A LOW STORED ENERGY, HIGH PRECISION SUPERCONDUCTING QUADRUPOLE FOR HIGH ENERGY BEAMS

A. Asner and D. Leroy
CERN
Geneva, Switzerland

1. Introduction

In this paper, the construction of a low stored energy, high precision superconducting beam transport quadrupole is reported. This quadrupole, named "CASTOR," although designed as a prototype, is fully representative as an operational superconducting beam transport element. The construction was completed within 10 months and testing had started by the end of August 1972. The very successful quadrupole performance during its first run is given in this report.

2. Magnet Characteristics

"CASTOR" has an annular cross section, 2 block constant current density winding per pole, consisting of 6 x 7 conductors and 16 x 7 conductors respectively. The block ends are rounded off and do not exceed the annular circumferential shape. The space between the 2 blocks at the ends is optimized with respect to the 12-pole component of the integrated fields and to the maximum field at the conductor.

The conductor — supplied by IMI, U.K. — is a 1.3 x 1.8 mm^2 rectangle, with 361 NbTi filaments of 53 μm diameter in a Cu matrix. The twist pitch is 1 in. The short sample characteristic is 1000 A in a perpendicular magnetic induction of 5 T ($\rho \sim 10^{-14}$ Ωm).

The conductor is insulated by an 80 μm thick "Kapton" film. Each layer of conductors is impregnated with an adhesive mixture of adequately loaded epoxy resin, pressed into position with

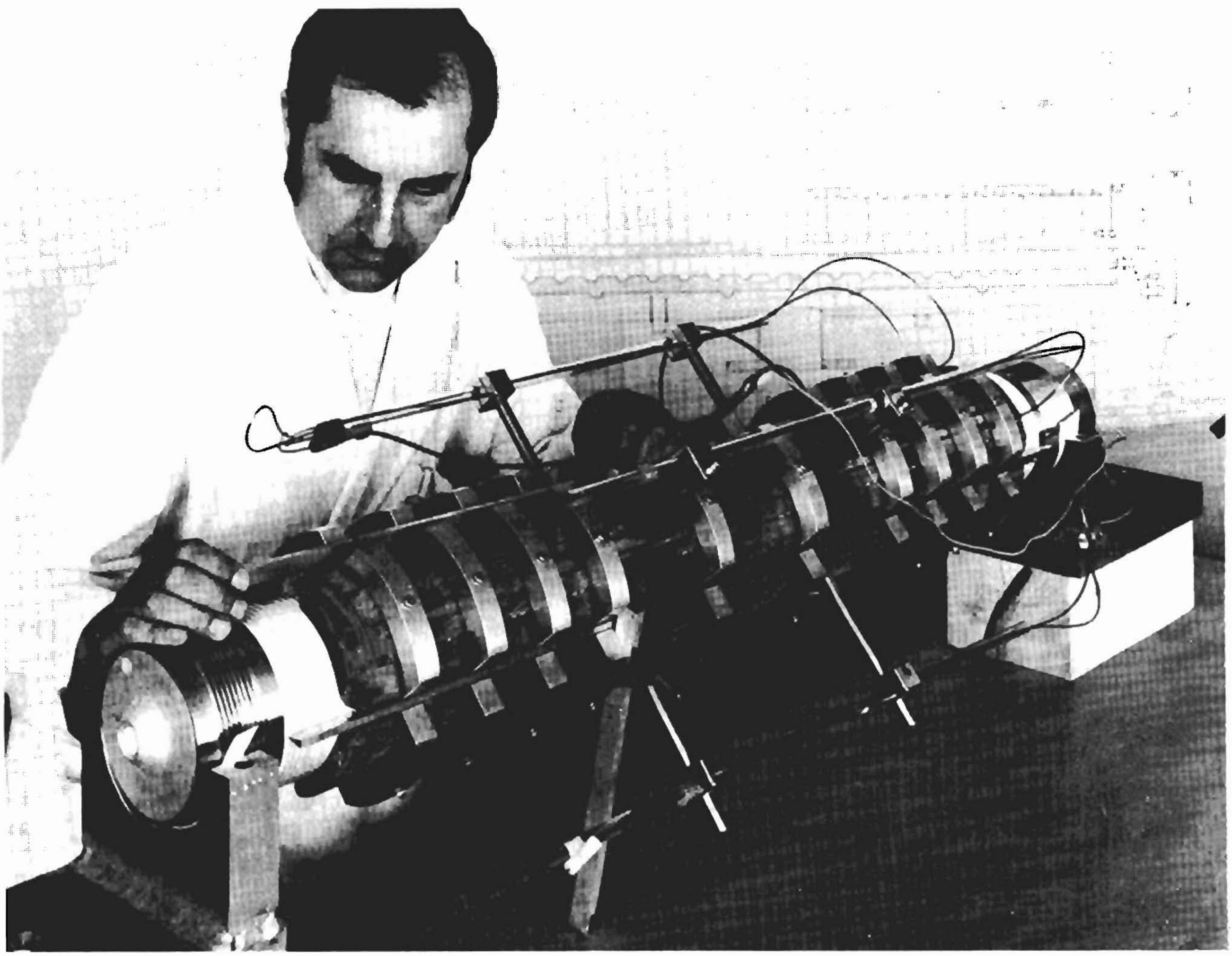

Fig. 1. The 4 poles are wound and assembled on the cold tube.
PHOTO CERN

precision and cured. The winding geometry is checked for each layer. The resin thickness on the external surfaces of the winding is below 0.1 mm.

Circumferential cooling channels are provided on each side of the winding blocks and holes are drilled in the copper pole for liquid helium circulation.

