European Organization for Nuclear Research
*Organisation européenne pour la recherche nucléaire*

EDMS No.: 3073893

DO-34483/TE

# Price Enquiry
# Technical Specification

# Supply of Coils for the LEIR Dipole Magnets

## Abstract

This Technical Specification concerns the supply of one set of two symmetric (one upper and one lower) spare coils for the LEIR dipole magnets. Each coil is made of approximately 190 m hollow copper conductor and shall be vacuum impregnated with epoxy resin. Their mass is approximately 1700 kg per coil. Deliveries are foreseen over 15 months from notification of the award of the Contract.

April 2025

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# 1. INTRODUCTION

The Contract will be performed in accordance with the General Conditions of CERN Contracts (CERN/FC/6674-II). However, this Technical Specification prevails over the General Conditions of CERN Contracts with regard to the particular provisions specified in this document, and this without prejudice to any other provision in the General Conditions of CERN Contracts.

Capitalised terms in the body text are defined either in the General Conditions of CERN Contracts or in the present document.

## 1.1 Introduction to CERN

CERN, the European Organization for Nuclear Research, is an intergovernmental organization with over 30 Member States[1]. Its seat is in Geneva but its premises are located on both sides of the French-Swiss border (https://maps.web.cern.ch/). CERN's mission is to enable international collaboration in the field of high-energy particle physics research and to this end it designs, builds and operates particle accelerators and the associated experimental areas. At present, more than 10 000 scientific users from research institutes all over the world are using CERN's installations for their experiments. Further information is available on the CERN website: http://cern.ch.

The accelerator complex at CERN is a succession of machines with increasingly higher energies. Each machine injects the beam into the next one, which takes over to bring the beam to an even higher energy, and so on. The flagship of this complex is the Large Hadron Collider (LHC) (see Figure 1).

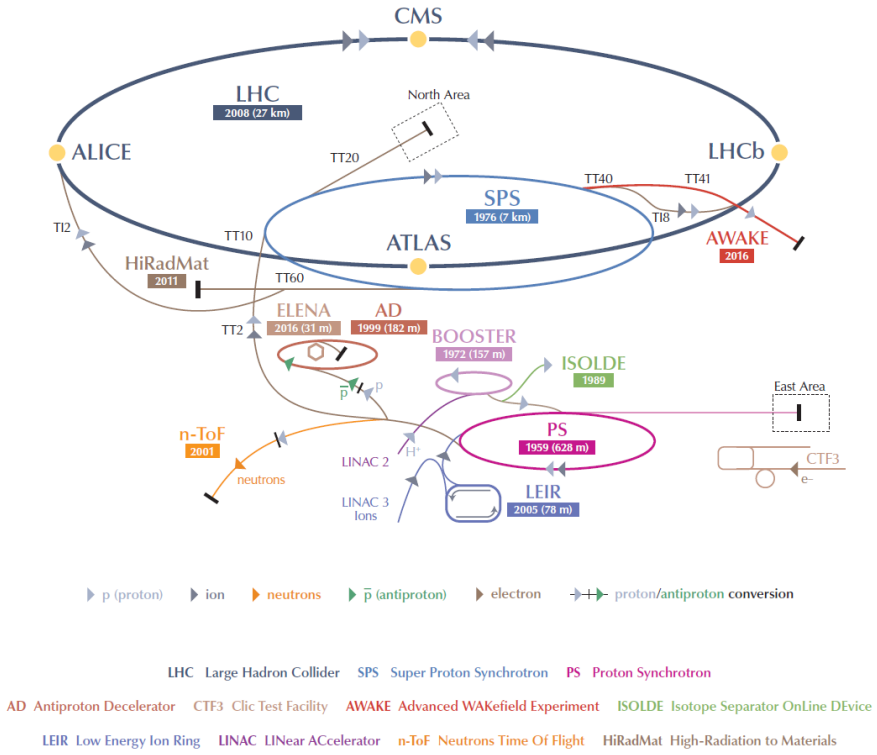


Figure 1: CERN Accelerator Complex

[1] http://home.web.cern.ch/about/member-states

### 1.2 Introduction to LEIR

The Low Energy Ion Ring (LEIR) is a central part of the lead ion injector chain for the LHC. It serves to transform several 200 µs long Linac3 pulses into short dense bunches useful for the LHC. LEIR is square shaped, and the bending of the beam is performed by four identical bending (dipole) magnets. Further information about the LEIR can be found at: https://home.cern/fr/science/accelerators/low-energy-ion-ring

