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The Large Hadron Collider Project ***IT-3168/AT/LHC***

Invitation to Tender Technical Specification for the Manufacture and Supply of 13000 A HTS Current Leads

Abstract

This Technical Specification concerns the manufacture and supply of 60 High Temperature Superconducting current leads used for powering the main dipole and main quadrupole superconducting magnets of the LHC machine. These leads will transport a maximum current of 13000 A d.c.

Delivery of the leads is expected to be spread from July 2004 to May 2006.

September 2003

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Terms and Definitions

Term	Definition
CDD	CERN Drawing Directory
EDMS	Engineering Data Management System
QAP	Quality Assurance Plan
DFLAS	Equipment code of 13000 A HTS current lead
HTS	High Temperature Superconductor
LTS	Low Temperature Superconductor
OF	Oxygen-Free
OFE	Oxygen-Free-Electrolytic
RRR[1]	Residual Resistivity Ratio

[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 1624 superconducting main dipole and main quadrupole magnets connected in series strings and operating at currents of up to 13000 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, and the inspection and acceptance criteria of these 13000 A HTS current leads.

2. SCOPE OF THE TENDER

2.1 Scope of the supply

The total supply shall consist of 60 HTS current leads rated for a maximum current of 13000 A, with a purchase option for up to 8 additional leads. 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.

- Procurement of all necessary raw materials, components and tooling which is not supplied by CERN (see Section 2.2).
- 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 leads.
- Inspection and quality control of the HTS 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

The following items will be supplied by CERN:

- 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 Sections 4.3.1 and 4.6).
- Temperature probes, integrated in a threaded copper block, and corresponding electrical wires (see Sections 4.3.11.1 and 4.5.1).
- Conductive paste (see Section 4.5.1).
- Suitable AISI 316 LN stainless steel tubes for machining the inserts for vacuum brazing and the stainless steel cylinder (see Sections 4.3.1.3, 4.3.5 and 4.3.6 and 4.3.7).
- Copper rods for the fin-type heat exchanger (see Section 4.3.3).

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.

3. GENERAL CONDITIONS FOR TENDERING AND CONTRACTING

Please refer to the commercial documents for more complete information.

Tenders will only be considered from firms having been selected as qualified bidders by CERN, as a result of the Market Survey ref. MS-3168/LHC/LHC. CERN reserves the right to disqualify any bidder whose reply to this Market Survey is found to have been incorrect.

3.1 Tender procedure

3.1.1 Pre-tender discussions

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

3.1.2 Alternative solutions

If the Bidder finds that any part of this Technical Specification is difficult, or costly to meet, he is free to propose an alternative solution, provided that the deviations from this Technical Specification, together with the reasons and advantages, are clearly indicated in the Tender. Such alternative solutions shall always be made in addition to a conforming bid, which shall comply fully with this Technical Specification.

CERN reserves the right to accept or reject the proposed alternative solutions without justification.

3.1.3 Preliminary programme

The Bidder shall propose a preliminary design and manufacturing schedule with the Tender, based on the specified CERN provisional delivery schedule.

3.1.4 Subcontractors

The Bidder shall declare in his Tender any subcontractors whose services he intends to use in the event of a Contract; please refer to the commercial documents for more details. If awarded the contract, the Bidder shall restrict himself both to the subcontractors and the amount mentioned in the Tender. If, for some reason, he wants to change any subcontractor, or the scope of subcontracted work, or the amount subcontracted, he shall obtain CERN's prior agreement in writing.

3.1.5 Technical Questionnaire

The Technical Questionnaire attached to this Technical Specification shall be completely filled in and returned with the Tender Form, otherwise the Tender will not be considered as complete and will be discarded.

3.1.6 Presentation of tender

The Bidder may be required to make a formal presentation of his Tender at CERN at his own expense and shall be ready to do so within a week of notification.

3.1.7 Country of origin

Please refer to the commercial documents for specific conditions concerning the country of origin of the equipment or services to be supplied.

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

The Contractor shall supply, within one month of notification of the Contract, a written programme detailing the manufacturing and testing schedules. The programme shall include preliminary dates for inspections and tests.

