LL

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN LIBRARIES, GENEVA

P00024686

CERN AT/94-14 (CR/MA)

LHC Note 270

see 9431

**Thermal Behaviour and Cryogenic Performance
of the first CERN/INFN Prototype Dipole Cryomagnet
for the CERN LHC Project**

L. Rossi*, V. Sergo, B. Szeless, L. Taviani, B. Vullierme, R. van Weelden
and L. Williams

* INFN, Milan, Italy

*Fifteenth International Cryogenic Engineering Conference ICEC 15
7-10 June 1994, Genova, Italy*

Geneva, Switzerland
27 June, 1994

Thermal Behaviour and Cryogenic Performance of the First CERN/INFN Prototype Dipole Cryomagnet for the CERN LHC Project

L.Rossi*, V.Sergo, B.Szeless, L.Tavian, B.Vullierme, R.van Weelderen, L.Williams.

* I.N.F.N., Milan, Italy.

CERN, CH-1211 Geneva 23 Switzerland.

The first 10 m long LHC prototype dipole magnet produced in industry has been mounted on the measurement test bench and operated at 1.8 K in a static bath of pressurized helium II. During tests its thermo-mechanical and cryogenic behaviour has been measured. The cooldown under different conditions, the resulting temperature gradients and the thermo-hydraulic consequences of resistive transitions have been investigated.

INTRODUCTION

In collaboration with European industry, CERN has launched the manufacture of seven 10 m long superconducting twin-aperture high field dipole accelerator magnets [1]. This effort forms part of a development programme leading ultimately to the selection of a dipole magnet suitable for series manufacture and to be incorporated in the Large Hadron Collider (LHC) project at CERN [2]. The first of these prototype dipole magnets financed and followed through manufacture by I.N.F.N. Milan, Italy was delivered to CERN in early February 1994 and installed on the magnet test bench for measurements of its thermal, mechanical and magnetic behaviour. A cross section of this magnet indicating its principal components appears in Figure 1. The first part, concerning cooldown, powering and quench behaviour of a two part test programme has been conducted culminating in a successful first quench from 1.9 K and 8.67 T slightly above the LHC nominal dipole field of 8.65 T. The second part of this programme concerning field quality analysis is currently underway. A companion paper [3] describes the system architecture the cryogenic system and constructional features of the test benches.

COOLDOWN

Magnet cooldown consists of three phases, phase 1 from ambient temperature to 90 K using a forced flow of helium gas cooled by liquid nitrogen, phase 2 from 90 K to 4.5 K directly using liquid helium and phase 3 down to 1.9 K by pumping on a cold source. During phases 1 and 2 cold gas initially and later liquid helium is admitted via the return box or "front" end of the magnet whereas in phase 3 the heat is extracted to the cold source in the feed box or "rear" end of the magnet. The first two phases of a cooldown are shown in Figure 2.

The refrigeration system is dimensioned to cool a 10 m prototype LHC dipole magnet from ambient temperature to 1.9 K in about 24 hours. For the cooldown cycles described here the cooling power has been limited by throttling the gas flow to 50 g/s, while maintaining a maximum longitudinal temperature difference of 50 K and this leads to an overall cooldown time of about 50 hours.

The temperature transients in different parts of the magnet, similar and closely grouped during phase 1 are less so in phase 2 indicating the longitudinal transition in the magnet from gas to liquid filled conditions. During phase 3, shown in Figure 3 the temperature profiles of different structural parts are again closely grouped. Finally, steady-state conditions at 1.9 K indicate about a 200 mK temperature difference between the pressurised and saturated cold source. This high value compared to the 100 mK expected is thought to

be due to a partial obstruction of the superfluid helium communication passage to the cold source at exit from the cold mass.

A global measurement of between 40 and 50 W heat load at 1.9 K with 2 warm bore inserts [4] in place for magnetic measurements was made. This compares with a combined estimate of 10 W for the cryomagnet and feed boxes and 30 W for the warm bore inserts. More precise heat load measurements will be performed using a full scale cryostat thermal model [5].

The transients seen by the thermal screen during cooling from the "front" end with nitrogen gas from ambient temperature to 80 K are presented in Figure 4. To avoid excessive initial asymmetric temperature distributions in the screen and consequent unacceptable deformations the initial difference between the nitrogen inlet temperature and the screen inlet azimuthal temperature was limited to about 75 K. The screen can be safely cooled within the time required to cool the dipole cold mass.

QUENCH BEHAVIOR

Following a quench at 12956 A, the evolution of pressure with time in the two dipole magnet end volumes is shown in Figure 5. The front end volume pressure is higher by about 1 bar, equivalent to the pressure drop over the magnet length of helium which is expelled through the relief valve at the rear end.

After quench detection, about 130 ms are required to initiate opening of the safety valve which then takes another 120 ms to open fully. The maximum end volume pressures are attained with the relief valve only 90 percent open which suggests that the valve passage is adequately sized, so that a reduction in maximum pressures may be obtained by reducing the initial opening.

Mass-flow measurements at the relief valve indicate that of a total helium inventory in the cold mass of about 37 kg, some 30 kg are expelled within 10 seconds with a maximum mass flow of 11 kg/s.

The variation in yoke temperature with time immediately following a quench appears in Figure 6. This shows, over the first 5 seconds, an initial discharge of subcooled liquid followed during a further 10 s by a two phase plateau and finally discharge of superheated vapour. The mass discharge occurs mostly during the first 10 s.

A maximum transient temperature difference after quench of 20 K between the collar and yoke at the magnet median plane was recorded and a coil hot spot temperature of about 215 K has been estimated.

REFERENCES

- 1 Perin, R., Status of the Large Hadron Collider Magnet Development, presented at the 13th International Conference on Magnet Technology (MT13), Victoria, Canada, 20-24 September 1993.
- 2 The LHC Study Group, The Large Hadron Collider Accelerator Project, CERN Report AC/93-03(LHC) (1993).
- 3 Benda, V., Granier, M., Lebrun, Ph., Novellini, G., Sergo, V., Tavian, L. and Vullierme, B., Cryogenic Benches for Superfluid Helium Testing of Full-Scale Prototype Superconducting Magnets for the CERN LHC Project, paper presented at this conference.
- 4 Clari, F., Dunkel, O., Genet, M., Gregory, Ch., Sievers, P. Prototype Development of a Warm Bore Insert for the LHC Magnet Measurements. presented at the 13th International Conference on Magnet Technology (MT13), Victoria, Canada, 20-24 September 1993.
- 5 Dufay, L., Ferlin, G., Lebrun, Ph., Riddone, G., Rieubland, J.M., Rijllart, A., Szeless, B. and Williams, L., A Full-Scale Thermal Model of a Prototype Dipole Cryomagnet for the CERN LHC Project, paper presented at this conference.

Figure 1 Magnet cross section showing temperature measurement locations

Figure 2 Cooldown of cold-mass from 300 K to 4.5 K

Figure 3 Cooldown of cold-mass from 4.5 K to 1.9 K

Figure 4 Cooldown of thermal shield from 300 K to 80 K

Figure 5 Evolution of quench current, end volume pressures and relief valve during quench

Figure 6 Mass flow and temperature evolution during quench