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The Large Hadron Collider Project ***Addendum No P059/R10***

Technical Specification for the Manufacture and Supply of 6000 A HTS Current Leads

Abstract

This Technical Specification concerns the manufacture and supply of 258 High Temperature Superconducting current leads used for powering the superconducting magnets of the LHC machine. These leads will transport a maximum current of 6000 A in d.c. mode.

Delivery of the series is expected to be spread from September 2004 to October 2006.

June 2004

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Terms and Definitions

Term	Definition
CDD	CERN Drawing Directory
EDMS	Engineering Data Management System
QAP	Quality Assurance Plan
DFLCS	Equipment code of 6000 A HTS current lead
HTS	High Temperature Superconductor
LTS	Low Temperature Superconductor
OF	Oxygen-Free
OFE	Oxygen-Free-Electrolytic
RRR[1]	Residual Resistivity Ratio
T	Temperature
RT	Room Temperature

[1] RRR is the ratio between the electrical resistivity of the material at room temperature and at liquid helium temperature

1. INTRODUCTION

1.1 Introduction to CERN

The European Organization for Nuclear Research (CERN) is an intergovernmental organization with 20 Member States*. It has its seat in Geneva but straddles the Swiss-French border. Its objective is to provide for collaboration among European States in the field of high energy particle physics research and to this end it designs, constructs and runs the necessary particle accelerators and the associated experimental areas.

At present more than 5000 physicists from research institutes world-wide use the CERN installations for their experiments.

1.2 Introduction to the LHC Project

The Large Hadron Collider (LHC) is the next accelerator being constructed on the CERN site. The LHC machine will mainly accelerate and collide 7 TeV proton beams but also heavier ions up to lead. It will be installed in the existing 27 km circumference tunnel, about 100 m underground, that previously housed the Large Electron Positron Collider (LEP). The LHC design is based on superconducting twin-aperture magnets which operate in a superfluid helium bath at 1.9 K.

1.3 Subject of this Technical Specification

The LHC will be equipped with superconducting dipole and quadrupole magnets connected in several series and operating at currents of up to 6000 A. These magnets will be powered via High Temperature Superconducting (HTS) current leads integrating HTS material in the form of stacks of BSCCO 2223 tapes. The leads will transfer the current from the room temperature electrical connection, through the helium gas environment of the cryostat, to a 4.5 K liquid helium bath.

This Technical Specification defines the design, the construction requirements, the manufacturing and assembly procedures, the tests and the inspection and acceptance criteria of these 6000 A HTS current leads.

2. SCOPE OF THE TENDER

2.1 Scope of the supply

The total supply shall consist of 258 HTS current leads rated for a maximum current of 6000 A d.c.

The supply comprises:

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* CERN Member States are: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, The Netherlands, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland and the United Kingdom.

- Complete design, manufacturing and operation of the required assembly and testing facilities.
- Production of complete manufacturing file and execution drawings.
- Manufacture and assembly of the HTS current leads.
- Inspection and quality control of the HTS current leads according to this Technical Specification.
- The supply, in the form of both paper and electronic data files, of all reports and records of inspections and tests carried out within the scope of this Technical Specification, according to forms and formats agreed with CERN.
- Transport packaging and safe transport of the HTS leads to CERN or other European sites to be designated.

2.2 Items supplied by CERN

All raw materials will be supplied by CERN. In addition, CERN will supply:

- Stacks of BSCCO 2223 tapes (see Section 4.3.8).
- Low Temperature Superconducting (LTS) wires (see Section 4.3.9).
- Cartridge heaters and corresponding electrical wires (see Section 4.6).
- Temperature probes, integrated in a threaded copper block, and corresponding electrical wires (see Section 4.5).
- Electrical connectors (see Section 4.3.1.4).
- Conductive paste (See Sections 4.5.1 and 4.6).
- Voltage taps (see Section 4.5.2).
- Ceramic insulators.
- Bellows.
- O-rings.
- Helicoflex® seals.
- Stycast® (see Section 4.4.3.4).
- Fibre-glass screws.

The Contractor shall be deemed to have accepted the items supplied by CERN if CERN is not informed in writing within two weeks of reception.

2.3 Items not supplied by CERN

CERN will not supply the brazing and the soldering alloys and the chemicals for cleaning and plating of the surfaces.

3. GENERAL CONDITIONS FOR CONTRACTING

Please refer to the Addendum No P059/R10 for more complete information.

3.1 Contractual procedure

The Contractor is strongly encouraged to contact CERN and discuss details of this Technical Specification. In particular, CERN wishes to ensure that no doubt exists as to the interpretation of this Technical Specification.

3.1.1 Alternative solutions

The manufacturing and assembly procedures described in this Technical Specification were validated at CERN during the assembly of a pre-series of 6000 A HTS current lead assemblies. No alternative solutions are accepted.

3.1.2 Preliminary programme

Before the 15^{th} of July 2004, the Contractor shall submit to CERN a Manufacturing File, which contains a manufacturing and testing schedule based on the specified CERN delivery schedule.

3.1.3 Subcontractors

The Contractor shall declare in the Manufacturing File any subcontractors whose services he intends to use. He shall restrict himself to the subcontractors and the amount mentioned in the Manufacturing File. If, for some reason, he wishes to change any subcontractor, or the scope of subcontracted work, or the amount subcontracted, he shall obtain CERN's prior agreement in writing.

3.2 Contract execution

3.2.1 Responsibility for design, components and performance

The Contractor shall be responsible for the conformity with this specification of all items supplied, irrespective of whether they have been chosen by the Contractor or suggested by CERN. CERN's approval of the design and component choice does not release the Contractor from his responsibilities in this respect.

3.2.2 Contract follow-up

3.2.2.1 Contract engineer

The Contractor shall assign an engineer to be responsible for the technical execution of the Contract and its follow-up throughout the duration of the Contract.

3.2.2.2 Progress report

A written progress report shall be sent to CERN every two weeks until completion of the Contract.

3.2.2.3 Design approval and production

A complete Manufacturing File, including execution drawings, shall be submitted to CERN for approval before the 15^{th} of July 2004. CERN will give its approval or refusal, in writing, within 2 weeks. The manufacture of equipment shall not start without CERN's written approval. If the Manufacturing File is refused, the Contractor shall submit a corrected file within two weeks.

The series production shall be preceded by the production of four current leads, which will be tested at CERN. The test will require about 3 weeks. Production of the series shall not start before CERN has given its formal approval of the pre-series in writing. If the pres-series fails the test and the Contractor is unable to rectify the problems and fabricate a pre-series conforming to this Technical Specification within two months, CERN reserves the right to terminate the Contract.

3.2.3 Deviations from this Technical Specification

If, after the Contract is placed, the Contractor discovers that he has misinterpreted this Technical Specification, this will not be accepted as an excuse for deviation from it and the Contractor shall deliver equipment in conformity with this Technical Specification at no extra cost.

During execution of the Contract, all deviations proposed by the Contractor from this Technical Specification, the Addendum, or any other subsequent contractual agreement, shall be submitted to CERN in writing. CERN reserves the right to reject or accept such proposals without justification.

CERN reserves the right to modify this Technical Specification during execution of the Contract. The consequences of such modifications shall be mutually agreed on between CERN and the Contractor.

3.3 Factory access

CERN and its representatives shall have free access during normal working hours to the manufacturing or assembly sites, including any subcontractor’s premises, during the Contract period. The place of manufacture may only be changed after written approval by CERN.

4. TECHNICAL REQUIREMENTS

4.1 General description

The 6000 A HTS current lead (Drwg.LHCDFLCS0001) consists of a resistive and a superconducting part (see Fig.1). The resistive part operates between room temperature and about 50 K. It is convection cooled by helium gas, made available by the LHC cryogenic system, which enters at about 20 K and 1.3 bar. The superconducting part operates between 50 K and the liquid helium temperature. It is self-cooled by the vapour generated by conduction of the lead at 4.5 K. The 20 K circuit and the 4.5 K circuit are hydraulically separated inside the lead.

