ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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The Large Hadron Collider Project ***IT-3308/AB/LHC***

Invitation to Tender

Technical Specification for LHC Collimators

Abstract

This Technical Specification concerns the construction, assembly, test and supply of 40 collimators for the LHC. These collimators are used for momentum and betatron cleaning of the LHC beams and for machine protection.

The delivery of the collimators is foreseen to be completed 13 months from placement of the Contract. An option for additional collimators is included.

October 2004

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Terms and Definitions

Term	Definition
CDD	CERN Drawing Directory
EDMS	Engineering Data Management System
QAP	Quality Assurance Plan

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 Introduction to the beam cleaning and collimation system

Each of the two LHC rings will have a stored beam energy of up to 350 MJ (at 7 TeV). The high energy density and the associated high proton loss rates requires an extensive dedicated collimation system with the following functionality:

- Efficient cleaning of the beam.
- Absorption of the lost power before it impacts on the super-conducting magnets.
- Minimization the beam background in the particle physics experiments.
- Passive protection of the machine aperture against abnormal beam loss.

1.4 Subject of the Specification

The particular conditions of the LHC require collimators which act as robust, fully controllable precision devices in a highly radioactive environment.

An LHC collimator comprises:

1) A "vacuum tank". This maintains the ultra-high vacuum of the LHC machine.
2) Two parallel "jaw" assemblies inside the tank which restrict the aperture and present dedicated blocks of material (jaws) to the circulating particle beam. This material is selected to fulfil specific requirements for particle-matter interactions (scattering angles, absorption of energy). The small beam size in the LHC requires small distances between the two long jaws and imposes stringent

* 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.

requirements for "jaw flatness" along the beam direction. A clamping mechanism with springs is required for connecting advanced carbon-carbon or graphite materials to the metallic support plates.

3) Cooling pipes. These are incorporated into the jaw assembly, inside the vacuum, and pass through vacuum flanges to the outside of the vacuum tank, where they are connected to the machine cooling circuit. Temperature sensors are located inside the jaws.

4) Sliding "RF contacts" inside the vacuum tank for guiding image currents and for shielding the tank volume from electro-magnetic fields. Longitudinal RF contacts keep the jaws in electrical contact with the beam pipe in the longitudinal direction. Other RF contacts close the gaps between the collimator jaws and the walls of the vacuum tanks.

5) Four "mechanical interfaces" to make the physical link between the jaws (inside vacuum) and the precise stepping motor drivers (outside vacuum). A 1.2 m long jaw is supported at each of its ends by one of these mechanical interfaces. Each interface contains a flexible bellows, an auto-retraction spring, a mechanism against angular blockage, a precision screw and an interface to a stepping motor.

6) "Switches" that define the range of valid mechanical movements for the motor units.

7) Various "calibrated sensor supports". The support of the jaws allows the precise calibration of the inside gap versus outside reference points. Precise sensors are put at calibrated support positions, allowing a full survey of the collimation position.

2. SCOPE OF THE TENDER

2.1 Scope of the supply

This Technical Specification comprises:

- manufacturing, assembly and delivery to CERN of 40 collimators of 2 different types (families),
- production of 2 sample of jaw assemblies,
- production of one welding sample,
- full test, inspection and quality control documentation in paper and electronic formats to be agreed by CERN,
- packaging and safe delivery to CERN.
- Manufacturing of one set of tools as in drawing LHCTCS_0017, LHCTCS_0022 and LHCTCS_0115.

2.2 Items supplied by CERN

- CERN will supply a complete set of execution drawings. Any deviation from or modification to the drawings or to the process of manufacture shall be subject to written approval by CERN.
- The plug-in system and the support including electronics and motorization is not part of this Invitation to Tender. However to guarantee the required precision of

the collimator jaws two sets of calibration units with motorization will be supplied by CERN for tests.

- Blanking flanges covers to close off collimators during transport.
- Please refer to the complete list of materials and components in Annex 1 that will be supplied by CERN.

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-3308/AB/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 Preliminary programme

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

3.1.3 Subcontractors

The Bidder shall declare in his Tender any subcontractors whose services he intends to use in the event of a Contract. 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 must obtain CERN's prior agreement in writing.

3.1.4 Presentation of tender

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

3.1.5 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 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 assumes responsibility for the performance of items and sub-systems supplied by CERN.

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 2 months until completion of the Contract.

3.2.2.3 Design approval and production

The execution drawings will be delivered by CERN. If the supplier makes his own execution drawings, he shall sent them to CERN fro approval before starting production. He shall upload these drawings into CDD. CERN will give its approval or refusal, in writing, within four weeks. Manufacture shall not start without CERN's written prior agreement.

The series production shall be preceded by the production of two samples of jaw assemblies and one welding sample (see paragraph 2.1). Production of the series shall not start before CERN has given its formal approval of the samples in writing.

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 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

A collimator design consists of two movable graphite blocks (jaws) each mounted onto a water cooled support unit. These assemblies are mounted inside a stainless steel ultra high vacuum tank. The jaw support units are connected, via vacuum bellows, to movable tables actuated by high precision stepping motors. The overall length of the vacuum tank for the collimator is 1480 mm.

The manufacturing consists of the appropriate machining of the different subcomponents made out of the materials listed in Annex 1 according to CERN drawings. In the process of assembly, brazing and electron beam and TIG welding will be required.

Prior to the final assembly, all components inside the vacuum tank shall be cleaned according to paragraph 4.9.

The Contractor will then proceed to the final assembly of the collimator and welding of the top cover. The Contractor is responsible for the final performances of the assembly according to paragraph 7 and the collimator shall be considered as completed only after fulfilling the complete acceptances tests.

CERN will supply the complete sets of drawings corresponding to the components to be machined, to the sub-assemblies and to the complete assembly. Any deviation or modification of the drawings or of the process of manufacturing shall be agreed in writing by CERN.