### 1.3 Introduction to the LEIR dipole magnets and their coils

This Technical Specification concerns the supply of one spare set of two symmetric coils (one upper and one lower) for the LEIR dipole magnets currently installed in the LEIR machine. The four 60 tons dipoles operate at a maximum field of 1.6 T (1.15 T nominal) at a peak current of 5000 A. The maximum dissipated power is 132 KW per magnet.

### 1.4 Introduction to Unit

The Normal-Conducting Magnet Section (NCM) is part of the Magnets, Superconductors & Cryostats (MSC) Group within the Technology Department (TE) and in charge of the design, construction, commissioning, maintenance and upgrade of the normal conducting magnets for present and future CERN accelerators and beam lines, as well as the management of non-installed magnets and spares. The NCM section aims to develop knowledge and maintain excellence in magnet technologies, radiation resistant magnets and in permanent magnets.

## 2. SCOPE OF THE SUPPLY

CERN intends to place a contract (the "Contract") for the supply of two coils (in whole or in part, the "Supply").

The successful bidder (the "Contractor") shall provide the Supply as defined in this Technical Specification, including its annexes.

### 2.1 Content of the Supply

### 2.2 Content of the Supply

The Supply shall include the following technical deliverables and activities:

- *Technical deliverables* as specified in § 3:
  - Two coils: one Type_1 and one Type_2 (see § 3.1);
  - Samples (see § 3.2).

- *Activities* as specified in § 4:
  - On the Contractor's site:
    - Design (see § 4.1.1);
    - Procurement of raw materials;
    - Procurement of the tooling;
    - Manufacturing of coils;

- Tests (see § 4.2);
- Packing, and shipping if requested (see § 4.1.7).

- *Documentation* as specified in § 5:
  - Manufacturing File (see § 5.1.1);
  - Quality Control Records (QCR) (see § 5.1.2);
  - Factory Acceptance Tests (FAT) report (see § 5.1.3);
  - Progress Reports (see § 5.2.1),

### 2.3 Equipment and materials provided by CERN

CERN will provide the following items and services for the purpose of the performance of the Contract:

- One drum of 200 m copper conductor for one coil.

## 3. SPECIFICATION OF THE TECHNICAL DELIVERABLES

The Supply shall include the technical deliverables as specified in the present section.

### 3.1 Technical deliverable

#### *3.1.1 General description of the coils*

Each coil is wound by two layers of six conductors (12 turns). The coils are made of hollow copper conductor insulated with a glass fibre tape and a thermo-setting radiation resistant epoxy resin. Each coil has two parallel cooling circuits (two inputs at the ends, one outlet in the middle). The electrical and hydraulic connections are brazed onto the conductors. The detailed dimensions and required tolerances can be found on the drawings LEIMU2HA0010 and LEIMU2HA0013.

A bronze end piece shall be brazed to the conductor on one hand as shown on the drawings LEIMU2HA0011, LEIMU2HA0012, LEIMU2HA0014.

#### *3.1.2 Winding of the coil*

Three options are available:

##### *3.1.2.1 Winding without internal splices*

The coil can be wound from two-piece lengths of conductor without any internal splices. Drawings for this option can be provided upon request.

##### *3.1.2.2 TIG Copper welding*

Pre-bend half-turns can be assembled using TIG welding. In this case, an automated rotating welding robot has to be used, performing a uniform welding between the conductor and the filler material using pure copper.

