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Document Title:	Detailed Specification for Cold Terminals for the Local Current Leads of SIS100
Description:	PSP-Code: 2.8.2.10.2 AID: 0004886 SIS100 Cold Terminal Assembly left AID: 0004887 SIS100 Cold Terminal Assembly right This document defines the requirements on Cold Terminals of SIS100 corrector magnets F-DS-SCM-en-MT_0135_Cold_Terminals-V008
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Abstract

This document defines the requirements on Cold Terminals of the local current leads of SIS100 corrector magnets (Local Current Leads) for installation in the SIS100 quadrupole units.

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1. Purpose and classification of the document

The purpose of this document is to specify the technical requirements for the production of the Cold Terminals of the current leads of SIS100 corrector magnets (Local Current Leads) for installation in the SIS100 quadrupole units.

2. Abbreviations, Terms and Definitions

Following abbreviations are used in this document:

HTS	High Temperature Superconductor
LTS	Low Temperature Superconductor (NbTi)
SIS100	SIS100 synchrotron

Following definitions are used in this document:

Liquid nitrogen temperature in terms of this document is the temperature of 77 K.

Helium temperature in terms of this document is the temperature of 4.5 – 5.0 K.

3. Scope of the technical System

3.1. System Overview

In the SIS100 synchrotron of FAIR, Quadrupole Doublet Modules are utilized for beam optics. Such modules contain of a pair of Quadrupole Units which, in turn, are formed by a superconducting quadrupole magnet and up to two superconducting corrector magnets (steerer, sextupoles, multipoles.)

The corrector magnets are individually powered by means of the Local Current Leads (LCL) installed in the Quadrupole Doublet Modules. The LCLs are rated to 250 A DC and are designed by use of HTS material with a top heat sink at the temperature level of 50 – 60 K and the bottom heat sink at the temperature level of 4.5 K. In operation, the corrector magnets are powered in AC mode with up to 250 A AC (details depend on the specific SIS100 operation cycle. Each current lead consists of the copper part, HTS stack and of the Cold Terminal assembly. The Cold Terminal assembly (Cold Terminal) is a part of the quadrupole unit and provides the interface between the coil of the corrector magnet and the HTS interception of the current lead. Installation of the Cold Terminal will be done by the company responsible for the production of the QP units.

3.2. Spare parts

The order will include about 5% to 10% of spare Cold Terminals to be defined at contracting.

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3.3. Scope of Delivery

- deliverables by the Contractor:
 - Cold Terminals assemblies right and left versions [2], [3] (see also Figure 2 and Figure 3)
 - Test reports and certificates from qualification test including power testing in liquid nitrogen as specified in Section 6.2 (FAT).
 - Work instructions for production
 - Quality control plans
 - FAT plans
 - FAT protocol template
- deliverables by the Company:
 - 3D models (CAD)
 - Technical drawings
 - LTS superconducting wire (NbTi)

4. System Specification

4.1. Parameter requirements (functional requirements)

Corrector magnets will be operated in both AC and DC modes. The maximal current of the corrector magnets and of their Cold Terminals is 250 A DC. In the bipolar AC mode, the magnets could be ramped between the minimal and the maximal currents with the ramp rates up to 1500 A/s. The heat generation in the Cold Terminals at liquid helium temperature and at 250 A DC must be less than 25 mW (i.e. voltage drop across the Cold Terminal contacts and HTS shall be less than 100 μ V at 250 A DC). The heat generation in the Cold Terminals is mainly caused by the power dissipation in the copper parts and in the soldered and screwed contact joints. For testing in liquid nitrogen, the acceptable value of the voltage drop is 300 μ V at 250 A DC. The electrical insulation between live circuit and ground at room temperature and at liquid nitrogen temperature shall be higher than 1 G Ω at the test voltage of 1250 V.

4.2. Interfaces

Cold Terminals are parts of the quadrupole unit. They are mounted in insulation vacuum on the base plate, which is cooled by two phase helium flow. The cold terminals are fixed on the base plate by two M6 screws. Depending of the type of the corrector magnet, up to six cold terminals will be mounted on one base plate. Each Cold Terminal contact plate will be connected to the HTS interception of a current lead assembly by four M3 screws. The electrical connection with the magnet

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coil will be done by means of a NbTi superconducting wires connected to the magnet busbars. The NbTi wires are soldered on the printed conductors of a PCB, which is soldered to a copper sheet for fixation on the base plate.