4.2 TCS type design

The secondary collimator consists of two movable graphite-based blocks (jaws, with length of 1200 mm) each mounted onto a water cooled support unit. These assemblies are mounted inside a stainless steel ultra high vacuum tank. See Figure 1 for a schematic view of the collimator.

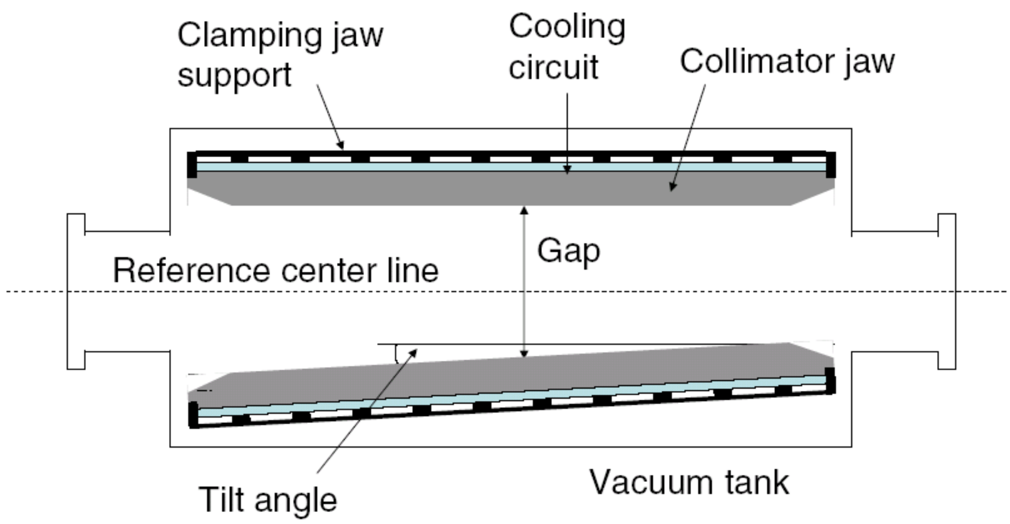

Figure 1: Sketch (top view) of the design for a secondary collimator. The jaws are supported through flexible bellows from the bottom to motors outside the vacuum (not shown).

The jaw support units are connected, via vacuum bellows, to movable tables actuated by high precision stepping motors. Motors and associated electronics are not subject of this call for tender. The overall length of the vacuum tank for the secondary collimator is 1480 mm, its width is 266 mm and its height 168 mm (see drawing LHCTCS_0001).

Table 1: Overview of design parameters and tolerances for the two collimator types

Type	TCS	TCP
Hardware		
Material for jaws	C or C-C	C or C-C
Jaw length	1.2 m	1.2 m
Flat top	1.0 m	**0.2 m**
Tapering	0.1 m at each end	0.1 m at each end
Width of jaw	80 mm	80 mm
Depth of jaw	25 mm	25 mm
RF contacts required	Yes	Yes
Cooling of jaw	Yes	Yes
Cooling of vacuum tank	Yes	Yes
Maximum pressure cooling circuit	20 bar	20 bar
Vacuum static pressure at 20°C	$<5.10^{-7}$Pa	$<5.10^{-7}$Pa
Length of vacuum tank	1480 mm	1480 mm
Mechanical movements		
Minimum gap	≤ 0.5 mm	≤ 0.5 mm
Maximum gap	≥ 60 mm	≥ 60 mm
Maximum gap center across zero	5 mm	5 mm
Maximum tilt	2.0 mrad	2.0 mrad
Maximum force for full-in position	350 N	350 N
Auto-retraction of jaws	Yes	Yes
Mechanical tolerances		
Jaw flatness after jaw assembly	40μm	40μm
Calibration inside gap – outside reference point	± 10μm	± 10μm
Accuracy sensor support points	± 5μm	± 5μm
Accuracy switches	± 50 μm	± 50 μm
Overall mechanical accuracy tank	± 0.3 mm	± 0.3 mm
Mechanical play	20 μm	20 μm

4.3 Variation 1: Primary collimators TCP

With regard to the reference design only the dimension of the active part of the jaw material changes from 1000 mm to 200 mm. A graphite-based jaw will be supplied with a flat top machined to 200 mm. **From the point of view of assembly and machining this type of collimator is identical to the TCS.**

4.4 Samples for testing

4.4.1 2 jaw assemblies

The selected bidder shall manufacture 2 jaw assemblies before starting the series production. Several tests will be performed:

- Flatness measurements on the jaw surface.
- Visual inspection of the brazing.
- Check of deformations of the pipe bends.
- Leak tightness test on the cooling circuit.
- Pressure test of the cooling circuit at 20 bar.
- Flow rate measurement.
- General assembly aspects of the clamping unit.
- Heat transfer under vacuum.

Once the tests are successfully passed, CERN will authorise the company to continue the manufacturing of the series collimators.

If the tests are unsuccessful, the jaw assemblies will be disassembled and if it is shown that the tolerances has not been respected, the manufacturer has to replace it at his own expenses.

4.4.2 Welding qualification

Before producing the collimator tanks, the manufacturer shall be required to undertake a welding qualification test of the welds and the welders. CERN will provide the stainless steel material (2 6 and 25 mm thick).

The qualification test shall be realised using the forming and welding equipment to be used in the series production of the collimator tanks.

The aim of this trial is to qualify the operating procedures for all the different welds of the collimator tank and to qualify the welders for the series production.

4.5 Materials

The main materials used for the production and assembly of the LHC collimators are listed in Annex 1.

4.5.1 Graphite

CERN shall be contacted in case of an accidental contamination of the graphite-based materials or if the packaging has been damaged during the transportation. The graphite-based is provided by CERN with the manufacturer certificates. The material will meet the flatness tolerance once clamped to a support with the required flatness. In a few cases it may be necessary to re-machine the assembly to correct for small movements.

The contractor shall measured the flatness of the assembled graphite jaw and send CERN the results. CERN will decide whether graphite machining is needed.