##### *3.1.2.3 Brazing technic with filler material*

Pre-bend half-turns can be assembled using brazed joints. In this case, Sil-Fos filler material shall be used. No flux shall be used at any time of the process.

Brazing qualification, brazing procedures and brazer approvals shall be conducted in accordance with ISO 17779 and EN ISO 13585:2012. To obtain high quality repeatability, the process 916 (induction brazing) shall be used. Quality level of the brazing need to comply with ISO 18279 level B.

Under this tender procedure, you are hereby requested to submit a bid in accordance with the specifications and requirements outlined under section 3.1.2.3.

### *3.1.3 Materials*

#### *3.1.3.1 Copper conductor*

The conductor shall be made of electrolytic oxygen free (OF) copper, with a conductivity greater than $5.8\times10^7$ S/m.

No inner joints (except for half turns option see §§ 3.1.2.2, 3.1.2.3) are allowed; therefore, the conductors shall be used in proper lengths.

#### *3.1.3.2 Conductor insulation*

The inter-turn insulation shall use half-overlapped using for example a single 0.25 mm thick tape wound with 48% overlap mica on a glass fibre tape, for a total thickness (per side) of 0.5 mm.

The ground insulation shall be:

- first, a 0.5 mm layer of glass fibre, using for example a single 0.25 mm thick tape butt-lapped;
- then, mica on glass fibre – of the same type used for the conductor insulation – for a thickness (per side) of 1 mm.

In addition, a final layer of 0.5 mm glass fibre tape – obtained for example with 0.25 mm thick tape wound with 48% overlap – shall be added around the insulated (inter-turn plus ground, as above) coil plus.

The arrangement of insulation thicknesses and materials is also summarized in the drawings.

In all cases the glass fibre shall be dry, E-type, with a silane (or equivalent) finish to improve the adherence to the epoxy.

#### *3.1.3.3 Epoxy resin*

The epoxy resin shall be of at least IEC 60085 Class E. The epoxy resin shall have a glass transition temperature greater than 75 °C. The epoxy resin shall be transparent when cured.

All parts of the epoxy resin shall be from the same manufacturer and brand to ensure compatibility.

An example of a suitable choice is Araldite® F with either HY 905 or HY 906 hardener.

#### *3.1.3.4 Filling material*

The pieces to fill the empty spaces before impregnation shall be made from glass fibre laminates. For relatively small volumes, glass fibre rope, cloth or tape can be used as well. Pure resin in excess of 1 mm thickness is not admitted.

### *3.1.4 Identification*

The upper coil (drawing number LEIMU2HA0010) shall be identified by PXMU2HAC01_XX0005.

The lower coil (drawing number LEIMU2HA0013) shall be identified by PXMU2HAC02_XX0005.

## 3.2 Samples

### *3.2.1 Bonding samples*

Five samples consisting of three pieces of conductor about 150 mm long insulated in the same manner as foreseen for the coils are requested. The conductor shall be similar in dimensions to the one used for the main windings. The geometry is sketched in Figure 2. These samples will be subjected at CERN to a shear test to check the quality of the bond, with a required strength greater than 5 N/mm$^2$.

In case the visual quality of the impregnation is poor, CERN reserves the right to perform dielectric tests to check the maximum DC voltage carrying capability – both between conductors and from copper to ground – to be found compatible with the requirements of § 4.2.1.3.

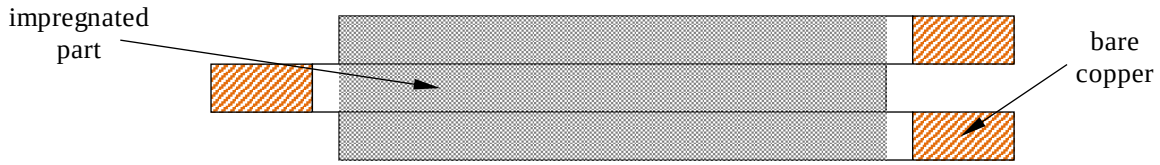


Figure 2: Sketch of sample of impregnated conductors

### *3.2.2 Resin samples*

Samples of resin from each of the impregnation processes are requested. The resin samples shall be between 1 and 2-mm-thick and at least 50 mm$^2$, they will be submitted to a glass transition measurement to ensure that the epoxy has been fully polymerised and mixed according to the resin manufacturer's recommendations.