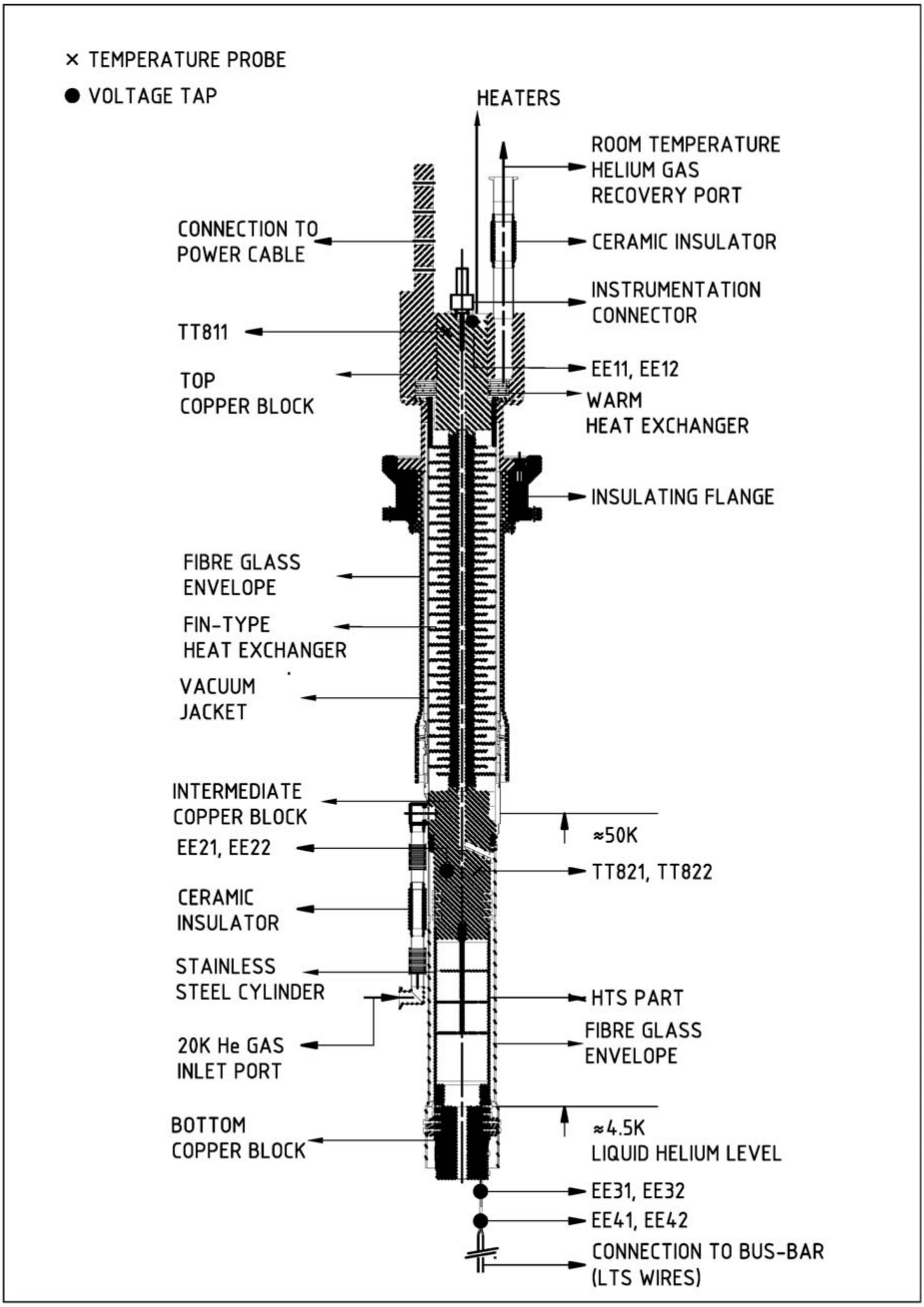

Fig. 1- 6000 A HTS lead schematic

The resistive part consists of:

• a top copper block (Drwg.LHCDFLCS008) which includes the connection to the power cable, the instrumentation connectors, the warm heat exchanger, the helium gas recovery connection and two cartridge heaters,

• an electrically insulating flange (Drwg.LHCDFLCS0011),

• a fin-type copper heat exchanger (Drwg.LHCDFLCS0030),

• a vacuum jacket (Drwg.LHCDFLCS0007), which provides the thermal insulation of the copper heat exchanger from the external environment.

The superconducting part (Drwg.LHCDFLCS0009) consists of:

• an intermediate copper block (Drwg.LHCDFLCS0043) at the level of the helium gas inlet connection (Drwg.LHCDFLCS0005),

• a stainless steel cylinder (Drwg.LHCDFLCS0046), onto which 18 stacks of BSCCO 2223 tapes are vacuum soldered,

• the stacks of BSCCO 2223 tapes,

• a bottom copper block (Drwg.LHCDFLCS0047) onto which the LTS wires are soldered and supported.

Fibre-glass components provide the electrical insulation of the lead external envelope.

Instrumentation (three temperature probes and eight voltage taps) is included in the lead body. The wires of these instrumentation signals terminate in two electrical connectors integrated in the top copper block.

4.2 Design criteria

The 6000 A HTS lead is designed to carry a maximum current of 6000 A d.c. between room temperature and the 4.5 K liquid helium bath.

The HTS material is characterized by a low thermal conductivity and practically zero electrical resistivity at temperatures below about liquid nitrogen temperature. Thanks to these properties, its integration in the colder part of the lead allows reducing the heat load into the liquid helium bath. When the lead is powered at nominal current, this reduction corresponds to a factor of about 10 if compared with a conventional self-cooled lead.

The design of the HTS current lead optimises the thermal and electrical performance of both the resistive and HTS parts. The hydraulic and electrical interfaces take into account the constraints given by the final integration in the LHC tunnel.

The design of the 6000 A HTS current lead has been validated at CERN with the manufacture, assembly and test under nominal operating conditions of several 6000 A HTS current leads. These current leads were built according to the CERN manufacturing drawings that are part of this Technical Specification.

For information, the main parameters of the 6000 A HTS lead are listed in Table 1.

Maximum d.c. current	6000	A
Working temperature range	293-4.5	K
Test temperature	293	K
Design pressure of hydraulic circuits	0.35	MPa
Test pressure of hydraulic circuits	0.45	MPa
Nominal pressure in hydraulic circuits	0.13	MPa
Nominal pressure in vacuum jacket	10^{-2}	Pa
Insulating test voltage in warm helium gas	1.3	kV d.c
Overall lead length	1445	mm
LTS wires free length	1200	mm
Copper RRR[2] of fin-type heat exchanger	80-100	-
External diameter of insulating flange	189	mm
External diameter of vacuum jacket	79	mm
Total mass	Approx. 50	kg

Table 1 - Main parameters of the 6000 A HTS lead

4.3 Materials and sub-assemblies

All raw materials are supplied by CERN.

The manufacture and assembly of the HTS current lead includes: high precision machining of copper and stainless steel, chemical surface preparation prior to vacuum brazing, vacuum soldering and TIG welding, vacuum brazing of OFE copper and stainless steel with high purity and low vapour pressure brazing alloys, vacuum soldering of the HTS stacks with Sn-Pb37 eutectic alloy, electron beam welding of copper and TIG welding of stainless steel.

4.3.1 Top copper block

The top copper block (Drwg. LHCDFLCS008) consists of an inner block (Drwg. LHCDFLCS041) and outer block (Drwg. LHCDFLCS039). These two blocks of OFE copper are vacuum brazed together.

The inner block includes 2 holes, 12.5 mm diameter and about 105 mm length, each of which houses a cartridge heater. It also includes a 16-pin electrical connector, into which terminate the wires of all the voltage taps and of two temperature probes integrated inside the body of the current lead.

The outer block includes the lug for the connection of the power cable, one temperature probe with the corresponding 4-pin electrical connector and the helium gas recovery connection.

A cylindrical heat exchanger is integrated between the two copper blocks. The inner and outer surfaces of the heat exchanger are vacuum brazed to the inner and outer copper blocks respectively.

Two stainless steel (AISI 316 LN) inserts are vacuum brazed in the outer copper block. They are used for the connection of the helium recovery connection (Drwg.