4.5.2 Special Treatment of Graphite-based Jaw Material

A heat treatment of 2h at 1000ºC of the carbon based jaw material shall be strictly followed. After this treatment the jaw shall be wrapped in silk paper and stored dry and clean, ideally only a short time before mounting into the cooling unit. The jaws shall be manipulated very carefully after this treatment and only with the use of gloves. This shall not prevent surface machining of the assembled carbon blocks, eventually required for achieving the target surface flatness.

4.6 Welding Technique

High quality welded joins are essential for maintaining the vacuum of the collimator. Two welding techniques shall be used for the assembly, Electron Beam Welding (EBW) for the main parts of the tank and manual TIG method for welding the other parts (e.g. Bellows).

It shall be the contractor's responsibility to qualify the welding procedures. A certified Welding Procedure Approval Record (WPAR) following ISO 15614-11 (see 5.1.2) shall be addressed to CERN together with design files (see section 3.2.2.3). Any deviation or repairs of the welding shall be agreed in writing by CERN before execution.

At any time during the manufacturing period, CERN may require, at one month notice, the welding procedure qualification tests to be repeated at no extra cost to CERN.

Before producing the collimator tank assembly, a qualification model shall be produced for approval by CERN.

4.7 Vacuum performance

All the equipment operated at room temperature in the LHC shall fulfil the Ultra High Vacuum requirements to achieve the required beam lifetime and avoid vacuum instabilities. To achieve such ultra-high vacuum, both the cleanliness of the inner surfaces at all stages of assembly work, the bakeout at 250°C during 24 hours and the use of appropriate materials are required.

In most of the locations, the maximum effective pumping speed which can be installed is limited to 20 l/s by the space available or by the conductance of the surrounding vacuum chambers. To achieve the required static pressure of 5.0×10^{-7} Pa (~5.0×10^{-9} mbar), the total outgassing flux of the collimator shall not exceed 10^{-5} Pa.l/s (~10^{-7} mbar.l/s).

4.8 Brazing

The assembly of the water-cooled support units shall be carried out by brazing in a vacuum furnace. The manufacturer can either use the CERN procedure or propose an own process, the quality of which shall be proved by adequate means, such as vacuum tests and photos of cuts (made after 3 immersions of the brazed piece into liquid nitrogen with intermediate warm-ups).

The vacuum brazing for the prototypes have been realized at CERN using an all-metal vacuum furnace. The use of high purity, low vapour pressure brazing alloys shall be required in all case. The brazing alloys tested at CERN were:

Type I: B-Ag72 Cu-780 (e.g. ISO 3677)

Type II:B-Ag68CuPd-807/810 (e.g. ISO 3677)

The machining tolerances on the drawings have been chosen for the use of these brazing materials.

The brazing steps have been:

1- Brazing of the glidcop® support, copper tubes and copper plate using type II alloy in form of foils.

2- Brazing of the ceramics isolators and the stainless steel feed through on the copper tubes using type I alloy in form of wires.

Prior brazing, the following surface treatment have been applied:

- Copper: chemical etching.

- Glidcop®: Nickel and copper plating.
- Stainless steel and ceramics feed through (external collar): Nickel plating.

The brazing process will be qualified by CERN. The manufacturer is nevertheless entirely responsible for this process.

The brazing of the feed through (Stainless steel) for the temperature sensors shall be done following the procedure tested at CERN.

Inside the vacuum tank, all the brazing shall be made under vacuum, brazing at atmospheric pressure is not allowed. Outside the vacuum tank, the use of brazing fluxes is strictly forbidden for reasons of corrosion (see Annex 2).

4.9 Degreasing and Final Cleaning for UHV Applications

4.9.1 Degreasing

Cutting fluids shall be an inert type of which do not attack the alloy surfaces. Additives containing silicone or halogens shall be excluded for machining of the components bodies. Cutting fluids have to be removed within 12 to 24 hours after machining.

4.9.2 Final cleaning for UHV applications

The subcomponents shall be cleaned prior to any assembly according to ultra-high-vacuum standards. A typical cleaning procedure is described below. The procedure used shall be transmitted to CERN for approval.

After final cleaning (transition periods), all components shall be handled, stored and transported as outlined in section 7.2. UHV good practice is mandatory, hence special care has to be taken not to contaminate the components during manufacturing, storage, transport and handling.

All surfaces of every component of the collimators shall be cleaned according to ultra high vacuum standards. After this cleaning, all surfaces eventually exposed to vacuum shall be manipulated only with clean tools or persons wearing clean plastic disposable gloves. No paper, cloth or any other material which could leave fibers on these surfaces shall be used.

The following cleaning procedure shall be used:

1. Degrease in perchloroethylene,
2. Ultrasonic cleaning in alkaline detergent (ph=9.7) at 60°C for 30 minutes. The detergent such as ALMECO 19® ref. P3-VR-580-17 is supplied by Henkel™ and made up to a concentration of 20g/l using demineralised water. If a different detergent is proposed, it shall be submitted to CERN for approval.
3. Immediate rinsing with demineralised water jet.
4. Immediate rinsing in demineralised water by immersion.
5. Drying in a hot air oven at 150°C.

The parts shall be packed immediately after cleaning and drying.

4.10 Bakeout

The design of the collimator allows a bakeout at 250°C during 24 hours of the collimator envelope with a heating and cooling rates regulated at 20°C/h.

Some accessories of the collimator body can not accept the nominal temperature of 250°C. Therefore, these components shall be protected such that during the bakeout cycles the appropriate temperatures as listed below are respected:

Motors: 60°

Switches: 60°

The supply of the bakeout equipment for the reception tests at the supplier premises is the responsibility of the supplier.

4.11 Helium leak testing

Each assembly shall be leak tight by UHV standards when tested with a global overpressure of 1 bar gaseous helium. Leak tightness of the assembly shall be defined, after applying the foregoing conditions for 10 min, as a total leak rate measured on a calibrated He leak detector not exceeding 1×10^{-11} Pa m^3s^{-1}.