A written progress report shall be sent to CERN every month 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 within three months after notification of the Contract. CERN will give its approval or refusal, in writing, within 2 weeks. The ordering of components and the manufacture of equipment shall not start without CERN's written prior agreement and approval of materials specification. 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 pre-series units, 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 Tender, 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, as stated in the Tender, may only be changed after written approval by CERN.

4. TECHNICAL REQUIREMENTS

4.1 General description

The 13000 A HTS current lead (Drwg.LHCDFLAS0001) 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.

The resistive part consists of:

- a top copper block (Drwg.LHCDFLAS008) which includes the connection to the power cable, the instrumentation connectors, the warm heat exchanger, the helium gas recovery connection and four cartridge heaters,
- an electrically insulating flange (Drwg.LHCDFLAS0011),
- a fin-type copper heat exchanger (Drwg.LHCDFLAS0030),
- a vacuum jacket (Drwg.LHCDFLAS0007), which provides the thermal insulation of the copper heat exchanger from the external environment.

The superconducting part (Drwg.LHCDFLAS0009) consists of:

- an intermediate copper block (Drwg.LHCDFLAS0043) at the level of the helium gas inlet connection (Drwg.LHCDFLAS0005),
- a stainless steel cylinder (Drwg.LHCDFLAS0046), onto which 36 stacks of BSCCO 2223 tapes are vacuum soldered,
- the stacks of BSCCO 2223 tapes,
- a bottom copper block (Drwg.LHCDFLAS0047) 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.

