CERN – European Organization for Nuclear Research
European Laboratory for Particle Physics

CTF3 Note 033
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(Injector, Magnet)

Technical Specification

SOLENOID MAGNETS MS464 FOR THE CTF3 INJECTOR

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Abstract

This technical specification concerns the supply of twelve solenoid coils for the drive beam injector of CTF3. These coils consist of four layers of copper windings and have no iron return yoke. Delivery of these magnets should be completed before August 2002.

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Table of Contents

1. INTRODUCTION 3

1.1 INTRODUCTION TO CERN 3
1.2 INTRODUCTION TO THE CTF3 PROJECT 3
1.3 SUBJECT OF THE SPECIFICATION 3
1.4 SCOPE OF THE SUPPLY 3

2. GENERAL CONDITIONS FOR TENDERING AND CONTRACTING 4

2.1 TENDER PROCEDURE 4
2.1.1 Pre-tender Discussions 4
2.1.2 Alternative Solutions 4
2.1.3 Preliminary Programme 4
2.1.4 Subcontractors 4
2.1.5 Country of Origin 4
2.2 CONTRACT EXECUTION 5
2.2.1 General 5
2.2.2 Responsibility for Design, Components and Performance 5
2.2.3 Production Planning and Contract Follow-up 5
2.2.4 Deviations from the Specification 5
2.3 FACTORY ACCESS 6

3. TECHNICAL REQUIREMENTS 6

3.1 GENERAL DESCRIPTION 6
3.2 TECHNICAL SPECIFICATION FOR THE COILS 6
3.2.1 Coil Characteristics 6
3.2.2 Materials 6
3.2.3 Manufacture/Assembly 7
3.2.4 Inspection and test requirements 9
3.3 TECHNICAL SPECIFICATION FOR THE MAGNET ASSEMBLY 10
3.3.1 Assembly 10
3.3.2 Inspection and test requirements 11

4. QUALITY CONTROL 11

4.1 INSPECTIONS, TESTS AND QUALITY CONTROL RECORDS 11
4.2 TECHNICAL INFORMATION TO BE FURNISHED BY THE BIDDER 11

5. PROVISIONAL ACCEPTANCE 11

6. SCHEDULE 12

7. DRAWINGS 12

1. INTRODUCTION

1.1 Introduction to CERN

The European Laboratory for Particle Physics (CERN) is a European intergovernmental organisation 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.

1.2 Introduction to the CTF3 Project

The CLIC Test Facility 3 (CTF3) is a test accelerator to develop the technology for future high-energy electron/positron accelerators. It will be built in the period from 2001 to 2005 in the buildings of the former LEP injector linac on the CERN site in Meyrin/Switzerland.

1.3 Subject of the Specification

The subjects of this specification are the technical requirements for the construction of twelve water-cooled copper coils. These magnets will be installed in the injector of CTF3.

The Bidder is asked to submit an offer for the supply of twelve solenoid coils of type MS464. These coils are made from two double layer pancakes with double windings for improved water-cooling. The offer shall include the costs for the design and construction of all necessary tooling, the cost for the quality control measurements and checks in accordance with the present specification.

1.4 Scope of the Supply

The supply includes:

- Design and construction of all necessary tooling (they shall be kept by the Contractor and stored in perfect conditions for at least five years)
- Manufacturing of 12 coils
- Performance of all measurements and tests to ensure the coil quality
- Complete documentation about the manufacture, measurements, and tests.
- Appropriate packing and transport to CERN Site / Meyrin / Switzerland

* 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.

2. GENERAL CONDITIONS FOR TENDERING AND CONTRACTING

Please refer to the Tender Form for more complete information.

2.1 Tender Procedure

2.1.1 Pre-tender Discussions

All interested bidders are strongly encouraged to contact CERN and discuss details of the specification before making an offer. In particular, CERN wishes to ensure that no doubt exists as to the interpretation of this specification.