A helium leak detector with a detection limit of a least 1×10^{-11}Pa m^3s^{-1} shall be used for this purpose. Use of vacuum grease is forbidden.

The test protocol that the Contractor intends to follow shall be submitted to CERN for approval before the tests are carried out, according to the following standards:

- ISO/AWI 12724 Testing for leaks using a mass spectrometer leak detector or residual gas analyser.
- ISO 3530 Mass spectrometer type leak detector calibration.
- NFA 09-490 Non destructive testing – Testing for leak tightness – Recommended practices for the specification and testing of gas-tightness.
- NFA 09-492 Non destructive testing – tightness testing – Method under vacuum with tracer gas.

The leak tightness of the cooling circuit after the brazing shall be established prior to any water test. In case any fluid has been injected in the cooling circuit prior to the leak detection, the cooling circuit shall be entirely dried, for example by hot air circulation.

4.12 Manufacturing and measurement

4.12.1 Procedure for production, testing and measurement based on prototype production at CERN

The main production steps are summarized in order to provide the contractor with a better understanding of the procedure followed during prototype production at CERN. This list should neither be considered as complete nor final. The manufacturer is responsible for developing a detailed and complete procedure for its own production line. Required mandatory tests are mentioned in italic style.

1. Jaws
   a. Inspection of ready machined jaws. Heat treatment of graphite jaws.
   b. Machining and forming of cooling pipes.
   c. Test of the cooling circuit with Helium overpressure.
   d. Machining of jaw support plates and clamping mechanism.
   e. Brazing of vacuum feed-through for cables to temperature sensors and vacuum end covers together with the cooling support.

f. Preparation of ceramic insulation for cables to temperature sensors.
g. Assembly of jaw, including installation of temperature sensors.
h. Measurement of surface flatness of the assembled jaw before and after a bake-out cycle. The measurement shall cover a matrix of 5 times 3 points over the jaw surface, equally spaced. The jaw shall be supported horizontally at its two support points.
i. Mounting of RF fingers at top and bottom of the jaw.
j. Mounting on vertical support tubes and brazing to vacuum end covers.
k. Brazing of vacuum feed-through for cables to temperature sensors.
l. Guiding of cables through the vertical support and the vacuum feed-through.
m. Pressure test of the cooling circuit at 20 bars.
n. Test for proper functioning of temperature sensors in the jaw.

2. Vacuum tank
   a. Machining of plates for vacuum tank.
   b. Machining of cooling circuit for the tank.
   c. Welding of flanges onto beam pipes.
   d. Welding of beam pipe onto tank front plate.
   e. Test for leak tightness of flanges.
   f. Welding of support feet to the bottom plate of the tank.
   g. TIG welding of connection pipes to the water circuit cooling plates.
   h. Close the cooling circuits on the front, bottom and top plate by EB welding
   i. Pressure test of the cooling circuit at 20 bars.
   j. Welding of empty tank.
   k. Welding of flexible bellows assembly to the vertical supports (shafts). The bellows assembly will be delivered by CERN as on drawing LHCTCS_0018.
   l. Welding of the bellows to the tank.
3. Mechanical table.
   a. Machining of plates and parts.
   b. Assembly and adjustment of sliding mechanism.
   c. Supports for cooling pipes, stepping motor, sensors and auto-retraction spring.
   d. Installation of switches, including the cabling to the connector.
   e. Partial installation of rack and pinion mechanism for control of maximum tilt angle.
4. Collimator assembly
   a. Placement of RF contact plates at bottom and top plate of tank.
   b. Placement of mechanical tables onto vacuum tank.
   c. Installation of transverse RF fingers at the end of the jaws.
   d. Placement of jaws into vacuum tank.
   e. Welding of the bellows shaft to the tightness cap of the cooling circuit of the jaw assembly.
   f. Fixation of flexible bellow to the sliding part of the mechanical table.

g. Brazing of connectors to jaw cooling line.
h. Installation of RF contact fingers to the flanges.
i. Definition of reference zero line. Adjust and tighten the mechanical stops (the 0 reference points and the maximum reference points).
j. Measurements of mechanical range in movements (maximum gap, minimum gap, range across zero, maximum tilt angle). Measurement of parallelism of jaws.
k. Verification that the RF contacts stay in contact over the full range of movements.
l. Adjustment of switches.
m. Installation of test control set-up.
n. Calibration of inside jaw positions with respect to 4 outside reference points and sensor mounting positions.
o. Welding of top plate onto the vacuum tank.
p. Pump down to UHV.
q. Full bake-out cycle at 250 °C.
r. Measurement of the reached vacuum pressure.
s. Pressure test of the cooling circuits at 20 bar with all connectors. Verify nominal flow rate and measure pressure drop.
t. Verification that switch positions are still reached under vacuum. A total of 100 cycles shall be performed for each collimator jaw.
u. Test that the mechanism for automatic retraction works under vacuum.
v. Dismounting of test control set-up.
w. Measurement of force required under vacuum to reach the full-in position of a given jaw.

4.12.2 Vacuum leak tightness:

Leak tightness shall be assured:

- On all sub-assemblies at room temperature before they are welded or brazed together:
- On the finished collimator at room temperature immediately after the final assembly
- On the final collimator at room temperature after having been baked under vacuum

UHV tests:

- Vacuum pumping prior to baking
- Vacuum pumping during bakeout to determine the pressure after 24 hours. The final pressure after baking (back at room temperature) should be lower than 5.10^{-7}Pa (~5.10^{-9} mbar).

4.12.3 Cooling water circuit testing

The cooling water circuit shall be tested as follows at room temperature:

- Leak tightness test with He overpressure after brazing of the cooling pipes to the support.