[2] RRR is the ratio between the electrical resistivity of the material at room temperature and at liquid helium temperature

LHCDFLCS0042) and for the TIG welding of the vacuum jacket (Drwg. LHCDFLCS0040). A stainless steel insert (AISI 316 LN) is vacuum brazed in the inner copper block. It serves for the integration of the 16-pin electrical connector (Drwg. LHCDFLCS0037).

4.3.1.1 Warm heat exchanger

A warm heat exchanger is vacuum brazed inside the top copper block (Drwg. LHCDFLCS0008, Drwg. LHCDFLCS0010). It consists of seven OFE Cu perforated plates (Drwg. LHCDFLCS0054) assembled and vacuum brazed between six inner and six outer silver plated copper rings (Drwg. LHCDFLCS0053, Drwg. LHCDFLCS0052).

4.3.1.2 Helium gas recovery connection

The helium gas recovery connection consists of a ceramic insulator with a DN-25 flange at each end. This component is connected via a metallic seal to the insert vacuum brazed in the top copper block.

The ceramic insulator shall have the following characteristics:

- operation from room to liquid nitrogen temperatures,
- capability to withstand a minimum number of 500 thermal cycles from room temperature to liquid nitrogen temperature without degrading of the mechanical and electrical properties,
- operation with up to 0.45 MPa differential pressure,
- capability to withstand a minimum force applied at the ends of 5 kg axial and 1 kg radial without degrading of the mechanical and electrical properties,
- capability to withstand a minimum insulation voltage of 1.3 kV, both polarities, in helium gas at room temperature and atmospheric pressure. The corresponding leakage current shall be less than or equal to 10 μA,
- leak tightness (see Section 7.2.4).

4.3.1.3 Inserts for vacuum brazing

A stainless steel (AISI 316LN) insert is vacuum brazed in the centre of the inner copper block (Drwg. LHCDFCCS0037). This insert receives the 16-pin Fischer connector.

A stainless steel (AISI316LN) insert is vacuum brazed in the copper outer block (Drwg. LHCDFLCS0042). This insert ends with a DN-25 flange that is connected to the helium gas recovery connection.

A stainless steel (AISI 316LN) ring is vacuum brazed to the bottom of the outer copper block (Drwg. LHCDFLCS0040). This ring is TIG welded to the vacuum jacket.

4.3.1.4 Electrical connectors

Two electrical connectors are integrated in the top copper block.

A 16-pin, leak-tight, Fischer connector (Fischer DEE104 A086) is screwed in the insert vacuum brazed at the centre of the top copper block. In this connector terminate the instrumentation wires of the two platinum resistance thermometers and of the eight voltage taps connected inside the lead.

A 4-pin connector is fixed in the copper outer block (LEMO EHG.00.304.CLL). In this connector terminate the instrumentation wires of the platinum resistance thermometer located in the copper outer block.

4.3.2 Electrical insulating flange

An insulating flange (Drwg. LHCDFLCS0011) is connected to the lead stainless steel flange (Drwg. LHCDFLCS0032). The insulating flange shall be made of EP GM3. After machining, the flange shall be vacuum impregnated with a homogeneous layer (15-20 micrometers thickness) of Parylene C® coating (deposition of polymer poly-para-xylene, which takes place at room temperature).

4.3.3 Copper heat exchanger

The copper heat exchanger (Drwg. LHCDFLCS0030) consists of a round bar, about 500 mm long, with fins to enhance the heat exchange with the helium gas. It has an external diameter of 63 mm and a central hole of 10 mm diameter. The tube with the fins shall be machined from a copper rod with a RRR between 80 and 100.

4.3.4 Vacuum jacket

The vacuum jacket (Drwg. LHCDFLCS0007) is made of austenitic stainless steel sub-components (AISI 304 L or AISI 316 L).

The inner component of the vacuum jacket (Drwg. LHCDFLCS0033) is made from a seamless stainless steel tube. It includes the inner tube and the port for the welding of the helium gas inlet connection. The inner surface of the tube shall be honed.

The outer component of the vacuum jacket includes:

- a top part with the stainless flange and the pumping connection (Drwg. LHCDFLCS0032, Drwg. LHCDFLCS0031). The pumping port shall be a DN-16 flange,
- a stainless steel tube (Drwg. LHCDFLCS0034),
- a bellow (Drwg. LHCDFLCS0035),
- a bottom connection (Drwg. LHCDFLCS0036).

The bellows has the following characteristics:

- operation at liquid nitrogen temperature,
- fatigue life of minimum 500 room temperature/liquid nitrogen cycles,
- mechanical stability under 0.45 MPa inner/outer pressure,
- compensation for a minimum axial movement of ±3 mm with a minimum number of 1000 guaranteed cycles,
- leak tightness (see Section 7.2.4),
- material- stainless steel of grade 316 L,
- compact design of the evolutions profile in the radial direction.

During assembly operations, the bellow shall be mechanically protected to avoid damage.

4.3.5 Intermediate copper block

The intermediate copper block (Drwg. LHCDFLCS0043) is connected at one end to the copper heat exchanger and at the other end to the stainless steel cylinder. It is made of OFE copper. It includes:

- the grooves for the BSCCO 2223 stacks,
- the housing of two platinum resistance probes,
- a stainless steel (AISI 316 LN) insert (Drwg. LHCDFLCS0044), vacuum brazed on the copper surface (Drwg. LHCDFLCS0006), which is welded to the vacuum jacket.

The helium gas cooling the copper heat exchanger is directed to the intermediate block via the helium gas inlet connection.

4.3.5.1 Helium gas inlet connection

The helium gas inlet connection is pre-assembled and welded to the lead body. It includes two stainless steel bellows separated by a ceramic insulator.

The two bellows have the following characteristics:

- operation at liquid nitrogen temperature,
- fatigue life of minimum 500 room temperature/liquid nitrogen cycles,
- mechanical stability under 0.45 MPa inner/outer pressure,
- compensation for axial movement of ±3 mm with a minimum number of 1000 guaranteed cycles,
- compensation for a minimum lateral movement of 2 mm with a minimum number of 1000 guaranteed cycles,
- leak tightness (see Section 7.2.4),
- material-stainless steel of grade 316 L,
- compact design.

The design of the bellows is such as to prevent buckling, after assembly, when subjected to the above listed loads/displacements.

The ceramic insulator has the following characteristics:

- operation from room temperature up to liquid helium temperature,
- capability to withstand a minimum number of 500 thermal cycles from room temperature to liquid helium temperature without degrading of the mechanical and electrical properties,
- operation with up to 0.45 MPa differential pressure,
- capability to withstand the forces exercised by the bellow when subjected to the maximum axial and/or lateral deformation,
- insulation voltage of 1.3 kV, both polarities, in helium gas at room temperature and atmospheric pressure. The corresponding leakage current shall be less or equal to 10 μA,
- leak tightness (see Section 7.2.4).

The inlet port of the helium gas inlet connection is a DN-16 flange modified to allow welding, during the integration of the lead, to the cryostat chimney (Drwg. LHCDFLCS0025).

4.3.6 Stainless steel cylinder

The stainless steel (AISI 316 LN) cylinder (Drwg. LHCDFLCS0046) is vacuum brazed at the ends to the intermediate and to the bottom copper block. Eighteen grooves are machined into the external surface of the cylinder. The stacks of BSCCO 2223 tapes are soldered in these grooves. The grooves shall be copper plated with a copper layer of 5-7 micrometers thickness. No copper plating may be present outside the grooves.

4.3.6.1 Convective screens

Three convective screens are located inside the stainless steel cylinder (Drwg. LHCDFLCS0001). They are supported by a stainless steel rod which is vacuum brazed to the intermediate copper block. The length of the supporting rod (Drwg. LHCDFLCS0045) shall be about 129 mm.

4.3.7 Bottom copper block

The bottom copper block is vacuum brazed to the bottom end of the stainless steel cylinder (Drwg. LHCDFLCS0009). It is made of oxygen free copper (Cu OFE). It includes (Drwg. LHCDFLCS0047):

- the grooves for the BSCCO 2223 stacks of tapes,
- the grooves for the LTS wires,
- a central hole of about 10 mm diameter,
- the holes with the brazed insert for the fixation of the clamp supporting the LTS wires.

