EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN

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TECHNICAL SPECIFICATION OF

NbTi SUPERCONDUCTING WIRES FOR THE SEXTUPOLAR CORRECTION MODELS

This specification concerns:

Manufacture, testing and delivery of :

- 800 m insulated superconducting wires made of NbTi in copper matrix with two different insulations.
- 400 m insulated hard copper wires having the same geometry and insulations.
- 20 m supple insulated superconducting wire having at least the same critical current as the previous superconducting wires.

DELIVERY DATE:	hard copper wires	1988-09-15
	superconducting wires	1988-10-15

Geneva, June 1988

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1. INTRODUCTION

In the frame of the high field magnet development for a future Large Hadron Collider (LHC), CERN has decided to launch the fabrication of two short models, about 1 m long, of the sextupole correction windings. They will be tested at CERN at low temperature (1,8° K) in the high induction (10 Tesla) of short models of the main LHC dipole magnet. The aim of those two models is to gain experience about their feasibility, their manufacturing processes and their mechanical stability in the pulsed induction of 1 T/min from 0.5 T to 10 T up to the quench current.

For the final design, 3136 sextupole correction windings, about 10 m long, will be necessary to equip the vacuum chambers of the 1568 twin aperture main dipole magnets of the LHC.

The present specification concerns the supply of 600 m of superconducting wires required for the above-mentioned two short models and 200 m of superconducting wires with thinner insulation which could possibly be used with a future automatic winding machine.

2. SCOPE OF THE SPECIFICATION

The present specification covers manufacture, testing, safe delivery to the CERN site, Meyrin, Switzerland, of:

- 600 m insulated superconducting wire made of single strand multifilamentary NbTi in copper matrix (wire diameter uninsulated 0.30 mm, insulated 0.41 mm), although the preferred unit length is 600 m, lengths of 200 m can, however, be accepted;
- 200 m same superconducting wire as above but with insulated diameter 0.35 mm;
- 200 m insulated hard copper wire (limit of elasticity at 0.2 % $\geq$ 18 daN/mm^2) having the same geometry and insulation as the above superconducting wire with 0.41 mm external diameter;
- 200 m same hard copper wire as above but with insulated diameter 0.35 mm;
- 20 m insulated supple superconducting wire made of tinned multistrand multifilamentary NbTi in copper matrix allowing at least the same critical current as the above superconducting wires.

Prices shall include all metallurgical, mechanical and electrical measurements and tests described in this specification. The necessary equipment has to be provided by the manufacturer.

Before delivering the superconducting wires, the manufacturer has to supply hard copper wires having the same dimensions with exactly the two same thicknesses of insulation. These cables will be used to experiment by CERN the fabrication procedures of dummy models.

In addition to a basic offer strictly complying with this technical specification, tenderers are invited to submit variants which present technical or financial advantages.

3. MAIN CHARACATERISTICS OF THE SUPERCONDUCTING WIRE

The main characteristics of the superconducting wire must be as follows:

Diameter before insulation	0.30 ± 0.01 mm
Diameter (thicker insulation, 600 m)	0.41 ± 0.01 mm
Diameter (thinner insulation, 200 m)	0.35 ± 0.01 mm
Cu/NbTi ratio	2 ± 0.1
Diameter of filaments	≤ 0.007 mm
Number of filaments	≥ 600
Filament twist pitch	≤ 30 mm
Effective area (Cu + NbTi)	0.0706 mm^2
Superconducting area	0.0235 mm^2
Copper resistivity at 293° K	≤ 1.77 x 10^{-8} Ω.m
Copper residual resistivity ratio (ρ_{293} K/$\rho_{4,2}$ K)	≥ 100
Nominal induction	10 T
Nominal temperature	2° K
Critical current density of superconductor	1560 A/mm^2
Wire critical current at 10 T and 2° K or 7 T and 4,2° K	≥ 36 A
High voltage insulation	3000 V DC

4. SUPERCONDUCTOR

The superconductor is a NbTi alloy. The manufacturer shall give the chemical composition of the superconductor established by representative samples of the NbTi used in the billet in the form of a works report according to norm DIN 50049/2.2.

5. MATRIX

The matrix which is surrounding the superconductor filaments is made of copper.

The manufacturer shall give the chemical composition of the matrix in the form of a works report according to norm DIN 50049/2.2.