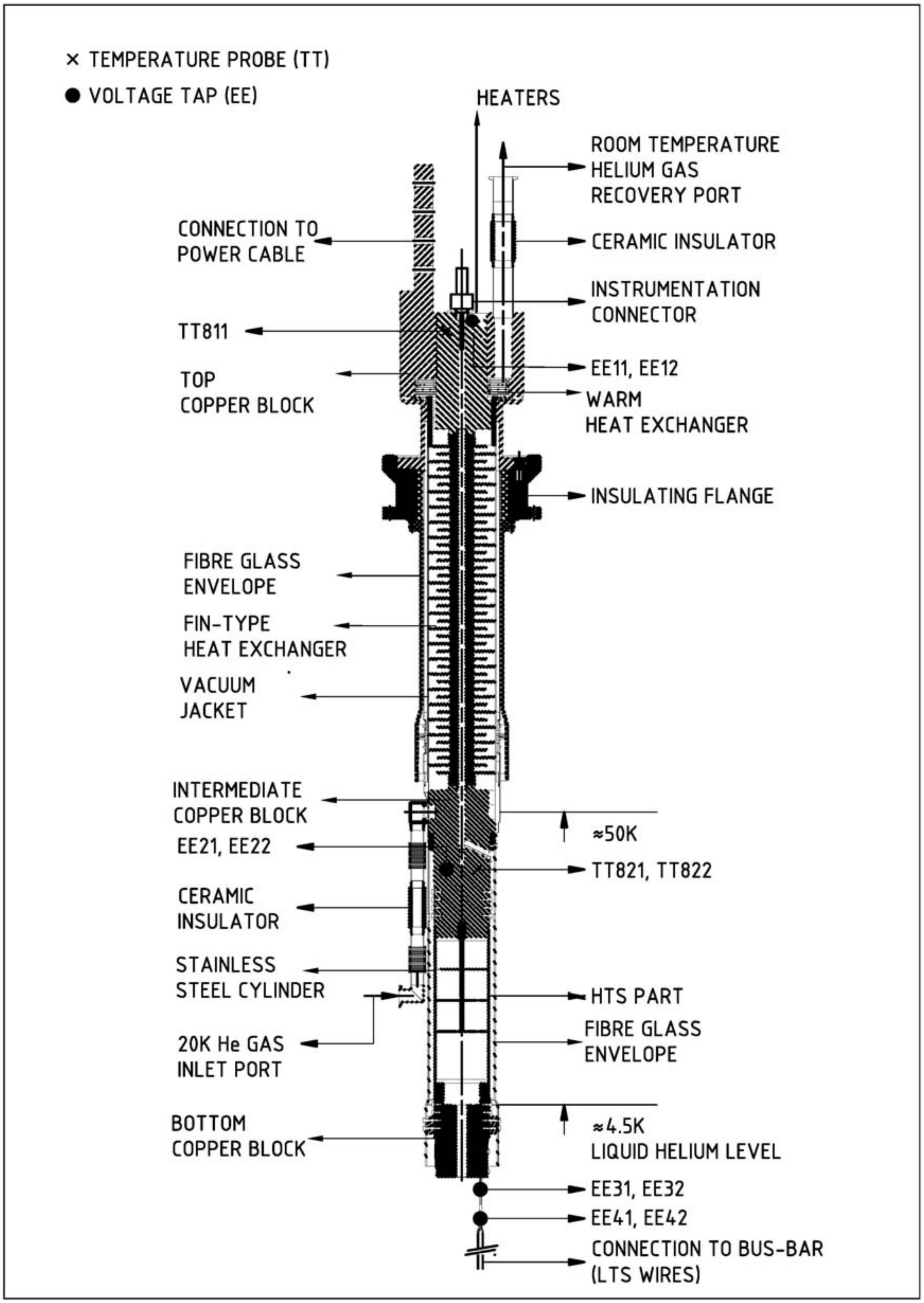

Fig. 1- 13000 A HTS lead schematic

4.2 Design criteria

The 13000 A HTS lead is designed to carry a maximum current of 13000 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 reduces 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 when compared to a conventional self-cooled lead.

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

The design of the 13000 A HTS lead has been validated at CERN with the manufacture, assembly and test under nominal operating conditions of a pair of 13000 A HTS prototype leads. These leads were built according to the CERN manufacturing drawings that are part of this Technical Specification.

For information, the main parameters of the 13000 A HTS lead are listed in Table 1.

Maximum d.c. current	13000	A
Working temperature range	293-4.5	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
Insulation test voltage in helium gas at room temperature	3.1	kV d.c.
Overall lead length	1395	mm
LTS wires free length	735	mm
Copper RRR of fin-type heat exchanger	80-100	-
External diameter of insulating flange	218	mm
External diameter of vacuum jacket	108	mm
Total mass	Approx. 700	N

Table 1 - Main parameters of the 13000 A HTS lead

4.3 Materials and sub-assemblies

The main raw materials to be supplied by the Contractor for the current lead assembly are: forged OFE copper for the vacuum brazed components, austenitic stainless steel 316 L (or 304 L) for the TIG welded components and glass- fibre composite (EP GM3) for the electrical insulating parts.

The manufacture and assembly of the HTS 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.LHCDFLAS008) consists of an inner block (Drwg.LHCDFLAS041) and outer block (Drwg.LHCDFLAS039). These two blocks of OFE copper are vacuum brazed together.

The inner block includes 4 holes, 12.5 mm diameter and about 105 mm length, each of which houses a CERN supplied 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 lead.

The outer block includes the lug for the connection of the power cables, 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 block respectively.

Two stainless steel (AISI 316 LN) inserts are vacuum brazed in the copper outer block. They are used for the connection of the helium recovery connection (Drwg.LHCDFLAS0042) and for the TIG welding of the vacuum jacket (Drwg.LHCDFLAS0040). A stainless steel insert (AISI 316 LN) is vacuum brazed in the copper inner block. It serves for the integration of the 16-pin electrical connector (Drwg.LHCDFLAS0037).

4.3.1.1 Warm heat exchanger

A warm heat exchanger is vacuum brazed inside the top copper block (Drwg.LHCDFLAA0006, Drwg.LHCDFLAS0010). It consists of seven OF Cu (or OFE Cu) perforated plates (Drwg.LHCDFLAS0054) assembled and vacuum brazed between seven inner and seven outer silver plated copper rings (Drwg.LHCDFLAS0052, Drwg.LHCDFLAS0053).