4.3.8 Stacks of BSCCO 2223 tapes

The stacks of BSCCO 2223 tapes are supplied by CERN. Each stack consists of 7 or 9 tapes of BSCCO 2223. The tapes will have been vacuum soldered together at about 240 °C. Each tape consists of a silver alloy matrix containing superconducting ceramic filaments. The stacks have a rectangular cross section of about 4.5 mm (wide) × 1.6-1.8 mm (thick).

The handling of the stacks shall be addressed as an extremely delicate operation.

4.3.9 LTS wires

The LTS wires are supplied by CERN. Each wire consists of a copper matrix with superconducting NbTi filaments. The surface of the copper wire is tinned. The diameter of the wire is 0.82 mm.

4.3.10 Fibre-glass components

Two fibre-glass components cover the vacuum jacket (Drwg. LHCDFLCS0014) and the superconducting part of the lead (Drwg. LHCFFLCS0017). The component covering the vacuum jacket is cut into two half cylinders which are supported on the insulating flange via insulating EP GM3, M4, screws. The cylinder covering the superconducting part of the lead shall be machined from an EP GM3 tube. At their bottom end, these two cylinders are supported via EP GM3 pieces on the vacuum jacket (Drwg. LHCDFLCS0016) and on the bottom copper block (Drwg. LHCDFLCS0015) respectively.

4.3.11 Instrumentation

Eight voltage taps and two temperature sensors are located inside the lead body. The position of these instrumentation signals as indicated in the drawing LHCDFLCS0002 shall be strictly respected. One additional temperature sensor is located in the top copper block.

4.3.11.1 Temperature sensors

The three temperature sensors are Pt-100 resistors. They are supplied by CERN already connected with the instrumentation wires and integrated in a copper block to be screwed inside the lead body (see Section 4.5).

4.3.11.2 Voltage taps

Eight voltage taps are connected inside the lead body. Each of them consists of a copper multi-strand wire of 0.16 mm^2 total cross section, electrically insulated with Polyimide. The external diameter of the insulated wire is 0.81 mm.

4.3.12 O-ring

A NBR (Nitril Butadiene Rubber) O-ring is positioned in the groove machined in the lower side of the lead stainless steel flange. It assures the leak tightness between the underside lead’s insulating flange and the external environment.

4.4 6000 A HTS current lead assembly

4.4.1 General

The 6000 A HTS current lead consists of several components assembled together via different technologies including vacuum brazing, vacuum soldering, TIG welding and Electron Beam welding.

Vacuum brazing shall be performed with low vapour pressure brazing alloys. These alloys shall be in conformity with conventional, high purity vacuum grade, brazing alloy standards. In particular, the carbon impurity limit shall be lower than 50 ppm.

Vacuum soldering shall be performed with high purity pressure solder alloys.

The importance of care and cleanliness in the handling of components to be brazed or soldered at all stages of manufacturing is emphasized. Clean plastic gloves shall be worn for the manipulation of components before and during assembly.

After vacuum brazing, sub-assemblies shall be clean, not oxidized and free of stains.

If surface coating is used for the vacuum brazing of stainless steel components (for instance Ni plating), this layer shall be removed in the region where the TIG welding takes place.

4.4.2 Vacuum brazing

4.4.2.1 Vacuum brazing materials

The definition of the machining tolerances and the design of the grooves for vacuum brazing is under the responsibility of the Contractor. The machining tolerances and the groove dimensions in the CERN manufacturing drawings have been chosen and tested for the use of the following brazing materials:

- Type 1: Ag72%, Cu28%; B-Ag72Cu-780 (cf. ISO 3677), purity higher than 99 %,
- Type 2: Ag68.4%, Cu26.6%, Pd5%; B-Ag68CuPd-807/810 (cf. ISO 3677), purity higher than 99 %,
- Type 3: Ag58.5%, Cu31.5%, Pd10%; B-Ag58CuPd-824/852 (cf. ISO 3677), purity higher than 99 %.

The conforming bid shall correspond to this specification.

4.4.2.2 Vacuum brazing sequence

The brazing sequence described in this section has been tested at CERN during the assembly of two 6000 A HTS prototype current leads.

1. For the warm heat exchanger, the copper rings are silver-plated. The copper rings and copper perforated plates are diffusion brazed in vacuum (Drwg. LHCDFLCS0010).

2. For the top copper block, two stainless steel inserts are vacuum brazed in the outer copper block (recommended brazing alloy Type 2 in section 4.4.2.1). A stainless steel insert is vacuum brazed in the inner copper block (recommended brazing alloy Type 2 in section 4.4.2.1).

3. The outer copper block, the inner copper block and the warm heat exchanger are vacuum brazed together in an up side-down configuration with respect to Fig.1 when positioned in the furnace (recommended brazing alloy Type 1 in section 4.4.2.1).

4. The intermediate copper block, the stainless steel cylinder, the convective screens, the bottom copper block, the two copper rods, 2 mm diameter, used for the soldering of the voltage tap signals (see section 4.5.2) and the stainless steel inserts (Drwg. LHCDFLCS0009) are vacuum brazed at the same time in an up side-down configuration with respect to Fig.1 when positioned in the furnace (recommended brazing alloys Type 1 and Type 2 in section 4.4.2.1). The two copper rods shall be positioned diametrically opposite, in the intermediate copper block, about 10 mm above the groove that will house the HTS stack.

Following the procedure described in the fourth sequence, the brazing of the convective screens cannot be visually inspected. If the convective screens are separately vacuum brazed to the intermediate copper block, it is recommended to use for this operation the brazing alloy Type 3 in section 4.4.2.1.

4.4.3 Vacuum soldering

After brazing of the HTS support unit (Drwg. LHCDFLCS0009), 18 HTS stacks shall be positioned in the grooves machined both in the stainless steel cylinder and in the intermediate and bottom copper blocks. The grooves in the stainless steel cylinder shall have been previously copper plated with a copper layer of 5-7 μm thickness. Prior to soldering, the Contractor shall ensure that the soldering surfaces are clean and free of oxidation.

The vacuum soldering of the HTS stacks shall be made via high purity eutectic SnPb37 alloy (melting point 183 ºC), without the use of any flux or anti-flux chemical agent. For the CERN prototype current leads, the maximum temperature in the copper block during the vacuum soldering was lower than 200 ºC. The typical heating time and stabilization at temperatures below the solder melting point was 7 hours, the heating time and stabilization with the furnace at 215 ºC was one hour and a half, the cool-down in vacuum took about 10 hours.

A SnPb foil of 0.1 mm thickness shall be positioned inside each groove prior to positioning of the HTS stack. This foil shall have the same width and length of the groove and therefore cover the LTS wires (see section below). A special tool shall be designed by the Contractor to maintain each stack positioned inside the groove during the assembly and during the soldering operations. The Contractor shall assure that, during soldering, each stack is pressed against the supporting groove with a uniform light pressure that does not damage the stack.

Before positioning of the HTS stacks, 36 LTS wires shall be pressed into the grooves machined in the bottom copper block (Drwg. LHCDFLCS0047). The wire's length shall cover the whole length of the groove. After this operation, the wires shall be shaped and fixed to the bottom copper block as indicated in Drwgs. LHCDFLCS0006 and LHCDFLCS0009. After soldering, the free length of LTS wires extending out of the bottom of the current lead shall be 1.2 m.

The soldering material shall form a continuous joint, without gaps, between each stack and the corresponding groove (top copper block and stainless steel cylinder) and between each stack and the two corresponding LTS wires (bottom copper block). The resulting wetted surface between the stack and the groove in the copper blocks and between the stacks and the LTS wires shall be 100 %. The wetted surface between the stack and the groove in the stainless steel cylinder shall be more than 95 %.

4.4.3.1 HTS stacks

The HTS stacks are delicate electrical conductors, which shall be handled with special precautions. They shall be kept straight to avoid breakage of the brittle internal ceramic filaments and consequent severe degradation of the stack's electrical properties. The Contractor shall ensure that no bending forces are applied to the stacks. Mishandling such us the dropping of a stack on the floor or any action that brings a permanent deformation will result in breakage of the superconductor.