2.1.2 Alternative Solutions

If the bidder finds that any part of this specification is difficult, or costly to meet, he is free to propose an alternative solution, provided that the deviations from this specification, together with the reasons and advantages, are clearly indicated in the tender. Such alternative solutions shall always be made in addition to the basic offer, which must comply fully with the specification.

However, CERN reserves the right to reject the proposed alternative solutions, which might affect the correct operation and performance of the supply.

2.1.3 Preliminary Programme

The bidder shall propose a preliminary design and manufacturing schedule with the tender, based on the specified CERN delivery schedule.

2.1.4 Subcontractors

The bidder shall declare in the tender document any subcontractors whose services he intends to use in the event of a contract. Refer to the Tender Form for more details. If awarded the contract, the bidder shall restrict himself both to the subcontractors and the amount mentioned in the tender document. If, for some reason, he wants to change any subcontractor and/or the amount subcontracted, he must obtain CERN’s prior agreement in writing if the amount involved exceeds 10 % of the total contract value.

2.1.5 Country of Origin

Please refer to the Tender Form.

2.2 Contract Execution

2.2.1 General

The successful Bidder, hereinafter called “the Contractor”, shall have in current use equipment, which is necessary to cover the requirements of this specification. References concerning the available installations shall be provided with the tender.

2.2.2 Responsibility for Design, Components and Performance

The contractor shall be responsible for the correct performance 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 components choice does not release the contractor from his responsibilities in this respect.

CERN assumes responsibility for the performance parameters controlled by items and sub-systems supplied by CERN.

2.2.3 Production Planning and Contract Follow-up

2.2.3.1 Contract Engineer

The contractor shall assign an engineer to be responsible for the contract and its follow-up including all contacts with CERN throughout the duration of the contract.

2.2.3.2 Progress Report

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

2.2.3.3 Design Approval and Fabrication

The detailed design shall be submitted to CERN for approval. CERN will give its approval or refusal, in writing, within four weeks. Component ordering and equipment manufacture shall not start without CERN’s written prior agreement.

2.2.4 Deviations from the Specification

CERN reserves the right to make minor modifications to the specification before placing the contract. Parameters and/or dimensions, which may change slightly, are clearly indicated in the tables and in the attached drawings by the letters T.B.C. (**T**o **B**e **C**onfirmed) just beside their nominal value. Unless clearly stated by the bidder in the tender document together with a justification, these minor changes must not affect the contractual price that shall remain fixed.

If, after the contract is placed, the contractor discovers that he has misinterpreted the specification, this will not be accepted, as an excuse and CERN will insist that the contractor deliver equipment to the specification at no extra cost.

During execution of the contract, all proposed deviations from the specification, the tender, or any other subsequent contractual agreement, shall be submitted to CERN in writing. CERN will give its approval or refusal also in writing.

2.3 Factory Access

CERN 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 Technical Questionnaire, may only be changed after written approval by CERN.

CERN will give five working days' notice of any visit.

3. TECHNICAL REQUIREMENTS

3.1 General Description

The twelve MS464 solenoid coils will be used to focus the electron beam of the CTF3 drive beam injector. They will provide an on axis magnetic field of up to 0.2 Tesla. Each coil is made from two double layer pancakes and has four water circuits for cooling. The coils are built from oxygen-free high-conductivity copper. The following sub-chapters describe the technical requirements for the coil manufacture and assembly.

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3.2 Technical Specification for the Coils

3.2.1 Coil Characteristics

Number of turns/coil		2x(2[1]x18)
Coil inside diameter	[mm]	460
Coil outside diameter	[mm]	844
Coil length	[mm]	45
Conductor length	[m]	≈150
Conductor size	[mm × mm]	9 ×9
Cooling hole diameter	[mm]	6
Weight per coil	[kg]	≈90
Electrical resistance at 20°C	[mΩ]	45
Max. Current	[A]	700
Dissipated power per coil @700 A	[kW]	26.2
Number of cooling circuits per coil		4
Pressure drop	[bar]	6.0
Flow per cooling circuit	[l/min]	4.4
Total cooling flow	[l/min]	17.6

3.2.2 Materials

The copper conductor that is used for the coils of high field resistive accelerator magnets must have a high electrical and thermal conductivity to keep the heat load low. Inside the hollow conductor, water circulates with pressures of up to 25 bar. Hence, the copper must be suitable for leak tight brazing. Due to the field quality requirements on these magnets and the limited available space for the coils the mechanical tolerances on the conductor are tight.