- Pressurize the system prior to vacuum feed through brazing with water to 20 bar.
- Isolate the pressure supply with a suitable valve.
- Check that the pressure remains constant over a period of 20 min.
- After the feed through brazing a simple test on the brazing shall be done with He overpressure.

After the integration into the vacuum tank the cooling circuit shall be tested once again. The above mentioned water pressure shall be maintained during the vacuum test.

A test with different flow rates to observe the pressure drop shall be done at the end of the water test. Demineralised water shall be used to clean the circuit. After this rinsing the bakeout of the collimator might follow.

4.12.4 Engineering drawings

All engineering drawings if prepared by the Contractor and Suppliers for the execution of the Contract shall comply with the procedure defined in chapter 8 of the LHC QAP document No LHC-PM-QA-306.00, "Drawing Process-External Drawings" and shall be uploaded into CDD.

4.12.5 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".

4.12.6 Quality control records

All specified tests and measurements carried out during all stages of production, from receipt of raw material up to delivery of the completed collimator, shall be recorded in specific files, collected in the 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".

5. APPLICABLE DOCUMENTS

Please refer to the cover letter or Instructions to Bidders for the complete list of enclosed documents which 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 additional standards are applicable for the execution of the Contract.

5.1.1 CERN standards

The CERN's specification No 1004 Ed. 3 for stainless steel (AISI 304 L) and CERN's specification No 2000 for OFE copper are used to provision the materials for tank and cooling units.

5.1.2 International standards

- EJMA — Standards of the Expansion Joint Manufacturers Association, Eighth Edition (2003).
- EN 288-3 (1992) — Specification and Approval of Welding Procedures for Metallic Materials – Part 3: Welding procedure tests for the arc welding of steels.
- ISO 15614-11 — Specification and Approval of Welding Procedures for Metallic Materials – Welding Procedure Test (1998).
- ISO 5817 (1992) — Arc-welded joints in steel – Guidance on quality level for imperfections.
- ISO/AWI 12724 — Testing for leaks using the mass spectrometer leak detector or residual gas analyser.
- ISO 3530 — Mass spectrometer type leak detector calibration.
- NFA 09-490 — Non destructive testing – Testing for leak tightness – Recommended practices for the specification and testing of gas-tightness.
- NFA 09-492 — Non destructive testing – Tightness testing – Method under vacuum with tracer gas.
- ASTM E45-97e1 — General technical requirements for steel and steel products.

6. QUALITY ASSURANCE PROVISIONS

The Contractor shall plan, establish, implement and adhere to a documented quality assurance program 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 are 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 2.

Table 2 - LHC QAP topics and documents

Topic	Document Title	Doc. Number
Policy and Organisation	Quality Assurance Policy and Organisation	LHC-PM-QA-100.00
	Glossary, Acronyms, Abbreviations	LHC-PM-QA-203.00
Planning	Planning and Scheduling Requirements for Institutes, Contractors and Suppliers	LHC-PM-QA-301.01
Design	Quality Assurance Categories	LHC-PM-QA-201.00
	Design Process and Control	LHC-PM-QA-307.00
	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

7. TESTS

The LHC collimators will be used as high precision devices. The demanding tolerances have been summarized in Table 1. Tests and measurements are essential for achieving the tolerances required for the LHC.

If a collimator is found to be defective during the acceptance tests, it will be disassembled and carefully checked. If it is demonstrated that tolerances and/or specifications have not been respected during manufacture or the unit has been damaged during transport, then the Contractor shall replace or repair the collimator concerned after consultation with CERN.

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

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 following tests and measurements shall be performed for every collimator by the contractor:

1. Jaw assembled but not mounted into vacuum tank
    a. Test of the cooling circuit with Helium overpressure.
    b. Measurement of surface flatness of the assembled jaw before and after a bake-out cycle. The measurement shall cover a matrix of 5 times 3 points over the jaw surface, equally spaced. Intermediate control of the planarity of jaw components during production is advised in order to achieve the specified tolerances in the assembled jaw. The jaw shall be supported horizontally at its two support points.

   c. Pressure test of the cooling circuit at 20 bars.
   d. Test for proper functioning of temperature sensors in the jaw.

2. Vacuum tank
   e. Test for leak tightness of flanges.
   f. Pressure test of the cooling circuit at 20 bars.
3. Collimator assembly
   g. Definition of reference zero line. Adjust and tighten the mechanical stops (the 0 reference points and the maximum reference points). Calibration of inside jaw positions with respect to this outside reference points.
   h. Measurements of mechanical range in movements (maximum gap, minimum gap, range across zero, maximum tilt angle). Measurement of parallelism of jaws.
   i. Measure the force to be ≤600N for full in position of each jaw.
   j. Verification that the RF contacts stay in contact over the full range of movements.
   k. Adjustment of switches (in, out, anti-collision at each end of jaw) for definition of allowed range of mechanical movement.
   l. Full bake-out cycle at 250 °C.
   m. Test for vacuum tightness and outgassing rate. Measurement of the final vacuum pressure. All leak testing shall be done using a helium mass spectrometer-type detector. The detection limit of the leak detector shall be lower than 10^{-11} Pa m^3s^{-1} (10^{-10} mbar l s^{-1}). No leak shall be detectable according to the procedure detailed in paragraph 4.10. In no case shall a leak be repaired without prior consultation and agreement from CERN
   n. Pressure test of the cooling circuits at 20 bar with all connectors. Verify nominal flow rate and measure pressure drop.
   o. Verification that switch positions are still reached under vacuum. A total of 100 cycles shall be performed for each collimator jaw.
   p. Test that the mechanism for automatic retraction works under vacuum.
   q. Measurement of force required under vacuum to reach the full-in position of a given jaw.

Every measurement and test must be summarized in written form in a production logbook that accompanies each collimator during all stages of its production. CERN provides two sets of motors and electronic equipment that are required for efficient movement of the collimator jaws during the tests. CERN will closely follow the test and measurement program.