Each stack will be visually inspected and electrically characterised by CERN prior to delivery to the current lead Contractor. However, before the assembly takes place, the Contractor shall perform a visual inspection of each stack and exclude those that present damage on their surfaces (folds, cracks due to bending, bubbles and/or dark spots). The faulty stacks shall be sent back to CERN with a document reporting the origin of the non-conformity. Faulty or mishandled stacks may under no circumstances be used for assembly.

Handling and assembly of the stacks shall be made with gloves and in a clean area.

The HTS stacks are supplied by CERN packed in nitrogen filled bags and protective cases. To avoid degradation of the surface, the HTS stacks shall be kept in their case up to the assembly phase.

After assembly of the stacks and of the LTS wires, the assembled current lead sub-component shall be protected by a cover. Such protection shall be maintained during the subsequent assembly phases of the current leads, as well during storage, transport and handling of the component. A box shall be designed and manufactured by the Contractor for safe transport of components to the assembly facilities (Electron Beam Welding, Parylene® C coating).

4.4.3.2 Soldering of LTS wires end

After vacuum soldering of the stacks and fixation of the LTS wires to the bottom copper block, the free extremity of the LTS wires, coming out straight from the current lead bottom end, shall be assembled into two flat rectangular cables (Drwg. LHCDFLCS0002, Drwg. LHCDFLCS0004 and Drwg. LHCDFLCS0006). The two flat cables shall be soldered (Sn-3.5 % Ag) in a mould over a length of 100 mm. The rectangular cross section of the soldered length shall be about 15 mm (wide) × 1.64 (thick) mm.

4.4.3.3 Parylene® coating

After vacuum soldering of the stacks and fixation of the LTS wires to the bottom copper block, the HTS unit shall be vacuum impregnated with a thin layer (15-20 micrometers) of Parylene® C coating (deposition of polymer poly-para-xylene at room temperature). During this operation, the top part of the intermediate copper block to be Electron Beam Welded, as well as the stainless steel insert in the intermediate copper block to be TIG welded, the two copper rods for the connection of the voltage taps, the holes for the integration of the temperature probes, the end surface of thee bottom copper block and the soldered length of LTS wires shall be screened and protected against Parylene® C deposition.

The Parylene® C coating shall cover in a uniform way the HTS stacks over their complete length, including the ends.

4.4.3.4 Sealing of the HTS stack's ends

After the Parylene® C impregnation, both ends of each of the HTS stacks shall be sealed with the epoxy resin Stycast 2850 FT (black) catalyzed with the curing agent Catalyst 24 LV (room temperature curing).

4.4.4 Electron Beam Welding

The top copper block and the intermediate copper block of the HTS element shall be Electron Beam welded to the two ends of the resistive heat exchanger (Drwg. LHCDFLCS0006). The Electron Beam Welding shall assure a complete penetration through the material's thickness (see section 7.1.1.1).

4.4.5 TIG welding

Stainless steel inserts are vacuum brazed on the top and on the intermediate copper block for the TIG Welding of the vacuum jacket.

4.4.5.1 Vacuum jacket

The vacuum jacket (Drwg. LHCDFLCS0007) is pre-assembled, inserted from the bottom of the HTS unit through the fin-type copper heat exchanger and finally TIG welded to the stainless steel inserts vacuum brazed on the top and on the intermediate copper block (Drwg. LHCDFLCS0004). After this operation, the electrically insulating flange (Drwg. LHCDFLCS0011) is inserted from the bottom of the current lead and fixed to the current lead stainless steel flange.

4.4.5.2 Helium gas inlet connection

The helium gas inlet connection is pre-assembled and TIG welded to the vacuum jacket (Drwg. LHCDFLCS0005). After welding to the vacuum jacket, a cover is TIG welded to the front opening.

4.4.6 Insulating components

Two half EP GM3 insulating cylinders are positioned around the vacuum jacket and fixed to the electrically insulating flange via EP GM3 screws. Prior to insertion of the insulating cylinders, the vacuum jacked shall be covered with a Kapton® foil, 0.1 mm thickness, overlapping over a length of at least 0.1 m.

An EP GM3 cylinder shall be inserted from the bottom of the HTS element and supported on the intermediate copper block.

4.4.7 Helium gas recovery connection

The helium gas recovery connection is fixed via a metallic Helicoflex seal to the insert brazed in the top copper block (DN-25 flange, Drwg. LHCDFLCS0001).

4.5 Integration of instrumentation signals

The HTS current lead incorporates three temperature probes and eight voltage taps. The temperature probes are Pt 100 resistors. They are supplied by CERN, already integrated in a threaded copper block, with the four twisted measuring wires connected on the sensor side. Such a component is hereafter called temperature sensor unit.

4.5.1 Temperature probes

Two temperature sensors units are integrated in the intermediate copper block (TT821 and TT822 in Fig.1). After the TIG welding operations (see section 4.4.5) and before the fixation of the insulating components (see section 4.4.6), these two temperature sensor units are inserted from the top of the current lead, passed inside the 10 mm diameter hole machined in the fin type heat exchanger and recuperated at the exit of the hole located in the intermediate block. The free end of the instrumentation wires is fixed on the top copper block. The Contractor shall procure tooling for this operation.

The instrumentation wires shall be positioned in the groove foreseen in the intermediate block and fixed with Kapton® adhesive. The threaded copper block of each temperature sensor shall be covered with heat conductive paste and screwed in the correspondent hole machined in the intermediate block. A fibre-glass plate fixes the temperature sensors against the intermediate block.

One additional temperature sensor unit (TT811 in Fig.1) is integrated in the top copper block.

4.5.2 Voltage taps

Together with the temperature sensor units, six voltage wires (EE21, EE22, EE31, EE32, EE41, EE42) are inserted in the inner hole of the fin type heat exchanger and extracted from the intermediate copper block. Two of these voltage taps (EE21, EE22) shall be soldered (eutectic Sn-Pb) to the 2 mm diameter copper rods that were vacuum brazed in the intermediate block. The remaining four voltage taps (EE31, EE32, EE41, EE42) are brought to the bottom end of the current lead. Each pair is soldered to one of two copper wires that are previously spot-soldered around the LTS wires coming out from the bottom of the current lead.

Two additional voltage taps (EE11, EE12) are connected inside the top inner block (Drwg. LHCDFLCS0002, Drwg. LHCDFLCS0023).

The voltage tap wires EE21, EE22, EE31, EE32, EE41 and EE42 shall be twisted up to the intermediate copper block. The voltage tap wires EE31, EE32, EE41, EE42 shall be twisted up to the bottom end of the current lead and supported on the current lead body.

4.5.3 Wiring scheme

All the voltage tap wires and the wires of temperature sensors TT821 and TT822 end in the 16-pin leak tight Fischer connector at the top of the resistive heat exchanger. After soldering of each wire according to Fig. 2, Fig.3 and Table 2, the connector is screwed into the insert that is vacuum brazed in the centre of the top copper block. This connection shall be leak tight.

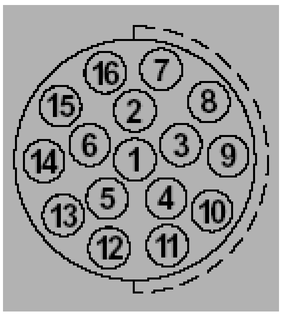

Fig.2- Schematic of DEE 104 A086 instrumentation connector (seen underside)

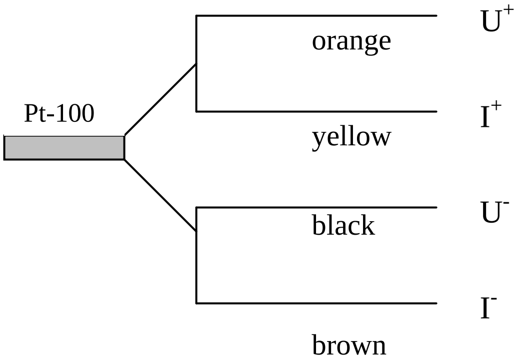

Fig.3: schematic of Pt-100 probe and instrumentation wires

Pin	Sensor	Signal
1	EE11	Voltage
2	EE12	Voltage
3	EE21	Voltage
4	EE22	Voltage
5	EE31	Voltage
6	EE32	Voltage
7	EE41	Voltage
8	EE42	Voltage
9	TT821	U^+
10	TT821	U^-
11	TT821	I^+
12	TT821	I^-
13	TT822	U^+
14	TT822	U^-
15	TT822	I^+
16	TT822	I^-

Table 2 - Pin designation of the DEE104 A086 Fischer connector

The four wires of the temperature sensor TT811 are soldered to the 4-pin LEMO connector according to the scheme summarized in Table 3. After this operation, the connector is mechanically fixed to the top copper block.