### *3.2.3 Insulation material samples*

A sample of each insulation material used.

### *3.2.4 Brazing samples*

The following samples shall be provided to CERN for metallurgical and / or mechanical analyses:

- five samples representing the winding brazed terminals;
- five samples of the inter-turn welding or brazing technique;
- five samples of the bronze fittings brazed to a piece of conductor.

The samples shall be prepared in dimensions similar to those used for the coils, brazed with the same procedure envisaged for the coils.

# 4. SPECIFICATION OF THE ACTIVITIES

The Supply shall include the activities listed in the present section. These activities shall comply with the requirements specified below.

## 4.1 Activities at the Contractor's Premises

During the Contract, CERN shall have free access, during normal working hours, to the Contractor's premises, including manufacturing and assembly sites and Subcontractor's premises. The change of manufacturing place is subject to prior written approval by CERN.

#### *4.1.1 Design Activities*

The Contractor shall perform the design activities according to ISO GPS standards (see § 6.2).

#### *4.1.2 Winding*

The winding shall take place in an environment free of dust, metallic particles or other contaminants. The surfaces of all coil components and related tooling shall be thoroughly cleaned and subsequently handled only using clean gloves. Since no inner splices or joints are allowed, the winding shall use a reserve of cable and be performed on a proper mandrel.

#### *4.1.3 Brazing*

All brazing shall be done using a silver phosphorus alloy.

#### *4.1.4 Application of the insulation*

The inter-turn insulation shall be applied only after the coil has been completely wound and formed.

Before applying the inter-turn insulation, the main conductor shall be sandblasted and then cleaned.

Before wrapping the ground insulation, all empty spaces shall be filled to avoid resin rich areas.

#### *4.1.5 Vacuum impregnation*

The geometry of the impregnated coil shall be made using a proper machined mould to respect the dimensions and tolerances. Techniques such as overwrapping with an anti-adhesive tape (Tedlar® or similar) shall be considered as inappropriate to match the required geometrical tolerances.

The mould with the assembled coil shall be heated and vacuum degassed. In parallel, the liquid resin shall be vacuum degassed. The vacuum level shall be recorded. The coil shall then be impregnated with the thermosetting resin. The temperature shall be measured on the mould and throughout the whole curing cycle thermal gradients shall be minimized. The curing cycle for each coil shall be recorded and attached to the documentation.

Pure resin in excess of 1 mm thickness is not admitted. The surfaces of the coils shall not be patched, machined or mechanically processed after impregnation, with the exception of careful removal of flash.

#### *4.1.6 Handling, transport and storage*

The coils shall be handled, transported and stored in an appropriate manner to avoid damage or deformation. They shall be stored in a dry, clean place, with the terminals closed and protected.

#### *4.1.7 Packing and Shipping*

The Contractor shall be responsible for the packing and, if requested by CERN for the transport to CERN. In this case, the Contractor shall take up a dedicated all-risk transport insurance for the Supply concerned in accordance with the provisions of DAP Incoterms 2020 conditions, CERN Prévessin (FR).

In all cases, the Contractor shall comply with the packing and shipping instructions available under: https://procurement.web.cern.ch/system/files/document/packing-and-shipping-instructions_0.pdf and, in particular, ensure that the Supply is packed in a way that guarantees the absence of any

contamination and that no damage or any possible deterioration in performance due to transport conditions can occur.

## 4.2 Inspections and Tests

Inspections and tests shall be in accordance with an Inspection and Test Plan (ITP), following the Manufacturing File (MF, see § 5.1.1). This plan shall detail the procedures and methods, with the description of how the results will be recorded and relative templates.