7.2 Tests to be carried out at CERN for provisional acceptance

The welding samples will be tested for conformity in line with standard EN-288-3. The jaw assemblies will be tested as described in section 4.4.1.

CERN will perform complete sets of measurements for a limited number of components to verify the performance after transport to CERN. In addition CERN foresee the following routine checks for all collimators delivered at CERN:

- Collimator flanges open:
   a. Visual inspection of free beam path for full open and full closed position. Measurement of maximum and minimum gap.
   b. Visual inspection of the jaw surface.

c. Visual inspection of the RF fingers.
d. Verification of switch positions and signals.
e. Test for maximum jaw tilt.

- Collimator under vacuum:
  a. Measurement of vacuum pressure.
  b. Check for mechanical range of movements.
  c. Check of temperature sensors.
  d. Test for automatic retraction.

For the provisional acceptance of a collimator all these tests shall be passed, including a lifetime test under vacuum over 100 cycles. Depending on the experience with the first delivered batch of collimators, CERN reserves the right to add additional acceptance tests.

If the test is unsuccessful, the collimator has to be disassembled and if CERN inspection and analysis show that the required tolerances have not been respected, the manufacturer has to replace on his own costs.

All collimators shall be equipped at CERN with the final position and gap sensors. The sensors will be calibrated using the calibration curves for external reference points, as provided by the contractor.

8. DELIVERY

8.1 Provisional delivery schedule

The collimators shall be delivered in the period from June 2005 to April 2006 in accordance to provisional delivery schedule below, assuming notification of the contract in January 2005. The first batch of collimators shall be delivered at the latest eight months after notification of the contract.

- Assembled Jaws by June 2005
- First five collimators by September 2005
- Rate 5 per months until April 2006

CERN reserves the right to split the order between two companies, either by number of components or by type.

8.2 Packing and transport to CERN

The Contractor is responsible for the packing and the transport to CERN. He shall ensure that the equipment is delivered to CERN without damage and any possible deterioration in performance due to transport conditions.

The collimators shall be blocked in open position for the transport to CERN. The collimators shall be supported individually. CERN experience shows that acceleration above 1g during transport cause damage. If any damage is found, the manufacturer will have to repair on his own costs. The collimator shall be sealed with dry nitrogen with an over pressure.

8.3 Acceptance and guarantee

Provisional acceptance 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 guarantee period is defined in the commercial documents.

9. CERN CONTACT PERSONS

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Annex 1: List of Drawings

Number CDD	Title	Material	Dimensions	Qte.
LHCTCS__0001	Ensemble Assembly			
LHCTCS__0002	Tank sans dessus Tank with out top			
LHCTCS__0003	Ensemble fond Bottom assembly			1
LHCTCS__0004	Plaque inferieure Lower plate	AISI 316LN or 304L	Tole / Sheet 25 (1212 x 262)	1
LHCTCS__0005	Plaque fermeture circuit eau Water circuit closing plate	AISI 316LN or 304L	Tole / Sheet 6 (744 x 124)	2
LHCTCS__0006	Bloc fixation rail Rail fixing block	AISI 304L	Méplat / Bar 30 x 10 (69)	6
LHCTCS__0007	Plot Plug	AISI 304L	Rond / Round Ø 40 (42)	12
LHCTCS__0008	Ensemble extremite End assembly			2
LHCTCS__0009	Tole extremite End sheet	AISI 316LN or 304L	Tole / Sheet 25 (262 x 134)	2
LHCTCS__0010	Plaque fermeture circuit eau Water closing circuit plate	AISI 316LN or 304L	Tole / Sheet 6 (80 x 55)	4
LHCTCS__0011	Transition Transition	AISI 316LN or 304L	Tole / Sheet 2 (130 x 117)	2
LHCTCS__0012	Bride DN 100 a collier DN 100 flange with collar	AISI 316LN	Ebauche bride / Blank flange	2
LHCTCS__0013	Tole laterale Side sheet	AISI 316LN or 304L	Tole / Sheet 6 (1208 x 124)	2
LHCTCS__0014	Ensemble couvercle tank Tank cover assembly			1
LHCTCS__0015	Couvercle tank Tank cover	AISI 316LN or 304L	Tole / Sheet 25 (1212 x 262)	1

LHCTCS__0016	Ensemble contact RF RF contact assembly			
LHCTCS__0017	Ensemble tank-soufflet Tank-bellow assembly			
LHCTCS__0018	Assemblage soufflet Bellow assembly			4
LHCTCS__0019	Collerette de base soufflet Bellow base cuff	AISI 316L	Rond / Round Ø 110 (20)	4
LHCTCS__0020	Collerette soufflet bellow cuff	AISI 316L	Rond / Round Ø 110 (11)	4
LHCTCS__0021	Arbre Shaft	AISI 304L	Rond / Round Ø 60 (256)	4
LHCTCS__0022	Outillage soudure soufflet-arbre Bellow-shaft welding equipment			
LHCTCS__0023	Support (outillage) Support	Al 6082	Rond / Round Ø 140 (117)	1
LHCTCS__0024	Arbre (outillage) Shaft	Al 6082	Rond / Round Ø 35 (289)	1
LHCTCS__0025	Bague serrage arbre (outillage) Shaft tightening bushing	Al 6082	Rond / Round Ø 60 (10)	1
LHCTCS__0026	Protection soufflet (outillage) Bellow protection	Al 6082	Tube / Pipe Ø 150-60 (57)	1
LHCTCS__0027	Goupille Centreuse (outillage) Centering pin	Al 6082	Rond / Round Ø 15 (15)	1
LHCTCS__0028	Gabarit (outillage) Model	Al 6082	Tole / Sheet 15 (280 x 200)	2
LHCTCS__0029	Protection soufflet (outillage) Protection bellow	Al 6082	Tube / Pipe Ø 80-60 (80)	4
LHCTCS__0030	Entretoise (outillage) Spacer	Al 6082	Rond / Round Ø 30 (50)	8
LHCTCS__0031	Ensemble bloc Block assembly			2