4.3.1.2 Helium gas recovery connection

The helium gas recovery connection consists of a ceramic (Al_2O_3) 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 50 N axial and 10 N radial without degrading of the mechanical and electrical properties,
- capability to withstand a minimum insulation voltage of 3.1 kV, both polarities, in helium gas at room temperature and atmospheric pressure. The corresponding leakage current shall be less than or equal to 3.1 μA,
- leak tightness (see Section 7.2.4).

Ceramic insulators with these characteristics can be supplied by FRIATEC AG.

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.LHCDFLAS0037). This insert receives the 16-pin connector (Fischer DEE 104 A086).

A stainless steel (AISI316LN) insert is vacuum brazed in the copper outer block (Drwg.LHCDFLAS0042). 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.LHCDFLAS0040). 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, connector (Fischer DEE 104 A086) is screwed in the insert vacuum brazed at the centre of the top copper block. The instrumentation wires of the two platinum resistance thermometers and of the eight voltage taps connected inside the lead terminate in this connector.

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

4.3.2 Electrical insulating flange

An insulating flange (Drwg.LHCDFLAS0011) is connected to stainless steel flange (Drwg.LHCDFLAS0032) of the lead. 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.LHCDFLAS0030) consists of a round bar, about 500 mm long, with fins to enhance the heat exchange with the helium gas. The conductor has an external diameter of 32 mm and a central hole of 10 mm diameter. The tube with the fins shall be machined from a forged copper rod with a RRR between 80 and 100.

4.3.4 Vacuum jacket

The vacuum jacket (Drwg.LHCDFLAS0007) is made of austenitic stainless steel sub-components (AISI 304 L or AISI 316 L).

The inner component of the vacuum jacket (Drwg.LHCDFLAS0033) 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.LHCDFLAS0032, Drwg.LHCDFLAS0031). The pumping port shall be a DN-16 flange,
- a stainless steel tube (Drwg.LHCDFLAS0034),
- a bellow (Drwg.LHCDFLAS0035),
- a bottom connection (Drwg.LHCDFLAS0036).

The bellow shall 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 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.

Bellows with these characteristics can be supplied by Calorstat.

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

4.3.5 Intermediate copper block

The intermediate copper block (Drwg.LHCDFLAS0043) 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.LHCDFLAS0044), vacuum brazed on the copper surface (Drwg.LHCDFLAS0006), 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 body of the lead via the access given by the front elbow (Drwg.LHCDFLAS0005). It includes two stainless steel bellows separated by a ceramic (Al_2O_3) insulator.

The two bellows shall 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.

Bellows with these characteristics can be supplied by Calorstat.

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

The ceramic insulator shall have 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 bellows when subjected to the maximum axial and/or lateral deformation,

• insulation voltage of 3.1 kV, both polarities, in helium gas at room temperature and atmospheric pressure. The corresponding leakage current shall be less or equal to 3.1 μA,

• leak tightness (see Section 7.2.4).

Ceramic insulators with these characteristics can be supplied by FRIATEC AG.

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.LHCDFLAS0025).

4.3.6 Stainless steel cylinder

The stainless steel (AISI 316 LN) cylinder (Drwg.LHCDFLAS0046) is vacuum brazed at the ends to the intermediate and bottom copper blocks. Thirty-six 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 μm 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.LHCDFLAS0001). They are supported by a stainless steel rod which is vacuum brazed to the intermediate copper block. The length of the supporting rod (Drwg.LHCDFLAS0045) shall be about 150 mm.

4.3.7 Bottom copper block

The bottom copper block is vacuum brazed to the bottom end of the stainless steel cylinder (Drwg.LHCDFLAS0009). It is made of oxygen free copper (OFE Cu). It includes (Drwg.LHCDFLAS0047):

• the grooves for the BSCCO 2223 stacks of tapes,

• the grooves for the LTS wires,

• a central hole of about 15 mm diameter,

• four holes of 10 mm diameter, on the bottom surface, into which four M6 stainless steel (AISI 316 LN) threaded inserts are vacuum brazed,

• 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 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 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.LHCDFLAS0014) and the superconducting part of the lead (Drwg.LHCFFLAS0017). 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.LHCDFLAS0016) and on the bottom copper block (Drwg.LHCDFLAS0015) respectively.

