Title
SUPERCONDUCTING PULSED SYNCHROTRON DIPOLE AMD DC BEAM TRANSPORT MAGNETS

Permalink
https://escholarship.org/uc/item/52365023

Authors
Eaton, W.F.
Gilbert, W.S.
Kilpatrick, R.A.
et al.

Publication Date
1971-02-01

Presented at the Particle
Accelerator Conference, Chicago, IL,
March 1-3, 1971

UCRL-20188
Preprint
c2

SUPERCONDUCTING PULSED SYNCHROTRON DIPOLE AND DC BEAM TRANSPORT MAGNETS

W. F. Eaton, W. S Gilbert, R. A. Kilpatrick,
R. B. Meuser, F. L. Toby, F. Voelker

February 1971

AEC Contract No. W-7405-eng-48

LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

DISCLAIMER

UCRL-20188

SUPERCONDUCTING PULSED SYNCHROTRON DIPOLE AND DC BEAM TRANSPORT MAGNETS[*]

W. F. Eaton, W. S. Gilbert, R. A. Kilpatrick, R. B. Meuser, F. L. Toby, F. Voelker

Lawrence Radiation Laboratory, University of California
Berkeley, California

Summary

Pulsed dipoles for superconducting synchrotron application have been built and tested. Low cyclic loss up to a central dipole field of 23kG has been demonstrated.

A large dc dipole transport element for Bevatron area use has been built and tested; the warm bore aperture is 8 in. and the design central field is 42kG. Details of this magnet and a companion quadrupole doublet follow.

Pulsed Synchrotron Dipoles

A tested pulse dipole for synchrotron use is ready now (Feb. 1971) if one is willing to settle for a central field of 23kG. The magnet is shown in Fig. 1 without its iron return yoke which was wound from 50-mil diamter (1.25 mm) iron wire to reduce eddy-current losses in the iron. Figure 2 is a cross-section drawing in which the constructional details can be seen. The losses are as expected for the 7μ NbTi filaments present in the 49-wire cable, which was supplied by Supercon.[†] The low loss of less than 9J/cycle corresponds to a "Q" greater than 500; no additional losses due to cable movement are observable in this dipole as compared with cyclic magnet loss of this type material in solenoids. The maximum field, however, was degraded since the magnet did not reach its short sample limit. The well-ventilated cable did not reach higher transition current when the iron return yoke was removed, even though the field value was reduced to 2/3 of the original value. There was no $\dot{B}$ dependence of transition current or cyclic loss up to 5kG/sec, which is the limit of the power supply used. A michrophone pickup did not show any correlation between wire movements and onset of magnet transition. The magnet was wax-impregnated to investigate the effect of wire motion, and the transition current was reduced from 685 to 615A and, naturally, the maximum heat that could be removed from the magnet was reduced. We are still investigating the causes of the magnet degradation. In all our pulse dipoles the conductor used gave short sample behavior in solenoid tests.

A different winding geometry was used in three other dipoles, as can be seen in Fig. 3. We call this a "random wound" geometry since there are no defined helium cooling passages through the winding. The Lambertson-Meuser end configuration reduces both field aberrations and field increases in the ends that are associated with most end windings.

Except for length and so-far-attained maximum central field, all the dipoles are appropriate for use in synchrotrons, having a 4-in. winding ID. The pertinent information is listed in Table 1 below. More magnets are being built with the aim of increasing the central dipole field to 50kG.

Table 1. Pulsed dipoles.

All magnets: ID = 4 in., OD = 6 in., length = 13 - 18 in. twisted multicore NbTi in Cu.

Magnet number	Wire & cable description	NbTi size	Description	Weight of conductor	B_{max}		$\dot{B}_{max}$	Q or $\frac{\mu_{max}}{(\Delta\mu)cycle}$
					Central field	% short sample		
1[††]	40 mil, 2:1 355 cores, Formvar, single wire.	30μ (1.2 mil)	Random wound. With and without wax impregnation. Some shorts. No iron	25 lb	24kG	50%	1.5kG/sec	160 at 10kG
2[††]	20 mil, 2:1 355 cores, Formvar 7-wire cable.	15μ (0.6 mil)	Same as above	16 lb (half magnet tested)	23kG	70%	~2kG/sec	220 at 23kG
3[††]	9 mil, 1.3:1 200 cores, Formvar, 49-wire cable.	10μ (0.4 mil)	Random wound, cable double Mylar tape insulated. No wax, iron, shorts.	12 lb (half magnet tested)	18kG	60%	~0.12kG/sec	~75 at 15kG (bad shorts)
4A[†]	8 mil, 1.1:1 400 cores, Formvar, 49-wire cable.	7μ (0.3 mil)	Orderly wound. Radial He cooling passages. No shorts. Iron return.	9 lb	23kG	70%	>6kG/sec power supply limited.	500 at 20kG
4B	Same as above	Same as above	No iron.	Same as above.	15kG	45%	Same as above	480 at 13kG
4C	Same as above	Same as above	No iron. Wax impregnated.	Same as above.	13kG	40%	~2.9kG/sec	420 at 8kG.