Pin	Sensor	Signal	Colour
1	TT811	U^+	Orange
2	TT811	U^-	Black
3	TT811	I^+	Yellow
4	TT811	I^-	Brown

Table 3 - Pin designation of the EHG.00.304.CLL LEMO connector

4.6 Cartridge heaters

After assembly of the HTS current lead, a cartridge heater delivered by CERN shall be integrated in each of the two holes drilled in the top copper block. Before integration, the external surface of the cartridge heater shall be covered with a conductive paste supplied by CERN.

The cartridge heaters have a diameter of 12.5 mm and a length of 100 mm. The corresponding holes in the copper block shall have a diameter of 12.5 H7 mm.

4.7 Information and documentation management

4.7.1 Manufacturing drawings

Manufacturing drawings prepared by the Contractor for the execution of the Contract shall comply with the procedure defined in chapter 6 of the LHC QAP document No LHC-PM-QA-306.00, "Drawing Process-External Drawings".

4.7.2 Planning and scheduling

Planning and scheduling activities shall be performed according to the procedure defined in the LHC QAP document No LHC-PM-QA-301.01, "Planning and Scheduling Requirements for Institutes, Contractors and Suppliers".

4.7.3 Quality control records

All specified tests and measurements carried out during all stages of production, from material procurement up to delivery and installation, shall be recorded in specific files (“Travellers”) and collected in a MTF (Manufacturing and Test Folder), according to the procedure defined in the LHC QAP document No LHC-PM-QA-309.00, “Fabrication and Inspection of Purchased Equipment”. The Travellers of each current lead shall include the results of the final tests (see section 7), the certified welder qualifications and the information on the materials. Each stack of HTS material will be identified with a CERN code. The Traveller document shall include the identification number of the stacks integrated in the current lead.

Copies of the Travellers shall be submitted to CERN for archiving in the CERN central database.

Each current lead shall be visibly and indelibly marked with the LHC part identification number: HCDFLCS001-BI000001 (the last six digits represent the sequential number). This number identifies the current lead unit.

The intermediate copper block of each HTS unit (Drwg.LHCDFLCS0009) shall be engraved with a sequential number corresponding to the last digits of the current lead part identification number (1,2,3….). In the Traveller, this number will correspond to the LHC part identification number HCDFLCS003-BI000001 (the last six digits represent the HTS unit sequential number). It identifies the HTS unit of each current lead.

Each stack delivered by CERN will be identified with a number printed on a removable label. This label shall be removed only at the moment of assembling the stacks to the HTS unit. The Contractor shall report in the Traveller document the identification number of the HTS stacks integrated in each HTS unit.

In the Traveller document, the identification number HCDFLCS002-BI000001 (the last six digits represent the sequential number) corresponds to the current lead top part (top copper block + copper heat exchanger + vacuum jacket).

5. APPLICABLE DOCUMENTS

Please refer to the Addendum No P059/R10 that forms part of this Technical Specification.

5.1 Standards

The following standards, in order of priority, are applicable for the execution of the Contract.

5.1.1 CERN standards

-CERN Safety Code D2 (May 1998)- "Safety code for industrial pressure vessels and pressurised pipelines".

-CERN Safety Code C1 (1996)- "Electrical safety code".

5.1.2 International standards

Wherever relevant EN or ISO Norm shall be applied:

-EN 287-1 - "Approval testing of welders - Fusion welding ". Part 1: Steel

-EN 288-3- "Specification and approval of welding procedures for metallic materials". Part 3: Welding procedures tests for the arc welding of steels

-ISO 15614-11- "Specification and approval of welding procedures for metallic materials- Welding procedures test". Part 11: Electron and Laser Beam welding.

-ISO 13919-1-"Electron and laser-beam welded joints-Guidance on quality levels for imperfections"

-ISO 3530- "Mass spectrometer type leak detector calibration".

-ISO/AWI 12724- "Testing for leaks using the mass spectrometer leak detector or residual gas analyser".

5.1.3 National standards

-NFA 09-490- "Non-destructive testing: testing for leak tightness recommended practises for the specification and testing of gas tightness".

-NFA 09-492- "Non-destructive testing tightness testing, method under vacuum with tracer-gas".

6. QUALITY ASSURANCE PROVISIONS

The Contractor shall plan, establish, implement and adhere to a documented quality assurance programme that fulfils all the requirements described in this Technical Specification and drawn up according to the Quality Assurance Plan for the LHC Project.

Please note that the quality assurance documents, CERN Standards and Purchasing documents referred to in this Technical Specification can be found on the enclosed CD-Rom entitled “CERN Official Documents”.

The list of relevant topics covered by the LHC Quality Assurance Plan, together with the corresponding documents, is given in Table 4 below.

Topic	Document Title	Doc. Number
Policy and Organisation	Quality Assurance Policy and Organisation	LHC-PM-QA-100.00
Planning	Planning and Scheduling Requirements for Institutes, Contractors and Suppliers	LHC-PM-QA-301.01
Design	Quality Assurance Categories	LHC-PM-QA-201.00
	Drawing Management and Control	LHC-PM-QA-305.00
	Drawing Process-External Drawings	LHC-PM-QA-306.00
Change Control	Configuration Management - Change Process And Control	LHC-PM-QA-304.00
Manufacturing and Inspection	Manufacturing and Inspection of Equipment	LHC-PM-QA-309.00
	Handling of Non-conforming Equipment	LHC-PM-QA-310.00
	LHC Part Identification	LHC-PM-QA-206.00

Table 4 - LHC QAP topics and documents

6.1 Quality Control

The Contractor shall be able to demonstrate that he has ISO 9002 series certification, or an equivalent quality control certification that is appropriate to the subject of this Technical Specification.

7. TESTS ON THE CURRENT LEAD

7.1 Tests to be carried out at the Contractor's premises during assembly

The Contractor is responsible for the definition of dimensional, leak tightness and electrical checks to be performed during manufacturing and assembly of the current lead. These tests shall be part of the Quality Assurance documents to be submitted to CERN for approval together with the manufacturing file.

7.1.1 Electrical joints

The assembly of the current lead includes a number of electrical joints made via Electron Beam Welding, vacuum brazing and vacuum soldering techniques. The performance of the lead depends on the good quality of these joints that shall be guaranteed.

The welding operations shall be performed by welders qualified according to European standards or equivalent.

7.1.1.1 Electron Beam Welding

The Electron Beam Welding between the top copper block and the heat exchanger and between the intermediate block and the heat exchanger shall assure:

- penetration through the complete copper depth (see Drwg. LHCDFLCS0006),
- high metallurgical quality and absence of defects such as porosity, cracks, lack of fusion and shrinkage voids (see Section 5).

The Contractor shall issue a welding procedure qualification (AWP) that meets the requirements of the Standards.

After optimisation of the welding procedures and parameters, the Contractor shall perform via a notified body radiography, microscopic analysis and ultrasonic tests on two samples welded with the welding parameters that are proposed to be used for the current leads series production. These samples shall have the same geometrical size and chemical composition of the two copper pieces to be Electron Beam Welded at the top and at the bottom of the fin type heat exchanger. The results of these tests and the samples shall be submitted to CERN for analysis and approval. For the acceptance level of the welded components, the Contractor shall refer to Section 7.3.2 of the European Standard EN ISO 15614-11 and to the Standard EN ISO 13919-1. The quality level B shall be applied to the welded joints. The approved parameters shall not be changed during the series production.

The Traveller document of each current lead shall include the data recorded by the Electron Beam Welding machine for quality assurance information.