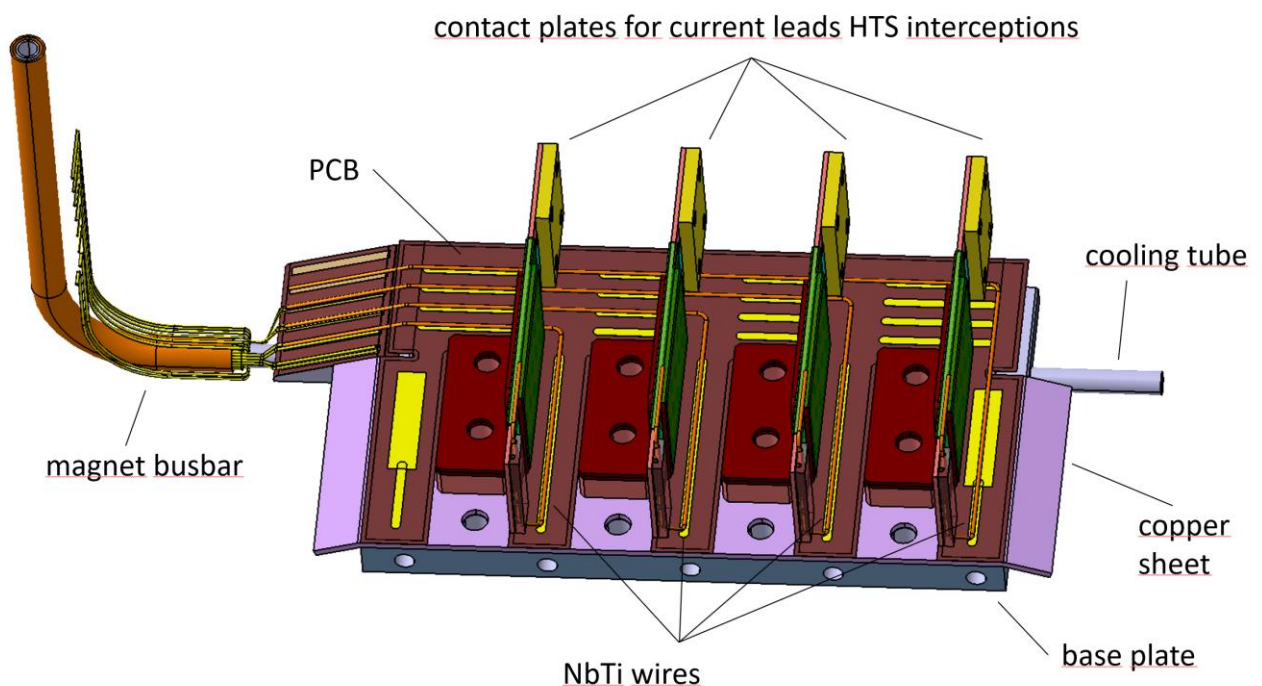


Figure 1: Cold terminals (left version) installed on a cooled base plate in a quadrupole unit.

4.1. System Components (technical requirements)

4.1.1. Cold Terminal Assemblies

A Cold Terminal assembly (Figure 2) consists of two electrically insulated sub-assemblies, the HTS/copper strip and the mounting block (Figure 3). Two versions of the Cold Terminals exist, a left and a right version, see [2], [3].

The mounting block provides the thermal contact to the cooled base plate of the quadrupole unit. The mounting block is at ground potential. The HTS/copper strip is part of the electrical circuit of the magnet. It consists of the gold-plated contact plate, a HTS tape soldered on a copper strip and two NbTi wires in a copper cap. The individual parts are soldered together. Especially, the HTS tape is

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soldered to the copper cap and to the both ends of the copper strips. On the magnet side the HTS tape is soldered to the doubled LTS wire.

Both sub-assemblies are bonded together and electrically insulated by means of glass fibre layers impregnated with epoxy compound.

