III contains the heater energy required to quench the coils in helium I and II at various magnet currents. Because the thermal contact between the heater and the conductor was poor, a quantitative interpretation of the data is not possible but it is clear that for similar currents and fields appreciably more energy is required to initiate a quench in He II than in He I.

Table III

Pulsed and Continuous Heat Input Required to Quench
a Superconducting Dipole D-7A

I		Helium I			Helium II	
	<250 ms	1 sec	Cont.	<250 ms	1 sec	Cont.
2000 A	220 mj	1200 mj	0.45 W	220 mj	1000 mj	1.3 W
3000 A	180 mj	750 mj				
4000 A	120 mj	390 mj				
4500 A	90 mj	270 mj				

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