During the series production, CERN will ask for regular radiography tests on electron beam welded joints. These tests will concern a total of 26 current leads to be selected during production. The results of these tests shall be submitted to CERN. In case of non-conformity, the Contractor shall agree with CERN on a procedure to repair or replace the components at his own expense. In addition, all the units since the last accepted test shall be re-tested at the Contractor’s expense. This operation will require the opening of the assembled current leads, which shall be done at the Contractor’s expense.

7.1.1.2 Vacuum brazing and vacuum soldering

The Contactor shall assure that the brazing of the copper outer block to the copper inner block results in 100 % wettability. The same applies for the soldering of the HTS stacks to the top and bottom copper blocks.

All the accessible vacuum brazed/soldered joints shall be visually inspected. The brazing/soldering alloy shall be systematically visible in the joints and no gap shall be present. Excessive flow of the brazing material at the surface of the pieces shall not be accepted.

The surface of the stainless steel inserts to be TIG welded shall be maintained perfectly clean and free of surface plating and/or brazing materials.

7.1.2 TIG welding

The vacuum jacket and the helium gas inlet connection shall be thermally shocked by immersion in liquid nitrogen after TIG welding of each sub-component.

After TIG welding of the vacuum jacket and of the helium gas inlet connection to the current lead, the new welds shall be thermally shocked with cold (77 K-100 K) nitrogen gas.

7.1.3 Ceramic insulators

The ceramic insulators of each current lead (Drwg. LHCDFLCS0024, Drwg. LHCDFLCS0032) shall be thermally shocked by immersion in liquid nitrogen and leak tested prior to integration in the current lead.

7.1.4 Mechanical tolerances

The following fabrication and assembly tolerances shall be reported in the Traveller document associated with each current lead:

- copper heat exchanger fins diameter (Φ=63g6),
- vacuum jacket inner tube internal diameter (Φ=63H7) ,
- concentricity between the copper heat exchanger and the intermediate copper block (Drwg. LHCDFLCS0006) after the Electron Beam Welding of the two ends of the heat exchanger. During this measurement, the current lead shall be maintained in a vertical position.

7.2 Test to be carried out at the Contractor’s premises after assembly

CERN reserves the right to be present, or to be represented by an organization of its choice, to witness any tests carried out at the Contractor's or his subcontractors' premises. The Contractor shall give at least 10 working days notice of the proposed date of any such tests. The Contractor shall carry out the tests in the following sequence: dimensional checks, pressure tests, electrical insulation tests, leak tightness tests and instrumentation tests. The results of these checks and tests shall be reported in the Traveller documents (see section 4.5.3 and Annex C).

7.2.1 Dimensional checks

The Contractor shall perform a number of dimensional checks on the current lead after assembly. In particular it shall be measured:

- the total length of the current lead,
- the length of the current lead under-side of the insulating flange,
- the maximum diameter of the current lead body,

• the radial extension of the helium gas inlet connection,

• the orientation of each hydraulic connection,

• the length between the helium gas recovery port and the upper side of the topper copper block,

• the length between the warm electrical connection to the power cables and the upper side of the topper copper block,

• the length between the helium inlet gas port and the under-side of the insulating flange,

• the free length of LTS wires from the bottom of the current lead body,

• the soldered length of the LTS wires.

These measurements shall conform to the corresponding dimensions indicated in the CERN drawings folder.

7.2.2 Pressure tests

The 20 K circuit of the resistive heat exchanger and the 4.5 K circuit of the HTS element shall be independently pressurized up to 0.45 MPa (pneumatic test). The Contractor shall provide the tooling necessary for the test.

During this test, the test pressure shall be kept for at least 10 minutes.

7.2.3 Electrical tests

A voltage of 1.3 kV, both polarities, shall be applied for 30 s between the current carrying part (top copper block) and the ground (metallic flange supporting the current lead insulating flange). The two ports of the inlet and exit hydraulic connections shall be grounded.

During this test, the 20 K circuit of the copper heat exchanger and the current lead external body (4.5 K circuit) shall be in helium gas at room temperature (0.13 MPa absolute pressure). The leakage current shall stay below 10 μA.

The Contractor shall provide the equipment and the tooling necessary for the test.

7.2.4 Leak tightness tests

The 20 K circuit of the fin-type heat exchanger shall be evacuated to below 0.1 Pa (10^{-6} bar) and helium leak tested. The integral of leaks detected shall stay below 10^{-7} Pa m^3 s^{-1} (10^{-9} bar l s^{-1}).

The vacuum jacket shall be evacuated to below 0.1 Pa (10^{-6} bar) and helium leak tested. The integral of leaks detected shall stay below 10^{-7} Pa m^3 s^{-1} (10^{-9} bar l s^{-1}).

The 4.5 K circuit of the current lead shall be evacuated to below 0.1 Pa (10^{-6} bar) and helium leak tested. The integral of leaks detected shall stay below 10^{-7} Pa m^3 s^{-1} (10^{-9} bar l s^{-1}).

The procedure for the leak tests will be supplied by CERN.

The sensitivity of the mass spectrometer leak detector shall be in accordance with the specified leak tightness value. The tests shall be performed in accordance with the international (or national equivalent, see section 5.1) leak testing standards by accredited personnel.

The Contractor shall provide the equipment and the tooling necessary for the test.

7.2.5 Instrumentation tests

The Contractor shall verify the integrity of the wires and the continuity of the instrumentation signals incorporated in the current lead. A current of 10 A d.c. shall be passed in the current lead body and the voltage drop between the top (EE11, EE12) and each of the remaining voltage signals shall be measured. The voltage drops measured at the exit of the instrumentation connector are in the range 0.2-2 mV.

The Contractor shall as well verify the electrical insulation of the temperature sensors from the current lead body after soldering of the wires and fixation of the 16-pin Fischer connector. The insulation test voltage between the four wires of each sensor and the current lead body is 200 V a.c. peak voltage, 50 Hz.

7.3 CERN tests

CERN reserves the right to perform any tests on any 6000 A HTS current lead to check the conformity with this Technical Specification.

The acceptance tests at CERN include the repetition by CERN of all the tests performed at the Contractor’s premises in order to verify the conformity to this Technical Specification.

In addition, CERN will test under nominal operating conditions each current lead. The Contractor will be invited to attend to the test. If the electrical and/or thermal performance of a current lead does not correspond to expectations, this will not constitute in itself a reason for rejection of the current lead. However if the subsequent inspection shows that the current lead does not conform to this Technical Specification, the Contractor shall replace the current lead free of charge to CERN. CERN reserves the right to ask for the repair or the replacement of the faulty component free of charge.

8. DELIVERY AND COMMISSIONING

8.1 Delivery schedule

The 6000 A HTS current leads shall be delivered to CERN or other European sites to be designated. The delivery schedule is given in Annex D.

8.2 Packing and transport

No shipment shall be carried out without written consent from CERN. The Travellers related to each current lead in a shipment shall be sent to CERN by electronic means (see Annex C) prior to shipment, and CERN will give approval within two weeks of their reception provided the data are acceptable. Certificates of conformity of each current lead shall accompany the shipment to its destination address.

The Contractor is responsible for the packing and the transport of the current leads. He shall ensure that the equipment is delivered safely in transport conditions protecting the supply from any damage or possible deterioration. Each current lead shall be individually packed. The packing shall support the current lead and protect it from moisture and any damage during handling and transport. It shall include shock indicators that shall be installed by the Contractor who is fully responsible for the design of the box.

The design of the box shall be such that it can be re-used without modifications, after extraction of the current lead, for transport of the component in the assembly and/or testing facilities. The packing and storage conditions shall provide for adequate marking or labelling in order to clearly and readily identify each current lead.

8.3 Acceptance and guarantee

Acceptance of the current lead will be given by CERN only after all items have been delivered in accordance with the conditions of the contract including documentation referred to in this Technical Specification, all tests specified have been successfully completed, and all test or other certificates have been supplied to CERN.

The Contractor shall guarantee that the current leads have been manufactured in accordance with this Technical Specification and shall take full responsibility for any manufacturing faults. Should any of the tests described in this Technical Specification reveal any manufacturing defects or damage occurring during transport, CERN will be entitled to the immediate replacement of the faulty current lead free of charge.