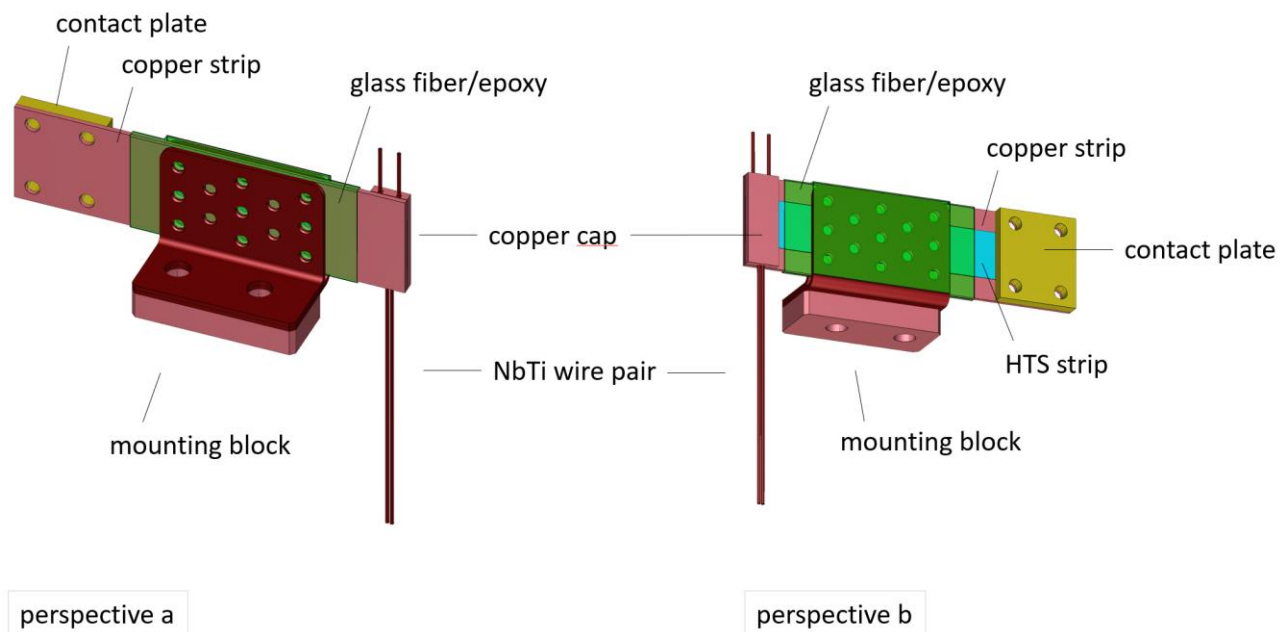


Figure 2: Cold Terminal assembly: left version, from two perspectives. For right version see [3]

For a good thermal coupling, the glass fibre layers shall be glued by epoxy compound Stycast 2850FT / CAT 24LV. Mixing ratio and curing sequence are described in the data sheet of the epoxy compound. The total thickness of glass fibre layers must be below 250 μm . Two layers of glass fibre have to be used; whereas for each layer, a thickness of 80 g/m^2 is recommended. Before application, the mixed epoxy compound has to be outgassed by use of proper equipment (e.g., vacuum desiccator).

For details of the individual parts of both sub-assemblies as well as instructions for manufacturing and assembly (soldering, isolation, bonding, glass-fibre wrapping) see [2], [3].

LTS wire for Cold Terminals will be supplied by Company. The parameters of the wire are given in the Table 1. The tinning of wire shall be done by Contractor. In order to prevent tin whiskers, a suitable type of tin must be chosen.

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Table 1: Parameters of the NbTi wire (to be supplied by Company)

Type	Low loss NbTi wire for SIS100 magnets
Diameter	0.8 mm
Critical current I_c (4.2 K, 2 T)	> 870 A
Matrix material	Cu/CuMn

The HTS tape for the Cold Terminals shall have a critical current of 500 A or higher in self-field at 77 K. The supplier and the type of the HTS tape must be agreed with the Company.

While soldering, the temperature of the HTS tape must not exceed 220 °C. Manual soldering with controlled temperature of the soldering iron is recommended. Low melting point solder and alcohol rosin flux must be used and the soldering time mustn't exceed 1 min. All gold-plated surfaces must be protected by adhesive Kapton tape.

All soldering and mounting procedures as well as the bonding procedure of the sub-assemblies (mounting block, HTS/copper strip) by means of epoxy impregnated glass fibre layers shall be described in work instructions and agreed with Company. See also Section 5.2.