---

[*] This work performed under the auspices of the Atomic Energy Commission.

[†] Norton Company - Supercon Division, 9 Erie Drive
Natick, Mass. 01760

[††] Cryomagnetics Corporation, 4955 Bannock St.
Denver, Colorado 80216

DC Beam Transport Magnets

Large-aperture (8-in. warm bore) transport elements are to be incorporated in a Bevatron experimental area beamline in mid-1971. The dipole and the matching quadrupole doublet have the following specifications:

Field strength or gradient	42kG	6kG/in.
Effective length	33 in.	25 in.(each)
Dewar length	53 in.	60 in.
Stored energy (max.)	0.7 MJ	0.1 MJ(each)

The completed bending magnet was tested in a vertical floor Dewar in December 1970 and is being installed in its horizontal warm-bore cryostat. Twelve layers of 0.045 - x .090-in. multicore twisted NbTi composite conductor (Cryomagnetics) are required for the design central field of 42kG with an 11-in.-thick iron return yoke around the cryostat. Figure 4 shows the magnet and Fig. 5 shows its cryostat with the iron return yoke.

Two transitions were made with the complete magnet without its iron return: the first occurred at a central field of 30kG, and the second occurred at 33kG exhibiting magnet traning. This second transition released 475kJ to the helium pool, since the dump circuit vacuum switch developed as bad vacuum. An industrial-type current switch will be used in the training program in the horizontal Dewar.

A matching quadrupole doublet is also under construction. Figure 5 shows two layers of one pole of one of the quadrupoles. These two layers have a transition current at the material short sample limit. The construction method used in both the dipole and quadrupole magnets is based upon winding each layer of conductor as a flat developed surface and then bending the layer around a cylindrical form. The individual rectangular conductors are insulated with a 0.005-in.-thick, 1/8-in. wide, fiberglass spiral winding. The bent layer halves (or quarters) are held to the magnet bore tube, or inner layers, with a helical winding of Dacron fishing line wound under considerable tension. This method provides layer-to-layer insulation as well as excellent helium permeation. As each layer is assembled, the insulation is checked with a capacitor discharge of some 300V.

<u>Note added in proof</u>: A pulsed synchrotron dipole with performance vastly improved over that of magnets 4A-C discussed above was tested at the end of Feb.1971. The same winding form and constructional techniques were used. The only change is that the insulation on the 8-mil diameter composite conductor (49 wires per cable) was changed from Formvar about 0.0005-in. (12μ) thick to a high resistance metal coating some 0.0001-in. (3μ) thick. The silver solder used, stay-brite 8, containing tin and silver is manufactured by the J. W. Harris Co., 10930 Deerfield Road, Cincinnati, Ohio 45242.

The magnet operates at the material short sample limit, 1020A at the 37kG we estimate the maximum field to be in the end winding. With no iron return yoke, the central field maximum is 25.5kG. We have been pulsing to 24kG maximum at a 4kG/sec rate with the losses about as expected from the superconducting filaments. $Q(\frac{\mu_{max}}{\Delta\mu})$ of 600 at $24kG_{max}$ has been measured.

The similar magnet with Formvar insulation only went to 685A maximum.

Calculations on dynamic stability of the two different cables (both made by Supercon) show that the difference can be explained by the properties of the insulations. With the Formvar insulation a dynamic stability limit for the cable of about 410A is predicted. The first magnet transition was 438A and training of several hundred pulses raised this to the maximum of 685A. With the metallic insulation the predicted stability limit is about 1120A and the magnet reached its short sample limit of 1024A on the first charge, even though there was considerable wire movement which we were able to pick up with a microphone.