4.3.11 Instrumentation

Eight voltage taps and two temperature sensors are located inside the body of the lead. The position of these instrumentation signals as indicated in the drawing LHCDFLAS0002 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 body of the lead (see Section 4.5).

4.3.11.2 Voltage taps

Eight voltage taps are connected inside the body of the lead. 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.

These wires are supplied by Habia Cable, Ref. H-H2619TF.

4.3.12 O-ring

A nitril butadiene rubber (NBR) 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 of the lead’s insulating flange and the external environment.

4.4 13000 A HTS lead assembly

4.4.1 General

The 13000 A HTS lead consists of several components assembled together via different technologies including vacuum brazing, vacuum soldering, TIG welding and electron beam welding. A clean area shall be needed for these operations (see Appendix B).

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 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 13000 A HTS prototype 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. LHCDFLAS0010).

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, 1.96 mm diameter, used for the soldering of the voltage tap signals (see section 4.5.2) and the stainless steel inserts (Drwg. LHCDFLAS0009) 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 opposite each other, 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.LHCDFLAS0009), 36 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 about 5 μm thickness. Prior to soldering, the Contractor shall ensure that the soldering surfaces are clean and free of oxidation.

Before positioning of the HTS stacks, 72 LTS wires shall be pressed into the grooves machined in the bottom copper block (Drwg.LHCDFLAS0047). 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.LHCDFLAS0006 and LHCDFLAS0009. After soldering, the free length of LTS wires extending out of the bottom of the lead shall be 0.75 m.

A Sn-Pb 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.

The vacuum soldering of the HTS stacks shall be made via high purity eutectic Sn-Pb37 alloy (melting point 183 ºC), without the use of any flux or anti-flux chemical agent. For the CERN prototype 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.

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 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 lead sub-component shall be protected by a cover. Such protection shall be maintained during the subsequent assembly phases of the 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.

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 lead bottom end, shall be assembled into two flat rectangular cables (Drwgs.LHCDFLAS0002, LHCDFLAS0004 and LHCDFLAS0006). 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 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 additionally 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 additionally electron beam welded to the two ends of the resistive heat exchanger (Drwg.LHCDFLAS0006). 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.LHCDFLAS0007) is pre-assembled, inserted from the bottom of the HTS unit over 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.LHCDFLAS0004). After this operation, the electrically insulating flange (Drwg.LHCDFLAS0011) is inserted from the bottom of the lead and fixed to the 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 via the opening in front of the elbow connection (Drwg.LHCDFLAS0005). 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.LHCDFLAS0001).

4.5 Integration of instrumentation signals

The HTS 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.

The voltage signal wires shall be supplied by the Manufacturer (see Section 4.3.11.2).

4.5.1 Temperature probes

Two temperature sensors units are integrated in the intermediate copper block (TT821 and TT822 in Drwg. LHCDFLAS0002). 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 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 Manufacturer 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.

The third temperature sensor unit (TT811 in Drwg. LHCDFLAS0002) 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 using the eutectic Sn-Pb alloy to the 1.96 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 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 lead.

Two additional voltage taps (EE11, EE12) are connected inside the top inner block (Drwg.LHCDFLAS0001, Drwg.LHCDFLAS0023).

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

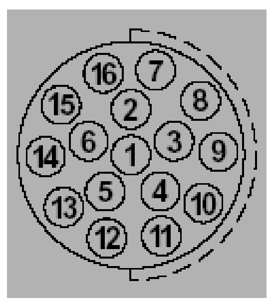

Fig.2- Schematic of DEE 104 A086 instrumentation connector (wires side)