CERN reserves the right to be present, or to be represented by an organisation of its choice, to witness any tests carried out at the Contractor's or his subcontractors' premises. The Contractor shall give at least ten working days' notice of the proposed date of any such tests.

The Contractor is welcome to complement the tests described here with additional ones on each coil during winding or before impregnation, as part of his quality control.

All coils shall successfully pass the inspections and tests detailed in this ITP. The Contractor shall inform CERN of any non-conformity and his intended method of repair. CERN reserves the right not to accept any repairs or to reject the proposed repair method. The time needed to rectify or re-produce the rejected coils shall not constitute a justification for delays.

### *4.2.1 Factory Acceptance Tests (FAT)*

The FAT for each coil shall be completed within two weeks following the vacuum impregnation. The Contractor shall compile the FAT results in a FAT report (see § 5.1.3) to be submitted to CERN for written approval prior to shipment of the Supply.

#### *4.2.1.1 Visual inspection*

The surface of the impregnated coils shall be free of cracks, bubbles, voids or dry spots.

#### *4.2.1.2 Thermal cycles*

With the use of a power converter and inlet cooling water at 20 °C ±5 °C, each coil shall be submitted to thermal cycles by adjusting the current or flow to obtain 50 °C temperature difference between inlet and outlet water. The current shall then be reduced to zero and the coil cooled to the inlet water temperature, and so on. This cycle shall be repeated 20 times. Logged data of inlet and outlet water temperature vs. time shall be recorded and attached to the documentation. Such cycles shall be performed before the tests defined in §§ 4.2.1.3 and 4.2.1.4.

#### *4.2.1.3 Ground insulation tests*

Each coil shall be immersed in tap water at ambient temperature for at least 8 hours, with only the electrical terminals above the water surface. The electrical conductivity of the water shall exceed 10 mS/cm. The following tests shall then be performed, chronologically as listed:

a. 10 kV DC applied between the main coil and ground (water) for 2 min;
b. 7 kV rms AC applied at 50 Hz applied between the main coil and ground (water) for 2 min;
c. repeat of tests in a. and b.

For all tests the DC insulation resistance shall be greater than 1 GΩ, without major degradation after the AC excitation.

The coils shall be thoroughly cleaned after wetting.

#### *4.2.1.4 Inter-turn insulation tests*

The inter-turn insulation of the main coil shall be checked with a capacitive discharge at 5 kV.

The Contractor shall propose a suitable inter-turn fault detection based on the discharges. The recorded signals of the discharges shall be provided in a text file (or equivalent) to CERN.

#### *4.2.1.5 Hydraulic test*

A flow test shall be performed, at the pressure drop of 12 bar. The measured flow shall be within 10% of the nominal value, to be defined with the pre-series coils.

Each coil shall be purged dry after the test.

#### *4.2.1.6 Electrical resistance and inductance*

The electrical resistance shall be measured and corrected to 20 °C. The measurement accuracy shall be better than 0.5%. The resistances shall not differ by more than 2% with respect to nominal values, to be defined with the pre-series coils.

The electrical inductance shall be measured at a set frequency, 20 Hz or lower. The measurement accuracy shall be better than 1%. The inductances shall not differ by more than 4% with respect to the nominal values, to be defined with the pre-series coils.

#### *4.2.1.7 Geometrical inspection*

The dimensions of each assembled coil pair shall be measured to check that the size and geometrical tolerances are satisfied.

### *4.2.2 Site Acceptance Tests (SAT)*

CERN, or a representative of its choice, will carry out the following SAT on its site.

#### *4.2.2.1 Test of Bonding Samples*

The bonding samples will be subjected to a shear test to verify the bond between the conductor and the insulation. The bond between the conductor and the insulation shall have a shear strength greater than 5 $N/mm^2$.

#### *4.2.2.2 Test of the Brazing Samples*

The brazing (and if applicable welding) samples will be subjected to metallurgical, mechanical, and non-invasive analyses to verify the quality of the brazing. Brazing copper-to-copper shall comply with ISO18279 level C.