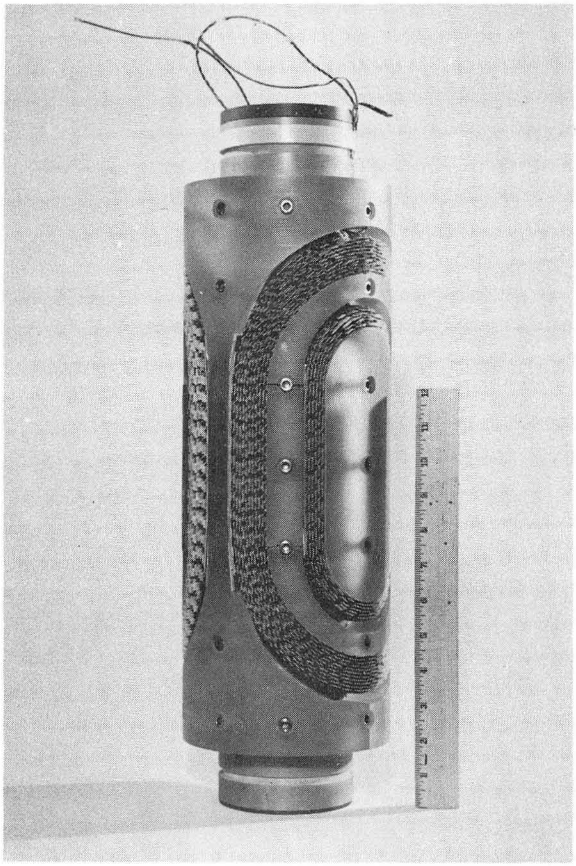

Fig. 1. Pulse dipole, orderly wound.

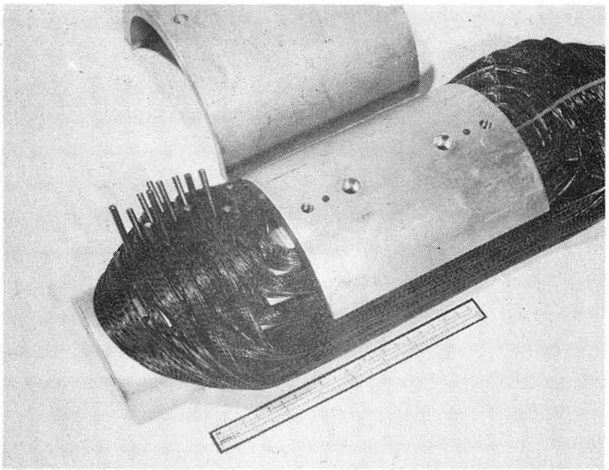

Fig. 3. Pulse dipole, random wound.

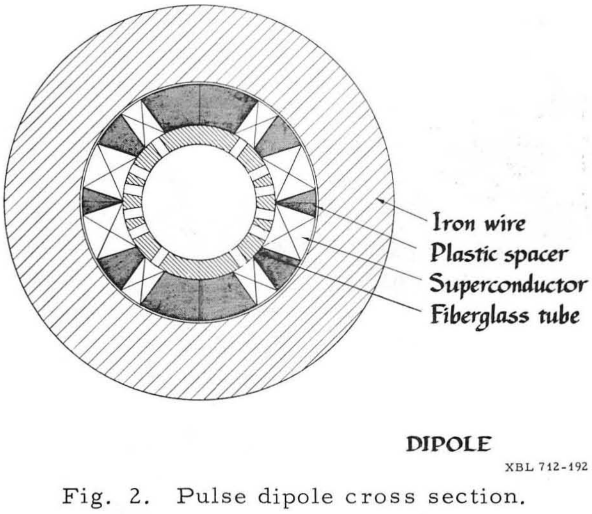

Fig. 2. Pulse dipole cross section.