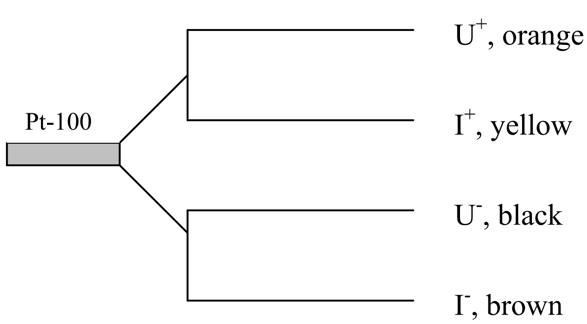

Fig.3: schematic of Pt-100 probe and instrumentation wires

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
1	TT811	U^+
2	TT811	U^-
3	TT811	I^+
4	TT811	I^-

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

4.6 Cartridge heaters

After assembly of the HTS lead, a cartridge heater delivered by CERN shall be integrated in each of the four 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 mm H7.

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 raw 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 raw 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 lead.

Copies of the Travellers shall be submitted to CERN for archiving in the CERN central database (see Annex C). The stainless steel flange of each current lead shall be engraved with the LHC part identification number that will be communicated by CERN.

5. APPLICABLE DOCUMENTS

Please refer to the cover letter for the complete list of enclosed documents that form part of this Invitation to Tender.

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

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. Copies of these documents are included with the Invitation to Tender.

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.LHCDFLAS0006),
- high metallurgical quality and absence of defects such as porosity, cracks, lack of fusion and shrinkage voids (see Section 5).

The Contractor shall issue within three months after notification of the Contract a welding procedure qualification (AWP) that meets the requirements of the Standards. Series production cannot start before CERN has approved it.

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 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 within four months after notification of the Contract. 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 Traveller document of each lead shall include the data recorded by the electron beam welding machine for quality assurance information.

During the series production, CERN will ask for radiography tests on electron beam welded joints of 10 leads. 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 opening of the assembled leads, which shall be made 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 thermal 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 thermal shocked with cold (77 K-100 K) nitrogen gas.

7.1.3 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=92g6),
- vacuum jacket inner tube internal diameter (Φ=92H7) ,
- concentricity between the top copper block and the copper heat exchanger (Drwg. LHCDFLAS0006) after the electron beam welding of the two ends of the heat exchanger. During this measurement, the 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 lead after assembly. In particular the following measurements shall be made:

- the total length of the lead,
- the length of the lead under-side of the insulating flange,
- the maximum diameter of the 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 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 3.1 kV (± 5 %), both polarities, shall be applied for 120 s between the current carrying part (top copper block) and the ground (metallic flange supporting the 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 lead external body (4.5 K circuit) shall be in helium gas at room temperature (0.13 MPa absolute pressure) and the instrumentation wires coming out from the electrical connectors shall be connected to the lead body. The leakage current shall stay below 3.1 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 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 lead. A current of 20 A d.c. shall be passed in the 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 0.2-5 mV.

The Contractor shall as well verify the electrical insulation of the temperature sensors from the 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 lead body is 200 V.

7.3 CERN tests

CERN reserves the right to perform any tests on any 13000 A current lead to check the conformity with this Technical Specification.

The acceptance tests at CERN includes 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 lead does not correspond to expectations, this will not constitute in itself a reason for rejection of the lead. However if the subsequent inspection shows the lead to be non-conform to this Technical Specification, the Contractor shall replace the 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 Provisional delivery schedule

The 13000 A HTS leads shall be delivered to CERN or other European sites to be designated. The delivery schedule is given in the commercial bidding documents.

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, whenever requested by CERN, 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 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 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 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.

The guarantee period is defined in the commercial documents.

9. CERN CONTACT PERSONS

Persons to be contacted for technical matters:

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

Persons to be contacted for commercial matters:

Name/Division/Group	Tel-Fax	Email
Deborah Abbott/SPL/PS	**Tel:** 0041-22-767-5160 **Fax:** 0041-22-767-7450	Deborah.Abbott@cern.ch
In case of absence: Ivo Lobmaier/SPL/PS	**Tel:** 0041-22-767-8836 **Fax:** 0041-22-767-7450	Ivo.Lobmaier@cern.ch