The necessary quantity of copper conductor shall be purchased by the Contractor from a Copper Manufacturer approved by CERN. The Contractor has to ensure that the

[1]Double windings

properties of the copper conductor fully satisfy the requirements of this specification. CERN reserves the right to verify that the copper conductor conforms to the specification.

CERN proposes to use Outokumpu OF-OK™ conductor type 6092. The Bidder may propose an alternative material for approval by CERN. In this case the offer shall contain detailed information about the material to prove that it fulfils the requirements of this specification.

3.2.2.1 Copper quality

The copper must be free of cracks, porosity and voids. It shall not have any tendency for hydrogen embrittlement. Very good characteristics for brazing are required as well as a ductibility, which permits the winding of the conductor into magnet coils with tight bends. The copper shall be Cu-OF Oxygen Free (ISO designation). The edges of the conductor shall be rounded off and its surface free from burr.

3.2.2.2 Composition

The composition shall be at minimum 99.95 % Cu (+ Ag). The Oxygen content shall be below 10 ppm.

3.2.2.3 Electrical Resistivity

The electrical resistivity shall be at maximum $1.724 \cdot 10^{-8}\ \Omega \cdot m$ at 20 °C.

3.2.2.4 Mechanical Properties

The copper shall be annealed (dead soft fully annealed temper).

3.2.2.5 Dimensions and Tolerances

The conductor shall have a square cross section of 9.0 mm (+0.1 mm / -0 mm) × 9.0 mm (+0.1 mm / -0 mm), edge rounding radius of 1.5 mm and a circular cooling hole with a diameter of 6.0 mm (+0.1 mm/ -0 mm).

The Contractor shall obtain the copper conductor from the manufacturer in sufficient lengths so that each single layer pancake can be wound from a single length of conductor without brazed joints.

3.2.2.6 Leak Tightness

The conductor shall be leak tight for water at a pressure of 60 bar in the cooling channel.

3.2.2.7 Stainless Steel Support Structure

The support structure shall be made from non-magnetic stainless steel. The relative magnetic suscebility of the steel has to stay below 1.01.

3.2.3 Manufacture/Assembly

Temperature gradients due to water-cooling and magnetic forces subject the coils to heavy stresses. The Contractor must assume complete responsibility that the coils will satisfy all requirements for the test described hereafter and assure undisturbed, safe operation lasting for years and in the presence of ionising radiation up to integrated dose levels of 10^7 Gy.

3.2.3.1 Winding

Each coil layer shall be wound from one conductor length. No conductor joints are admitted inside the coil layer. The winding shall be done on an appropriate mandrel. During winding the conductor has to be kept under mechanical tension. The winding tool shall be designed by the Contractor.

3.2.3.2 Electrical and hydraulic connections

A connection block is used for electrical as well as hydraulic connections. The blocks are hard brazed to the copper conductor.

For brazing operations of copper to copper joints during the coil fabrication, a brazing filler material shall be used which is specially formulated to join copper to copper without flux. All brazed joints must be leak tested before coil impregnation to ensure that they are absolutely watertight. The Contractor is entirely responsible to ensure that neither obstructions nor leakage appear even after prolonged magnet operation and in the presence of ionizing radiation up to integrated dose levels of 10^7 Gy.

All hydraulic connections are made by means of stainless steel type SAGANA UCSI 221-M6 bulkhead ferrule unions (these could be delivered by CERN if required).

The Contractor shall take particular care in cleaning off after brazing residuals from scouring fluids (outside and inside).

3.2.3.3 Interface stainless steel support structure / coil

For the interface between the stainless steel support structure and the coil the contractor is asked to fix in place the position of the stainless steel plate on the insulation with two alignment pins on both sides.