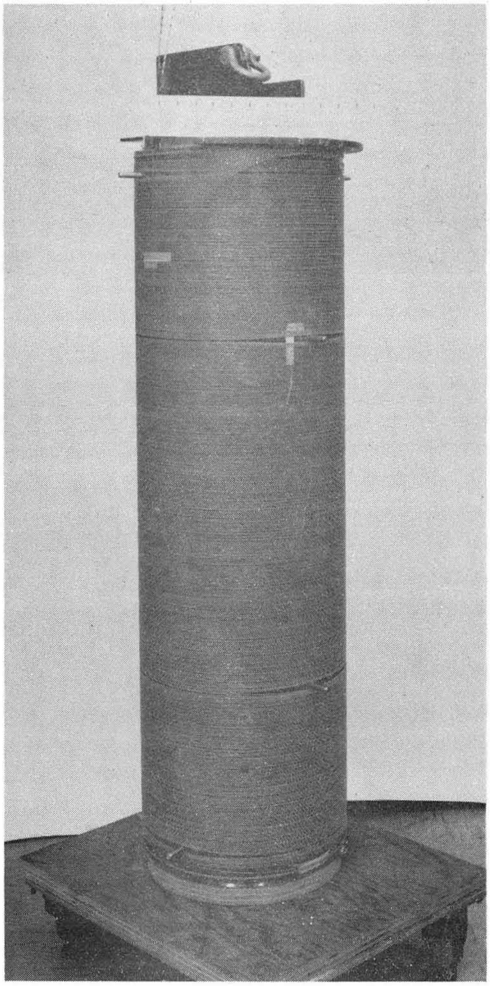

Fig: 4. DC transport dipole.

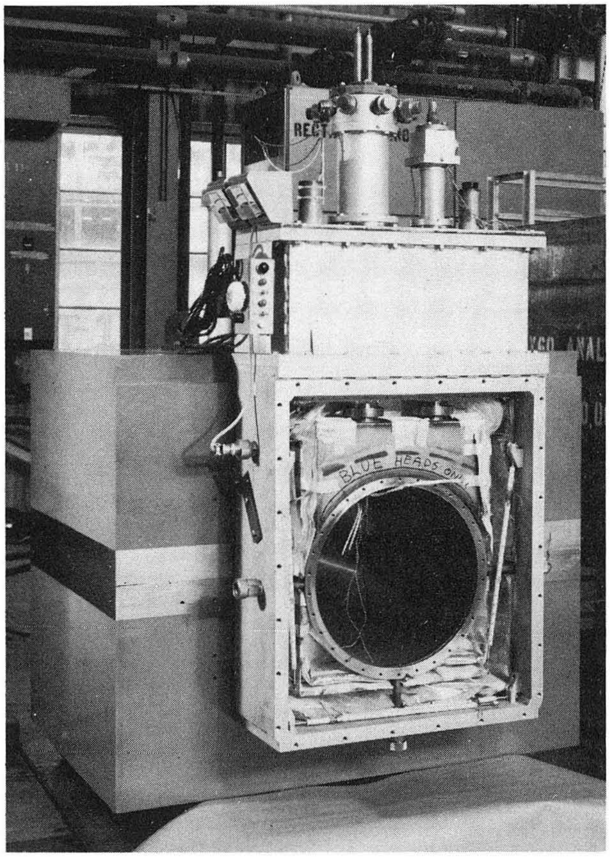

Fig. 5. Cryostat - dc dipole.

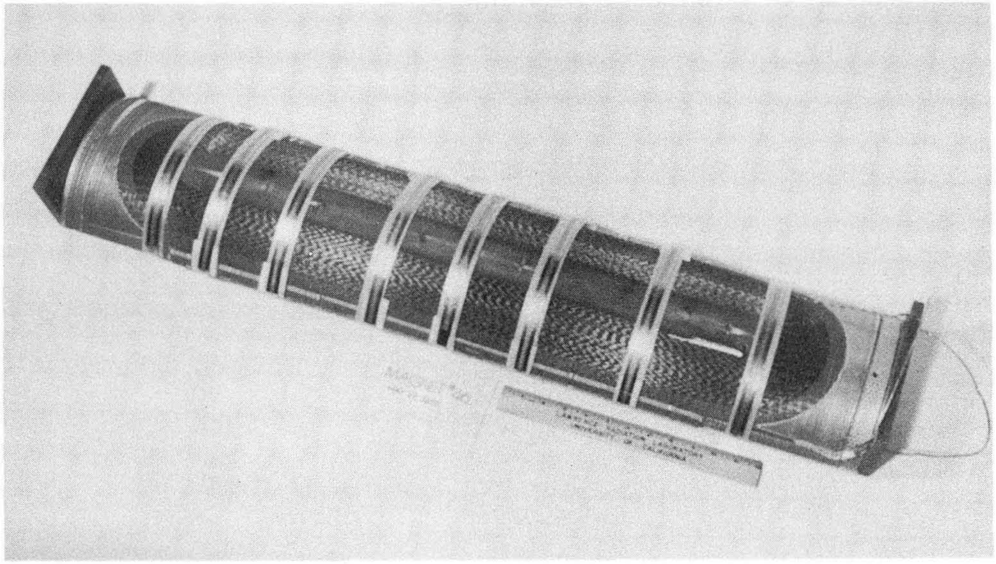

Fig. 6. DC transport quadrupole.

TECHNICAL INFORMATION DIVISION
LAWRENCE RADIATION LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720