LHCTCS__0032	Assemblage plaque extrémité Plate end assembly			2
LHCTCS__0033	Circuit refroidissement Cooling circuit			2
LHCTCS__0034	Circuit supérieure refroidissement Upper cooling circuit	Cu OFE	Carré 9,trou 6 (4210)	2
LHCTCS__0035	Circuit inférieure refroidissement Lower cooling circuit	Cu OFE	Carré 9,trou 6 (4165)	2
LHCTCS__0036	Poutre Beam	GLIDCOP	Tole / Sheet 40 (1060 x 40)	2
LHCTCS__0037	Plaque d'appui (Cuivre) Support plate	Cu OFE	Tole / Sheet 5 (1060 x 5)	2
LHCTCS__0038	Bague etancheite Tightness cap	AISI 304 LN	Rond / Round Ø 30 (15)	4
LHCTCS__0039	Douille raccord Connection socket	AISI 304L	Rond / Round Ø 12 (20)	8
LHCTCS__0040	Plaque guidage supérieure Upper guiding plate	AISI 304L	Tole / Sheet 20 (130 x 65)	4
LHCTCS__0041	Plaque guidage inférieure Lower guiding plate	AISI 304L	Tole / Sheet 20 (130 x 65)	4
LHCTCS__0042	Plaque positionnement supérieure Upper positioning plate	AISI 304L	Tole / Sheet 20 (130 x 65)	4
LHCTCS__0043	Plaque positionnement inférieure Lower positioning plate	AISI 304L	Tole / Sheet 20 (130 x 65)	4
LHCTCS__0044	Plaque support ressort Spring supporting plate	AISI 304L	Tole / Sheet 10 (150 x 80)	12
LHCTCS__0045	Assemblage contact RF sur clamp RF contact assembly on block			8
LHCTCS__0046	Clamp serrage Tightening clamp	GLIDCOP	Tole / Sheet 15 (319 x 78)	8
LHCTCS__0047	Clamp extrémité droite	GLIDCOP	Tole / Sheet 15 (279.5 x	4

	Right end clamp		78)	
LHCTCS__0048	Clamp extrémité gauche Left end clamp	GLIDCOP	Tole / Sheet 15 (279.5 x 78)	4
LHCTCS__0049	Contact RF RF contact	Cu Be 2	L=316 mm et 276 mm	8
LHCTCS__0050	Barrette serrage contact RF RF contact tightening bar	AISI 304L	Tole / Sheet 1 (276 et 316 x 7)	8
LHCTCS__0051	Liaison clamp Connection clamp	Cuivre beryllium	Bande / Stripe 0.1 (30 X 10)	12
LHCTCS__0052	Bloc graphite TCS Graphite block TCS	Graphite		2
LHCTCS__0053	Bloc graphite 200mm utile TCP 200mm graphite block TCP	Graphite		2
LHCTCS__0054	Taquet maintient Holding clip	AISI 304L	Méplat / Bar 20 x 8 (32)	28
LHCTCS__0055	Plaque de tension pivot Pivot tensioning plate	AISI 316L	Tole / Sheet 2 (110 x 78)	4
LHCTCS__0056	Guide contact sur bloc Contact guide on block	AISI 304L	Tole / Sheet 2 (67.5 x 110)	4
LHCTCS__0057	Rondelle axe Axle washer	AISI 304L	Rond / Round Ø 60 (2)	8
LHCTCS__0058	Ecrou axe Axle nut	AISI 304L	Rond / Round Ø 60 (9)	4
LHCTCS__0059	Assemblage collerette support Cuff support assembly			2
LHCTCS__0060	Bague exterieure collerette External cuff cap	AISI 304L	Rond / Round Ø 100 (4)	2
LHCTCS__0061	Anneau de centrage Centering ring	AISI 304L	Tube / Pipe Ø 80-84 (16)	2
LHCTCS__0062	Contact RF bride-transition Flange-transition RF contact	Cuivre beryllium	Bande / Stripe 0.5 (115 X 3)	40
LHCTCS__0063	Contact RF bride-Bloc Flange-block RF contact	Cuivre beryllium	Bande / Stripe 0.5 (165 x 3)	60

LHCTCS__0064	Anneau de serrage contact Climping ring contact	AISI 304L	Rond / Round Ø 100 (2.5)	2
LHCTCS__0065	Assemblage rail longitudinal Longitudinal rail assembly			2
LHCTCS__0066	Rail contact longitudinal Longitudinal contact rail	AISI 304L	Tole / Sheet 1.5 (1200 x 90)	2
LHCTCS__0067	Contact extremite rail Rail extremity rail	Cuivre beryllium	Bande / Stripe 0.2 (60 x ±40)	4
LHCTCS__0068	Axe contact Contact axle	AISI 304L	Rond / Round Ø 3 (80)	8
LHCTCS__0069	Barre d'appui sur platine Support bar on plate	Al 6082	Méplat / Bar 30 x 40 (380)	4
LHCTCS__0070	Douille de centrage platine Table centring socket	Ac. Inox.	Tube / Pipe Ø 10-14 (10)	16
LHCTCS__0071	Ensemble platine Table assembly			2
LHCTCS__0072	Ensemble goupillage platine Table pin assembly			2
LHCTCS__0073	Base platine Table base	Al 6082	Tole / Sheet 40 (400 x 190)	2
LHCTCS__0074	Platine mobile Mobile table	Al 6082	Tole / Sheet 25 (186 x 150)	4
LHCTCS__0075	Support moteur Motor support	Al 6082	Tole / Sheet 100 (150 x 149)	4
LHCTCS__0076	Support ecrou vis translation Translation screw nut support	Al 6082	Tole / Sheet 50 (93 x 66)	4
LHCTCS__0077	Piece liaison support moteur Motor support connection	Al 6082	Méplat / Bar 60 x 30 (90)	2
LHCTCS__0078	Support butee Stop support	Al 6082	Meplat 80 x 15 (55)	4
LHCTCS__0079	Tampon fin de course Stop buffer	Ac. Inox.	Vis / Screw hexagonale M6 x 10	4