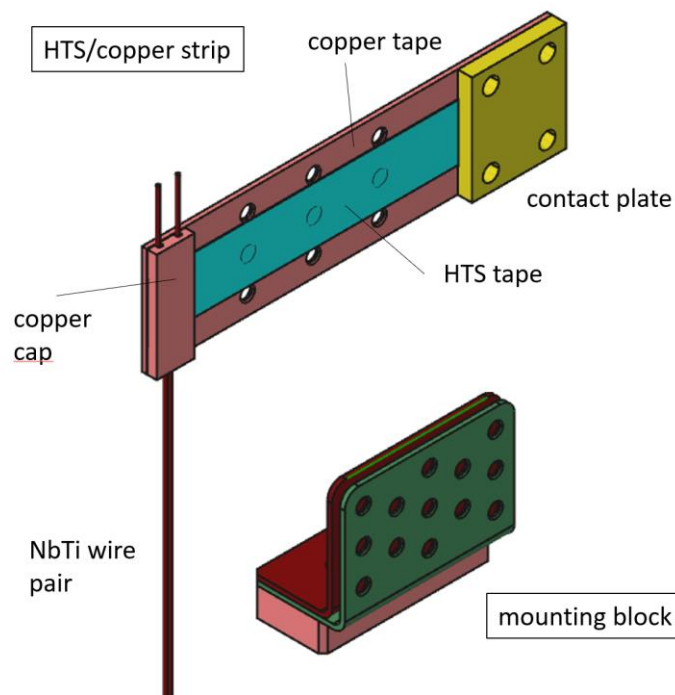


Figure 3: Cold terminal sub-assemblies, left version (for right version see [3]): HTS/copper strip and mounting block. Not shown: glass fiber/epoxy layers for bonding and electric isolation.

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5. Procedures

5.1. Design Phase

Design of Cold Terminals was done by Company. To optimize the production, the Contractor may propose minor design changes which must be agreed with Company in the Manufacturing Design Review (Section 5.2)

Procedures of the design reviews are described in [4].

5.2. Production Phase

Cold Terminals shall be produced according to the technical drawings [2], [3] provided by Company. The manufacturing and testing procedures shall be described in the work instruction and agreed with Company.

Each cold terminal shall be labelled with an individual component ID number (CID) provided by the Company. These CID numbers shall be used for identification of testing and production reports.

Before start of production, the Contractor shall prepare and execute the Manufacturing Design Review (MDR). Following topics must be presented and agreed with Company:

- Overview of manufacturing process
- Quality plan
- FAT testing plan and protocol templates
- Work instructions, especially on soldering and bonding (glass fibre/epoxy) procedures
- Templates of FAT protocols
- Labelling and packaging concept
- Overall time schedule

6. Quality Assurance, Tests, and Acceptance

6.1. Quality Assurance System of the Contractor

Contractor shall compile a quality plan and a work instruction for the soldering procedure and for the assembling process. The quality plan and work instructions shall be approved by Company before the start of production.

At least following tests shall be executed and protocolled during production:

- High voltage tests
- Continuous dimensional inspection according to check sizes defined in the corresponding drawings

High voltage testing (insulation resistance vs. ground) has to be tested for each Cold Terminal two times, after assembling/ epoxy curing and after thermal cycling and testing in liquid nitrogen. The high voltage testing procedure is described in section 6.2. After testing in liquid nitrogen and before electrical test, the Cold Terminals need drying (i.e. keeping 2 days in dry conditions at room temperature).

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The epoxy filling process needs to be executed in a moisture and humidity controlled environment avoiding water contamination of the epoxy. The cold terminals need to be continuously handled and stored in dry conditions including transport.

6.2. Factory Acceptance Test (FAT)

Factory Acceptance Test of Cold Terminals consists of the visual inspection, dimensional inspection, high voltage tests and power tests in liquid nitrogen.

Visual inspection after completion of production and testing:

- checking the gold plated contact surfaces for scratches and visible damages
- visual inspection of soldering joints with respect to full removal of flux

Dimensional inspection:

position of the contact plate relative to the base plate shall be checked within FAT. Check dimensions are indicated in the assembly drawings [2], [3].

High voltage test:

HV test shall be done in two steps. The test voltages are 500 V and 1200 V. In each step, the test voltage shall be applied for 2 minutes. The acceptance criterion is $R_{ins} > 1 \text{ G}\Omega$.

Power tests in liquid nitrogen:

The aim of the test is to show that it was no quenches up to 300 A DC on HTS tape at liquid nitrogen temperatures. Also, it must be shown that the voltage drop on soldered joints and on screwed gold-plated contacts is lower than 300 μV at 250 A – that represents a good quality of screwed electrical contact surfaces.

Before starting the tests, each Cold Terminal shall be 5 times cooled down in liquid nitrogen and warmed up to the room temperature (thermal cycling).

Testing scheme is presented in Figure 4. The Cold Terminal must be connected to the power supply using two contacts, main and auxiliary. The reusable auxiliary copper contact shall be connected to the edge of the NbTi wire. The connection can be done either by a spring-loaded clamp or by soldering with low melting temperature solder (60 - 80 °C). The gold-plated screwed joints shall be fixed by M3 screws with stainless steel spring washers. The torque of brass screws shall be $< 0.4 \text{ N}\cdot\text{m}$.

The testing time at 300 A must be at least 2 min.