An iron ring, split in two semi-annular parts, surrounds the winding and a very efficient mechanical clamping is obtained by an external stainless-steel ring.

3. Cryostat Characteristics

The cryostat has a liquid N_2 screen. The magnet and the helium tank form a complete mechanical structure supported by the N_2 tank via fibreglass rings. The N_2 tank is in return fixed to the cover of the vacuum tank by similar rings. All the tanks are made of stainless steel. This type of construction is very convenient for assembling the cryostat. Due to the concentric structure of the cryostats, the displacement of the magnetic centre is minimized. The cooling of the magnet to liquid N_2 temperature is realized by a liquid N_2 circulation in a concentric system located within the pressurized helium tank.

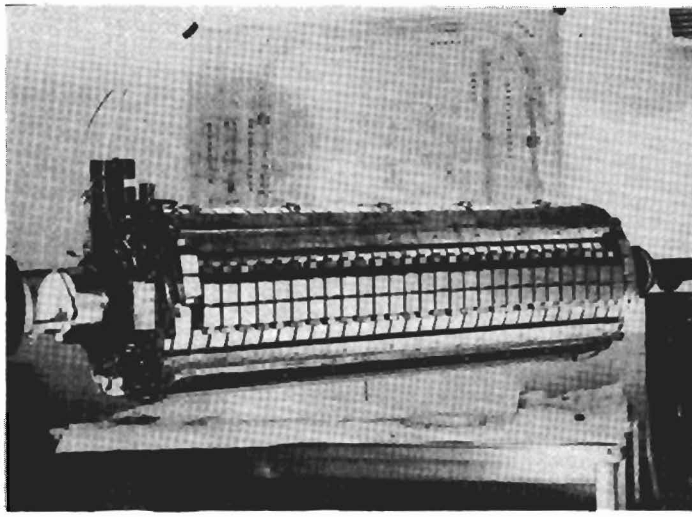

Fig. 2. The assembled magnet with its clamping system.

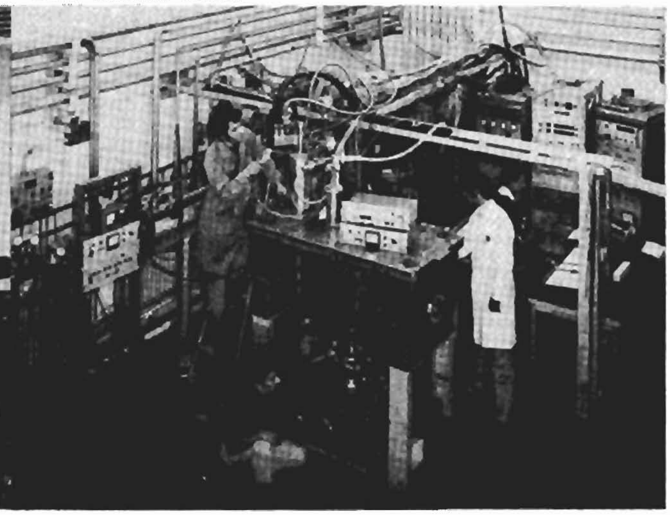

Fig. 3. The magnet during testing.

The integrated field error at r = 5 cm is $< 1\ ^{o}/oo$, as measured on a 1:1 copper model without iron. With iron, the calculated errors at r = 5 cm in function of the current density have a maximum value of $\sim 1\ ^{o}/oo$, given mainly by a 12-pole component due to saturation.

The summary of the magnet characteristics is given in Table I.

TABLE I. CASTOR Magnet Characteristics

Radius of room temperature bore	4.5 cm
Inner radius of the winding	6.5 cm
Outer radius of the winding	7.9 cm
Inner radius of the iron	8.5 cm
Outer radius of the iron	14.2 cm
Length of the straight part	0.80 m
Overall length of the winding	0.90 m
Gradient at 900 A	50 T/m
Current density in the winding at 900 A	3.15×10^8 A/m^2
Filling factor in the winding	0.80
Stored energy at 900 A	25 kJ
Weight of the magnet	500 kg
Length of the cryostat	1.35 m
Width of the cryostat	0.63 m

A very low loss and automatic transfer line system of 5.5 m length was designed as part of the cryostat.

4. Results

During the first run, the current of 810 A was obtained after some training. The experiment was stopped at this stage in order to prepare measuring equipment. The charging time at 810 A was 6 minutes. The raising of the current was easy and fast, so that we are confident to obtain 900 A at the next run.

We also made some preliminary field measurements: at 500 A the integrated gradient error was 0.9 $^{o}/oo$ at r = 3 cm and the integrated gradient was 25.5 T·m/m, corresponding to an equivalent length of 0.88 m and a gradient of 28.9 T/m.

The total losses of the cryostat including the transfer line were measured at 700 A and amounted to 4.9 W. The autonomy of the cryostat between two transfers is 6 hours and the helium filling time is 30 minutes. The transfer line losses are $\sim$ 0.2 W/m.

The cooling down to liquid N_2 temperature time constant is 38 hours and the cooling down to 4.2 K was achieved with an efficiency of 0.2 litres of liquid helium per kg.

5. Acknowledgements

We thank C. Iselin and F. Schäff for their assistance in magnetic field computations. We also wish to express our thanks to L. Vuffray for the coil winding, to M. Granier for the design support and to H. Rieder for his work on cryogenic and electronic equipment. Thanks as well go to L. Magnani for the data-logger construction, to U. Silvestri and G. Colini for their technical assistance and to M. Ponzo for skillful welding.

We also appreciate helpful discussions with D. Hay, visitor from CEA, Cambridge, Massachusetts.

We are grateful to the PS Department of CERN for the constant support and interest in this project.