#### *4.2.2.3 Test of the Resin Samples*

The resin samples will be subjected to glass transition measurements to verify that the resin has been mixed and cured according to the resin manufacturer's recommendation. The glass transition temperature shall in all cases be above 70°C and match within 5°C the data sheet value for the mix and curing cycle specified in the MF (see § 5.1.1).

#### *4.2.2.4 Test of the Pre-Series and Series*

Prior to acceptance, CERN may repeat the FAT tests described in § 4.2.1 to verify the conformity.

CERN, or a representative of its choice, will carry out the same tests as specified from § 4.2.1.1 to 4.2.1.7 in the framework of SAT of the Supply.

# 5. SPECIFICATION OF THE DOCUMENTATION

The Supply shall include the documentation related to the Supply (§ 5.1) and the documentation related to the performance of the Contract (§ 5.2). This documentation shall comply with the requirements specified below.

## 5.1 Documentation Related to the Supply

The documentation related to the Supply shall include:

- The Manufacturing File (MF) (see § 5.1.1);
- The Quality Control Record (QCR) (see § 5.1.2);
- The Factory Acceptance Tests (FAT) report (see § 5.1.3).

### *5.1.1 The Manufacturing File (MF)*

The MF shall include:

- 3D models;
- the relevant drawings, dimensioned according to ISO standards;
- the impregnation procedure;
- the brazing and/or welding procedure, if applicable;
- an Inspection and Test Plan, prepared on the basis of § 4.2, with the relative templates to be used for documentation purposes;
- the name and address of main suppliers of critical materials, such as the conductor, the epoxy resin and the mica / glass fiber tapes;
- the identification code (see § 3.1.4).

### *5.1.2 Quality Control Records (QCR)*

The QCR shall contain:

- all the documentation related to the test results, according to the ITP of § 4.2;
- the material certificates.

### *5.1.3 Factory Acceptance Test report*

The Contractor shall submit a FAT report in accordance with the schedule defined in § 7.1, including:

- All tests performed;
- All test results;
- All non-conformities;
- All modifications performed;
- Anything else of interest for CERN.

## 5.2 Documentation Related to the Performance of the Contract

The Contractor shall submit documentation related to the performance of the Contract including:

- Progress Reports (see § 5.2.1).

#### *5.2.1 Progress Reports*

The Contractor shall submit monthly progress reports including the actual progress in comparison to the scheduled progress (see § 7.3).

### 5.3 Creation, Updating and Control of Documents

The Contractor shall apply professional standards and codes in matters of document editing, design/drawing process, design reviews and approval, naming conventions and tagging, quality assurance/control.

The full documentation supplied in the framework of the Contract (including all drawings and schematics) shall be in English and optionally also in French.

The Contractor shall submit all documents produced exclusively in the following electronic formats:

- 3D models in CATIA® and/or STEP format;
- Drawings in CATIA®, AUTOCAD® **or** PDF® format;
- Text documents in PDF® format;
- Schedules in PDF® format.

## 6. APPLICABLE NORMS AND STANDARDS

The Supply shall comply with Laws. For the purpose of the Contract, Laws shall include all relevant norms and standards and, and in particular:

### 6.1 Rules

- CERN Safety rules, available under: http://cern.ch/safety-rules, in particular:
  - CERN Safety Instruction IS-41: *The use of plastic and other non-metallic materials at CERN with respect to fire safety and radiation resistance*;
  - CERN Safety Code C1: *Electrical safety code;*
- French rules.

### 6.2 Norms and Standards

- ISO Drawing standards according to CERN document: "ISO Drawing standards according to CERN document: "Collection of applicable GPS Standards at CERN, https://edms.cern.ch/document/3169160 ";
- EN 13605:2021: *Copper and copper alloys - Copper profiles and profiled wire for electrical purposes;*
- ISO 18279: 2002: *Brazing – Imperfections in brazed joints;*
- IEC 60085: 2007 class E: *Electrical insulation - Thermal evaluation and designation;*
- ISO 17779:2021 and EN ISO 13585:2021; *Brazing specifications and qualifications testing;*
- ISO 18279: 2023 level C; *Brazing – Imperfections in brazed joints*.