The acceptance criteria are:

- No quenches up to 300 A DC at $T = 77 \text{ K}$
- Voltage drop at HTS part at 250 A is less than 100 μV at 77 K
- total voltage drop including contact resistance at 250 A is less than 300 μV at 77 K

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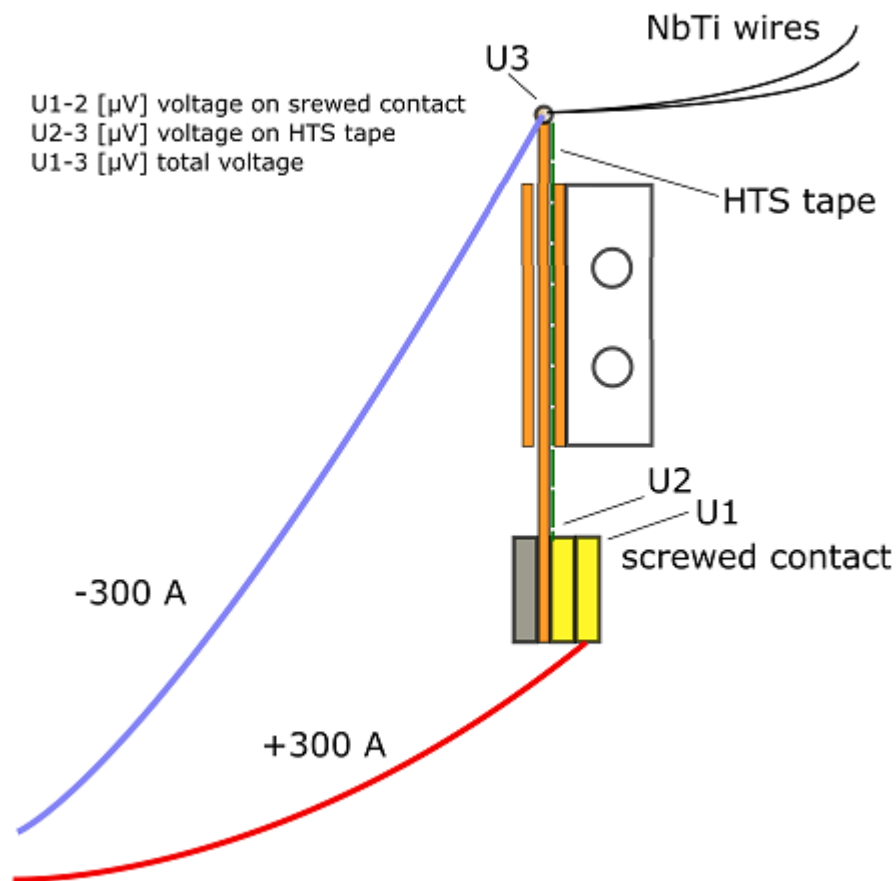


Figure 4: power test of Cold Terminals in liquid nitrogen

The FAT protocols need to be provided by the Contractor and need to be agreed with the Company in the manufacturing design review.

6.3. Site Acceptance Test (SAT)

The SAT will include the visual inspection of all Cold Terminals. High voltage tests and power tests in liquid nitrogen will be done for few samples on a random basis. The power tests will be done in DC and in AC mode.

7. Documentation

For each Cold Terminal, the results of all tests included in the quality plan and in the FAT test program must be delivered in PDF/A format according to Section 6 of the General Specification [1]. Templates of the test protocols must be agreed with the Company.

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8. Packaging and transportation

After testing and before shipment, the gold-plated contact surfaces shall be protected by adhesive Kapton tape. For shipment, the Cold Terminals shall be protected against moisture, dust and mechanical damages. Hard copies of the FAT reports must be included in the box.

9. Related Documents

- [1] MANDATORY: General Specification, F-GS-PMO-en-General_Specification-V004, EDMS ID 1365092 v.5.
- [2] MANDATORY: Cold terminal left version:
 - a. MG-1132432-A-V09_-_Current lead adapter left.pdf, assembly drawing,
 - b. MG-1132432-A-V09_-_Current lead adapter left.stp, 3D model (STP)
 - c. S_MG-1132432-A-V09_-_Current lead adapter left.pdf, bill of materials
 - d. related drawings.
- [3] MANDATORY: Cold terminal right version:
 - a. MG-1132432-A-V10_-_Current lead adapter right.pdf, assembly drawing,
 - b. MG-1132432-A-V10_-_Current lead adapter right.stp, 3D model (STP)
 - c. S_MG-1132432-A-V10_-_Current lead adapter right.pdf, bill of materials
 - d. related drawings.
- [4] MANDATORY: Procedure for Design Reviews F-VA-QUA-en-0006 Design Reviews, EDMS ID 1514206 v.11.