If the Contractor prefers another solution for the interface between the stainless steel support structure and the coil he is free to propose it. An alternative solution should, however, provide better or equal dimensional tolerances and better or equal stability. Apart from this the conditions as specified in §2.1.2 *Alternative Solutions* apply.

3.2.3.4 Threaded Insert

The threaded insert in the resin at the top of the coil (item 19 on drawing CTFMS4640001) is supposed to be used for lifting the coil. It has to be sufficiently strong attached to the resin to support a weight of at least 120 kg.

3.2.3.5 Electrical insulation

All insulation and winding operations must take place in an environment free of dust, metallic particles or other contaminants. The coils must in all respects behave as rigid units so that relative movements between individual turns due to the action of magnetic forces and thermal stresses inside the coils are excluded. The coils must be constructed in such a way and the insulation must be sufficiently strong and elastic to withstand a large number of on-off cycles ($>10^4$) and operation over 20 years.

The inter-turn insulation of the conductor and the insulation to ground must be made of glass fiber tape specially treated to obtain good adhesion to the epoxy resin.

Empty spaces shall be completely filled with glass fiber to avoid resin rich areas (danger of brittleness and possible cracks). The use of filler materials other than glass fiber is not permitted. The tapes must be of the type specially treated in order to obtain a good adhesion to epoxy resins. For the same reason the conductor must be carefully cleaned with acetone or a similar solvent immediately before the insulating process.

The magnets will be operated in an environment with high radiation levels. The epoxy resin must withstand a total integrated dose of 10^7 Gy. CERN can give advice for the choice of the resin.

The resin shall be of type Araldite F or equivalent. The Contractor must submit detailed information about the composition, curing cycle, curing temperatures, radiation hardness and other relevant procedures of the proposed epoxy resin before manufacture for approval by CERN.

The finished coils must be free of cracks, voids or dry spots. The coil surface shall not be patched, machined or mechanically processed after molding except that careful removal of flash will be permitted.

3.2.3.6 Coil identification

An indelible series number, marked on a connecting plate must identify each coil. The results of all tests must refer to this number.

3.2.4 Inspection and test requirements

3.2.4.1 Copper quality

The Contractor shall obtain complete quality control records from the manufacturer of the copper conductor and is responsible to ensure that the copper quality meets the technical requirements defined in this specification. A copy of the quality control records shall be sent to CERN before the coil construction begins.

3.2.4.2 Epoxy quality

The Contractor shall obtain a complete product information from the manufacturer of the epoxy resin and is responsible to ensure that the resin quality meets the technical requirements defined in this specification, in particular radiation hardness. A copy of the product information shall be sent to CERN before the coil construction begins.

3.2.4.3 Leak tests of brazed joints

All brazed joints must be leak tested before the coil impregnation at 60 bar water pressure for at least 5 minutes. No evidence of leak must appear.

3.2.4.4 Visual inspection

The finished coils must be free of cracks, voids or dry spots.

3.2.4.5 Dimensional compliance with specification

The dimensions of the coil shall be measured with appropriate measuring equipment and recorded. They have to be within the specified tolerances.

3.2.4.6 Hydraulic tests

The finished coil shall be leak and flow tested. The water flow through each cooling circuit of the coil shall be measured. For a pressure drop of 6 bar the water flow of the circuit must exceed 4.2 l/min. The measured flow for all cooling circuits of all coils must be equal within 5%.

The finished coils must be leak tested at 40 bar. No evidence of leak must appear.

3.2.4.7 Electrical tests

After the hydraulics test specified above, the finished coils must be emptied of water, blown dry and prepared for the succeeding electrical tests.

The coil resistance shall be measured and corrected to 20°C, the accuracy of the method for measurement being better than 0.5 %.

For measuring the insulation resistance the coil shall be completely immersed into tap water. At the beginning and after 8 hours immersion time the insulation resistance shall be measured with a voltage of at least 2.0 kV d.c. The resistance must be stable with time and must exceed 10^8 Ω. At the end of the immersion time a voltage of 5.0 kV a.c. shall be applied for at least one minute. Afterwards the insulation resistance shall be measured as described above and satisfy the same criteria. Immediately after these tests the interturn insulation must be tested. CERN proposes to use a capacitor discharge with at least 2 kV peak. The Contractor may propose a different method for approval by CERN.