# 7. PERFORMANCE OF THE CONTRACT

## 7.1 Schedule

The contractor shall deliver the supply according to the following schedule:

Table 2. Schedule

| | Milestones | Weeks |
|---|---|---|
| $T_0$ | Notification of award of the Contract to the Contractor | |
| | Delivery of the Manufacturing File (see § 5.1.1) | $T_0$ + 12 |
| $T_1$ | Acceptance by CERN of the above-mentioned documentation | |
| | Delivery of equipment and material made available by CERN (see § 2.3) | $T_1$ + 2 |
| | Delivery of FAT report (see § 5.1.3) for written approval by CERN | $T_1$ + 41 |
| | Delivery of the Supply at CERN and related technical documentation | $T_1$ + 42 |

## 7.2 Contractor's Personnel

The Contractor shall assign an appropriate number of qualified personnel for the performance of the Contract. The personnel assigned by the Contractor shall at all times remain under the sole direction and responsibility of the Contractor.

## 7.3 Contract Follow-Up and Progress Monitoring

The Contractor shall assign a person in charge of the technical execution of the Contract and its follow-up, as well as a person in charge of the commercial follow-up, during the whole duration of the Contract. These persons shall be able to communicate (spoken AND written) in at least one of the official languages of CERN (English and/or French).

The Contractor shall send to CERN a written progress report (as specified in § 5.2.1) every month until the end of the Contract. All communications and documents shall be in English AND/OR French.

## 7.4 Acceptance of the Supply by CERN

### *7.4.1 Acceptance of the Manufacturing file documentation*

The Contractor shall submit to CERN for acceptance the Manufacturing file documentation as specified in § 5.1.1 and according to the schedule defined in § 7.1.

CERN will verify the conformity of the Manufacturing file documentation in accordance with clause 22 of the General Conditions of CERN Contracts.

The ordering of components shall be subject to CERN's prior written acceptance of the Manufacturing file documentation.

### *7.4.2 Acceptance of the Supply*

The Contractor shall deliver to CERN for acceptance the Supply as specified in § 3.1 and according to the schedule defined in § 7.1 and with the documentation as defined in § 5.1.

CERN will verify the conformity of the Supply in accordance with clause 22 of the General Conditions of CERN Contracts.

In addition, such acceptance of the Supply will be subject to:

- The successful completion of the SAT (see § 4.2.2);
- All compliant tests results or other certificates requested by CERN;
- The delivery of all documentation (see § 5.1) requested by CERN;
- The conformity of the Supply with this Technical Specification and its Annexes.

## 8. CERN REPRESENTATIVES

All commercial and technical correspondence concerning the Price Enquiry shall be communicated to the CERN Procurement officer and in copy to the Technical officer. Any communication by or to any other person than the CERN Procurement Service shall not be valid and have no effect.

| **Procurement officer** | **Tel** | **Email** |
|---|---|---|
| Julia Bentchikou | Tel: +41 22 766 7471 | julia.ranya.bentchikou@cern.ch |
| In case of absence: | | |
| Andrea Musso | Tel: +41 22 767 0762 | andrea.musso@cern.ch |
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| Dominque Bodart | Tel: +41 22 766 9344 | dominique.bodart@cern.ch |
| In case of absence: | | |
| Daniel Schoerling | Tel: +41 22 767 9588 | daniel.schoerling@cern.ch |

## 9. ANNEXES

The following drawings are part of the present Technical Specification:

- LEIMU2HA0010: LEIR main bending upper coil;
- LEIMU2HA0011: Connector Leir bending magnet BHN;
- LEIMU2HA0012: Connector Leir bending magnet BHN;
- LEIMU2HA0013: LEIR main bending lower coil;
- LEIMU2HA0014: Connector Leir bending magnet BHN.