The manufacture shall propose a method for checking the Cu/NbTi ratio, e.g. by weighing the different components of the samples.

6. INSULATION

Although thin, the insulation must prevent short-circuits under severe conditions of high voltage (when a quench occurs), high mechanical constraints (due to prestresses at room temperature, thermal expansion and electromechanical forces), and presence of ionizing radiations. It is required that the insulation resistance according to § 7.4 on irradiated wires after being exposed to an integrated dose of 10^7 Gy (10^9 rad) is greater than 10^9 Ω. The tenderer must give evidence of such a radiation hardness of his insulation.

For the thin insulation wire, varnish or enamel is acceptable although a wrapped polyimid film would be preferred.

For the thicker insulation wire, the coating must be compatible with the Al_2O_3 filled expoxy resin to be curable at 150° C.

7. FACTORY TESTS

A CERN representative may attend all or part of the measurements undertaken in the manufacturer's premises and described in this specification. The samples will be taken from the beginning and the end of each unit length.

7.1 Critical current of samples

The critical current in the strand is the current measured at an apparent resistivity of 10^{-14} Ω.m taking into account the section of the superconductor only. The manufacturer has to perform the short sample critical current measurements of the superconducting wires. The tenderer shall describe the sample arrangement, the test set-up, and the equipment to record the current sharing and the resistance grow-up. According to this arrangement, CERN and the manufacturer will agree on the protocol of short sample measurements and the value of the magnetic field seen by the strand.

The tenderer must state in his offer the guaranteed values of the strand critical current at 4,2° K and 7 T. He shall also notify his possibility to make critical current measurements at 1,8° K and 10 T and the extra charge for these measurements, if any.

The manufacturer must give evidence that a compression of 9 ± 2 daN/mm^2 does not alter the critical current more than 5 %.

7.2 Mechanical measurements

The superconducting wire diameter shall be measured and recorded each 30 m under an agreed tension. The tolerances must be kept within the one specified in Chapter 3, before as well as after insulation.

The wire compressibility will be determined by measuring the height of 34 samples (5 cm long) of the superconducting wire of 0.41 mm diameter stacked with alternated position into a measuring fixture (manufactured by the tenderer) under a pressure of 9 ± 2 daN/mm^2.

On one sample of each type of insulation an adhesion test shall be performed according to VSM 23713 and the abrasion resistance checked according to VSM 23710.

A sample of each type of insulation shall be wound with 10 adjacent turns around a mandrel of 7 mm diameter and immersed in liquid nitrogen (77° K) during 30 minutes for thermal shocks and inspected as indicated according to IEC 251-1/9.

7.3 Residual resistivity ratio

The residual resistivity ratio (RRR) will be calculated from the measurements of the resistances of the strand short samples at room temperature (293° K) and at 4,2° K without external field applied.

7.4 High voltage and insulation resistance

The wire samples are immersed in tap water (75 mm minimum) and tested with a high voltage of 3 kV d.c. during one minute. The insulation resistance between the conductor and tap water, before and after the high voltage test, must be greater than 10^9 Ω at 2,5 kV d.c. This test has to be performed with samples which have been bent by 180° with a radius of five times the diameter of the wire.

8. TRANSPORT

The tenderer is responsible for safe transport and delivery to CERN of the insulated wires.

Precautions have to be taken to spool the wire in such a way to prevent damage to the wire properties. In particular, no cross-overs and no penetration of one layer into another are allowed.

9. DOCUMENTS

9.1 Technical information to be communicated in the offer

a) Data on superconducting wire:

- unit length
- maximum allowable compressive forces
- minimum allowable radii for cabling
- copper to superconductor ratio

b) Data on superconductor:

- type of superconducting alloy
- the number and the diameter of filaments in the strands
- their geometrical distribution in the copper matrix
- the twist pitch

c) Data on copper matrix:

- copper resistivity
- residual resistivity ratio (from 293° K to 4,2° K)
- copper modulus of elasticity
- limit of elasticity at 0,2 %

c) Data on insulation:

- types of insulation
- properties under radiation.

9.2 Technical information to be communicated by the manufacturer

Two copies of the certificates established at the time of the tests of the samples taken from the beginning and the end of each unit length.

The number of samples and their lengths must be suitable to perform the factory tests specified in Chapter 7.