3.3 Technical Specification for the Magnet Assembly

3.3.1 Assembly

The coils shall be delivered mounted on the stainless steel supports.

The electrical connection of the coils shall be done according to the electrical schematics in the drawings.

The use of any materials containing halogens, such as PVC, is not permitted throughout the whole magnet manufacture.

Each coil shall be identified by a unique serial number and a marking plate in a suitable position. The plate must be marked with the following:

1. Serial number
2. Max. current
3. Resistance at 20°
4. Water flow (l/min), nom.
5. Pressure drop (bar), nom.
6. Coil weight

3.3.1.1 Cooling system

Stainless steel tubes connect the coils to the main water manifolds. The tubes are insulated from the manifolds by means of insulators made of vetresite.

All brazings must be carried out with great care. The Contractor is entirely responsible that neither obstructions nor leakage may occur even after prolonged magnet operation.

The maximum pressure of the cooling water will be 25 bar and the maximum outlet temperature 65°C. The cooling system must be suitable for continuous operation under these conditions.

3.3.1.2 Electrical terminals

The connections to the coils are made with insulated copper bars. To conform to our existing cables, the terminals have to be made as indicated on the drawings.

3.3.2 Inspection and test requirements

3.3.2.1 Magnet resistance

The magnet resistance shall be measured and corrected to 20 ^{o}C, the accuracy of the method for measurement being better than 0.5 %.

3.3.2.2 Insulation resistance

The insulation resistance between the coils and the yoke must be measured with a voltage of at least 2 kV d.c. The resistance must be stable with time and must exceed $10^8\ \Omega$.

3.3.2.3 Leak test of the finished magnet

The whole cooling system of the finished magnet must be pressurised with water to 40 bar during 30 minutes. It must be absolutely watertight.

4. QUALITY CONTROL

4.1 Inspections, tests and Quality Control Records

All inspections and tests of the coils and the completed assembly shall be carried out at the Contractor's premises. CERN shall be given written notice two weeks in advance of the tests. CERN reserves the right to witness any of the tests and inspections mentioned below. All tests and measurements carried out during all stages of production, from raw material procurement up to delivery, have to be thoroughly recorded and documented in a specific file, referred to as Quality Control Record. The Quality Control Records must be made available to CERN upon request at each stage of the production. Copies of all Quality Control Records must be sent to CERN before provisional acceptance and authorization for shipment can be given.

CERN reserves the right to repeat any of the tests and/or measurements after delivery to CERN.

4.2 Technical Information to be furnished by the Bidder

- Mechanical, electrical and chemical properties of the copper and insulation materials; address of the supplier(s); detailed description of the insulating and impregnation procedure.
- Name and address of any subcontractor
- Any important modification with respect to the present specification

5. PROVISIONAL ACCEPTANCE

Copies of all Quality Control Records must be sent to CERN before authorization for shipment to CERN can be given. CERN reserves the right to repeat any of the tests described above. Should these tests reveal any defects due to faulty construction, damage during transport, or failure of the magnets to meet the specified mechanical tolerances and electrical tests, CERN will be entitled to the urgent repair or replacement of the faulty part(s) by the contractor free of charge.

6. SCHEDULE

As part of the offer, the Bidder shall submit a written programme detailing the manufacturing and testing schedules, fixing the milestones described in the Technical Questionnaire.

The magnets shall be delivered according to the delivery schedule in the Tender Form.

7. DRAWINGS

The following drawings are part of the specification:
CTFMS4640001, CTFMS4640002, CTFMS4640003, CTFMS4640004, CTFMS4640005, CTFMS4640006, CTFMS4640007, CTFMS4640008

They show the dimensions and tolerances of the solenoid coils. All drawings shall be used for the purpose of tendering only and are not valid for execution. After possible minor modifications, the drawings will be validated to form part of the Contract.