ANNEX A: LIST OF DRAWINGS

Number	Title
LHCDFLAS0001	GENERAL ASSEMBLY
LHCDFLAS0002	INTERFACE DRAWING
LHCDFLAS0003	SEQUENCE OF WELDING OPERATIONS
LHCDFLAS0004	SUB-ASSEMBLY-RESISTIVE PART+HTS+LTS+VACUUM JACKET
LHCDFLAS0005	SUB-ASSEMBLY-He GAS INLET CONNECTION
LHCDFLAS0006	SUB-ASSEMBLY-RESISTIVE PART+HTS+LTS
LHCDFLAS0007	SUB-ASSEMBLY-VACUUM JACKET
LHCDFLAS0008	SUB-ASSEMBLY-TOP COPPER BLOCK
LHCDFLAS0009	SUB-ASSEMBLY-HTS+LTS
LHCDFLAS0010	SUB-ASSEMBLY-WARM HEAT EXCHANGER
LHCDFLAS0011	INSULATING FLANGE
LHCDFLAS0012	INSULATING RING MALE
LHCDFLAS0013	INSULATING RING FEMALE
LHCDFLAS0014	RESISTIVE PART INSULATING PROTECTION
LHCDFLAS0015	SHIM FOR HTS INSULATING PROTECTION
LHCDFLAS0016	HALF SHIM FOR RESISTIVE PART INSULATING PROTECTION
LHCDFLAS0017	HTS INSULATING PROTECTION
LHCDFLAS0018	CONNECTOR SUPPORT PLATE
LHCDFLAS0019	THERMAL SENSOR
LHCDFLAS0020	PLATE FOR SENSOR
LHCDFLAS0021	TOP INSULATING PROTECTION
LHCDFLAS0022	BOTTOM INSULATING PROTECTION
LHCDFLAS0023	TOP VOLTAGE TAP RING
LHCDFLAS0024	INVAR WASHER
LHCDFLAS0025	MODIFIED DN-16
LHCDFLAS0026	BELLOW
LHCDFLAS0027	INSULATOR
LHCDFLAS0028	ELBOW CONNECTION
LHCDFLAS0029	ELBOW CONNECTION COVER
LHCDFLAS0030	COPPER HEAT EXCHANGER
LHCDFLAS0031	UNION SMALL FLANGE DN 16
LHCDFLAS0032	STAINLESS STEEL FLANGE
LHCDFLAS0033	VACUUM JACKET INNER TUBE
LHCDFLAS0034	VACUUM JACKET OUTER TUBE
LHCDFLAS0035	BELLOW

Number	Title
LHCDFLAS0036	CONNECTION UNDER BELLOW
LHCDFLAS0037	INSERT FOR ELECTRICAL CONNECTOR
LHCDFLAS0038	CERAMIC INSULATOR
LHCDFLAS0039	OUTER BLOCK
LHCDFLAS0040	RING ON TOP COPPER BLOCK
LHCDFLAS0041	INNER TOP BLOCK
LHCDFLAS0042	INSERT FOR HELIUM OUTLET CONNECTION
LHCDFLAS0043	INTERMEDIATE COPPER BLOCK
LHCDFLAS0044	INSERT ON INTERMEDIATE BLOCK
LHCDFLAS0045	CONVECTIVE SCREENS
LHCDFLAS0046	HTS SUPPORTING TUBE
LHCDFLAS0047	BOTTOM COPPER BLOCK
LHCDFLAS0048	STACK OF HTS TAPES
LHCDFLAS0049	CLAMP FOR LTS WIRES
LHCDFLAS0050	M4 TAPPED CYLINDER
LHCDFLAS0051	M6 TAPPED CYLINDER
LHCDFLAS0052	INNER RING
LHCDFLAS0053	OUTER RING
LHCDFLAS0054	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 tests reports on each current lead assembly 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:

- batch number of each subcomponent and relative raw materials certificate,
- lead serial number,
- results of the tests performed at the manufacturer premises, including date and place of the tests and name and qualification of the personnel who has performed the tests,
- identification number of the HTS stacks integrated in the lead.

ANNEX D: CD-ROM "CERN OFFICIAL DOCUMENTS"