9. CERN CONTACT PERSONS

Persons to be contacted for technical matters:

Name/Division/Group	Tel-Fax	Email
Amalia Ballarino	**Tel:** 0041-22-767-3296 **Fax:** 0041-22-767-6180	Amalia.Ballarino@cern.ch
In case of absence:		
Karl Hubert Mess	**Tel:** 0041-22-767-76642 **Fax:** 0041-22-767-6180	Karl.Hubert.Mess@cern.ch

ANNEX A: LIST OF DRAWINGS

Number	Title
LHCDFLCS0001	GENERAL ASSEMBLY
LHCDFLCS0002	INTERFACE DRAWING
LHCDFLCS0003	SEQUENCE OF WELDING OPERATIONS
LHCDFLCS0004	SUB-ASSEMBLY-RESISTIVE PART+HTS+LTS+VACUUM JACKET
LHCDFLCS0005	SUB-ASSEMBLY-He GAS INLET CONNECTION
LHCDFLCS0006	SUB-ASSEMBLY-RESISTIVE PART+HTS+LTS
LHCDFLCS0007	SUB-ASSEMBLY-VACUUM JACKET
LHCDFLCS0008	SUB-ASSEMBLY-TOP COPPER BLOCK
LHCDFLCS0009	SUB-ASSEMBLY-HTS+LTS
LHCDFLCS0010	SUB-ASSEMBLY-WARM HEAT EXCHANGER
LHCDFLCS0011	INSULATING FLANGE
LHCDFLCS0012	INSULATING RING MALE
LHCDFLCS0013	INSULATING RING FEMALE
LHCDFLCS0014	RESISTIVE PART INSULATING PROTECTION
LHCDFLCS0015	SHIM FOR HTS INSULATING PROTECTION
LHCDFLCS0016	HALF SHIM FOR RESISTIVE PART INSULATING PROTECTION
LHCDFLCS0017	HTS INSULATING PROTECTION
LHCDFLCS0018	CONNECTOR SUPPORT PLATE
LHCDFLCS0019	THERMAL SENSOR
LHCDFLCS0020	PLATE FOR SENSOR
LHCDFLCS0021	TOP INSULATING PROTECTION
LHCDFLCS0022	BOTTOM INSULATING PROTECTION
LHCDFLCS0023	TOP VOLTAGE TAP RING
LHCDFLCS0024	INVAR WASHER
LHCDFLCS0025	MODIFIED DN-16
LHCDFLCS0026	BELLOW
LHCDFLCS0027	INSULATOR
LHCDFLCS0028	ELBOW CONNECTION
LHCDFLCS0030	COPPER HEAT EXCHANGER
LHCDFLCS0031	UNION SMALL FLANGE DN 16
LHCDFLCS0032	STAINLESS STEEL FLANGE
LHCDFLCS0033	VACUUM JACKET INNER TUBE
LHCDFLCS0034	VACUUM JACKET OUTER TUBE
LHCDFLCS0035	BELLOW

Number	Title
LHCDFLCS0036	CONNECTION UNDER BELLOW
LHCDFLCS0037	INSERT FOR ELECTRICAL CONNECTOR
LHCDFLCS0038	CERAMIC INSULATOR
LHCDFLCS0039	OUTER BLOCK
LHCDFLCS0040	RING ON TOP COPPER BLOCK
LHCDFLCS0041	INNER TOP BLOCK
LHCDFLCS0042	INSERT FOR HELIUM OUTLET CONNECTION
LHCDFLCS0043	INTERMEDIATE COPPER BLOCK
LHCDFLCS0044	INSERT ON INTERMEDIATE BLOCK
LHCDFLCS0045	CONVECTIVE SCREENS
LHCDFLCS0046	HTS SUPPORTING TUBE
LHCDFLCS0047	BOTTOM COPPER BLOCK
LHCDFLCS0048	STACK OF HTS TAPES
LHCDFLCS0049	CLAMP FOR LTS WIRES
LHCDFLCS0050	M4 TAPPED CYLINDER
LHCDFLCS0052	INNER RING
LHCDFLCS0053	OUTER RING
LHCDFLCS0054	GRID

ANNEX B: REQUIREMENTS FOR CLEAN AREA

1. SCOPE

This Annex outlines the requirements for the area where the current lead assembly will take place.

2. DEFINITION OF CLEAN CONDITIONS

The term CLEAN CONDITIONS refers to the working conditions and special measures which shall be applied to avoid contamination by conventional workshop contaminants such as oil, machine or finger grease, dirt, atmospheric dust, paint, etc.

3. DESCRIPTION OF A CLEAN AREA

A CLEAN AREA is a separate building or annex. A suitable area of the normal workshop space may be adapted, provided it is completely isolated from the rest of the workshop.

The clean area is a controlled area with:

- Environmental control of particulate contamination, temperature 20 °C ± 10 °C, humidity (40% ± 20 %), air change and filtering of the inlet air.
- Slightly over-pressurized to avoid air in-leaks.
- A floor of fine screed concrete or equivalent, which shall be adequately painted or sealed.
- Adequate lighting for the type of process being carried out.
- Adequate heating well guarded to reduce the risk of fire. NB: Naked-flame heating is not acceptable.
- Specific controls for entrance and exit, including doormats designed for this purpose.

3.1 Environment

Smoking is strictly forbidden. Panels indicating that the CLEAN AREA is a NON SMOKING AREA shall be placed at the entrance and in visible places. The storage, preparation and consumption of food and drinks shall not be permitted.

3.2 Working dress

Normal working dress shall be clean laboratory type-coat, suitable clean gloves and clean disposable overshoes.

3.3 Tools and Equipment

A minimum quantity of degreased and cleaned hand-tools and equipment shall be maintained in the CLEAN AREA as part of its permanent equipment.

If overhead cranes are present there should be a roof over the clean area to prevent oil and particles from falling down onto the work in progress.

ANNEX C: EXCHANGE OF INFORMATION

The test reports on each current lead shall be submitted to CERN for approval before delivery and shall be included in the Traveller document. The following information shall be included in a data/sheet computer readable file:

- identification number of current lead, HTS unit and HTS stacks,
- results of all tests performed at the contractor premises, including date and place of the tests and name and qualification of the personnel who has performed the tests.

ANNEX D: DELIVERY SCHEDULE

Delivery date	Number of 6000 A current leads
15th September 2004	4
15th October 2004	4
1st November 2004	4
1st December 2004	8
1st January 2005	8
1st February 2005	12
1st March 2005	12
1st April 2005	12
1st May 2005	12
1st June 2005	12
1st July 2005	12
1st August 2005	12
1st September 2005	12
1st October 2005	12
1st November 2005	8
1st December 2005	12
1st January 2006	8
1st February 2006	12
1st March 2006	8
1st April 2006	12
1st May 2006	8
1st June 2006	12
1st July 2006	8
1st August 2006	12
1st October 2006	22

ANNEX E: MILESTONES

In order to achieve the agreed delivery schedule, the following milestones are proposed:

Starting from 1st July 2004, a written report shall be sent to CERN, every two weeks, on the advancement of the project.

15th July 2004: Quality Assurance documents shall be submitted to CERN for approval together with the Manufacturing File, including the execution drawings, updated after March 2004, the manufacturing and the testing schedules.

31st July 2004: Welding Procedure Qualification (see section 7.1.1.1) shall be submitted to CERN for approval.

31st July 2004: detailed documentation on brazing and soldering procedures, including specification of selected alloys (dimension and composition), information on thermal cycle with proposal of the template for the measured temperature profile to be supplied with each current lead, drawings of tooling for brazing and soldering operations shall be submitted to CERN for approval.

31th July 2004: two samples consisting of one stack vacuum soldered to a stainless steel support, electro-plated as for the HTS support unit, and Parylene® coated with the set-up purchased by BINP shall be delivered to CERN for analysis.

31th July 2004: one sample of copper Electron Beam welded as in the current lead body shall be delivered to CERN for analysis.

31th July 2004: detailed documentation on cleaning and electro-plating procedures shall be sent to CERN.

15th August 2004: one complete HTS unit (with the four HTS stacks and the LTS wires vacuum soldered) Parylene® coated shall be delivered to CERN.

15th September 2004: first delivery of four 6000 A HTS current leads (see Annex D).

ANNEX F: CD-ROM "CERN OFFICIAL DOCUMENTS"