LHCTCS__0080	Axe outillage alignement moteur Motor alignement axle (equipment)	Al 6082	Rond / Round Ø 60 (175)	2
LHCTCS__0081	Douille outillage alignement moteur Motor alignement socket (equipment)	Al 6082	Rond / Round Ø 80 (100)	2
LHCTCS__0082	Assemblage vis a rouleau Screw roller assembly			4
LHCTCS__0083	Support vis translation Translation screw support	AISI 304L	Rond / Round Ø 25 (50)	4
LHCTCS__0084	Centreur ressort de compensation Compensating spring tool	Al 6082	Rond / Round Ø 60 (61)	4
LHCTCS__0085	Support ressort vis Spring screw support	Al 6082	Rond / Round Ø 80 (85)	4
LHCTCS__0086	Rondelle serrage roulement Bearing tightening washer	Al 6082	Rond / Round Ø 60 (5)	4
LHCTCS__0087	Entretoise cremaillere Rack spacer	Al 6082	Méplat / Bar 30 x 15 (56)	4
LHCTCS__0088	Cremaillere Rack	Ac. Inox.		4
LHCTCS__0089	Ensemble pignon Pinion assembly			2
LHCTCS__0090	Etrier support pignon Pinion support stirrup	Al 6082	Méplat / Bar 80 x 40 (236)	2
LHCTCS__0091	Axe pignon Pinion axle	AISI 304L	Rond / Round Ø 50 (72.2)	4
LHCTCS__0092	Pignon Pinion	Laiton		4
LHCTCS__0093	Rondelle butee pignon Pinion stop washer	AISI 304L	Rond / Round Ø 30 (5)	4
LHCTCS__0094	Support bride et butee Flange and stop support	Al 6082	Carré 50 (80)	4
LHCTCS__0095	Support tube Tube support	Al 6082	Méplat / Bar 50 x 12 (52)	4

LHCTCS__0096	Collier serrage tube Tightening collar	Al 6082	Méplat / Bar 50 x 12 (11)	4
LHCTCS__0097	Tuyau entrée collimateur Water inlet pipe	AISI 316L	Tube / Pipe Ø 8-10 (163)	4
LHCTCS__0098	Tuyau sortie collimateur Water outlet pipe	AISI 316L	Tube / Pipe Ø 8-10 (163)	4
LHCTCS__0099	Support switch Switch support	Al 6082	Tole / Sheet 5 (91 x 50)	4
LHCTCS__0100	Support switch anti collision Anti collision switch support	Al 6082	Méplat / Bar 50 x 30 (70)	2
LHCTCS__0101	Support came pour switch Switch cam support	Al 6082	Méplat / Bar 20 x 15 (54)	2
LHCTCS__0102	Came simple Single cam	Al 6082	Méplat / Bar 20 x 20 (22)	4
LHCTCS__0103	Came double Dual cam	Al 6082	Méplat / Bar 30 x 20 (22)	4
LHCTCS__0104	Bride serrage potentiometre Potentiometer tightening flange	Al 6082	Méplat / Bar 30 x 10 (29)	6
LHCTCS__0105	Support potentiometre Potentiometer support	Al 6082	Méplat / Bar 30 x 12 (54)	4
LHCTCS__0106	Support potentiometre et came potentiometer and cam support	Al 6082	Tole / Sheet 40 (54 x 50)	2
LHCTCS__0107	Support tige et potentiometre lineaire Potentiometer stem support	Al 6082	Méplat / Bar 40 x 20 (45)	2
LHCTCS__0108	Attache potentiometre deplacement Displacement potentiometer attach	Al 6082	Carré 40 (40)	2
LHCTCS__0109	Support connecteur 8 pins 8 pin connector support	Al 6082	Equerre 30x30x4 (40)	4
LHCTCS__0110	Support connecteur 4 pins 4 pin connector support	Al 6082	Equerre 30x30x4 (40)	2
LHCTCS__0111	Tige anti collision	Ac. Inox.	Barre hex. 10 (100)	2

	Anti collision stem			
LHCTCS__0112	Capot protection vis translation Screw protection cap	Al 6082	Rond / Round Ø 80 (50)	4
LHCTCS__0113	Plaque protection Protection plate	Al 6082	Tole / Sheet 3 (400 x 150)	2
LHCTCS__0114	Tole protection cremaillere Rack protection sheet	Ac. Inox.	Tole / Sheet 2 (260 x 90)	2
LHCTCS__0115	Ensemble compression ressort Compression spring assembly			1
LHCTCS__0116	Tige Stem	Al 6082	Rond / Round Ø 30 (400)	1
LHCTCS__0117	Rondelle Washer	Laiton	Rond / Round Ø 60 (15)	1
LHCTCS__0118	Ecrou M24 Nut M24	Ac. Inox.	Rond / Round Ø 60 (20)	1
LHCTCS__0119	Axe limitation angulaire platine Table angular limitation axle	Al 6082	Rond / Round Ø 20 (636)	2
LHCTCS__0120	Douille d'extremite axe de liaison Plate socket axle	Al 6082	Tube / Pipe Ø 25-20 (35)	4
LHCTCS__0121	Support transport Transport support	Acier	HE A 260 (560)	1

Annex 2: Memo on Soldering flux for main bus bars

LHC-CRI-I2/MH 05/07/01
EDMS No. 318079

memo

From: Soldering-Flux Working Group

To: J.P. Bacher, A. Ballarino, K. Barth, C. Benvenuti, A. Bézaguet, J. Billan, L. Bottura, J. Brahy, R. Brun, L. Bruno, J. Casas-Cubillos, I. Collins, P. Cruikshank, D. Delikaris, W. Erdt, L. Evans P. Faugeras, G. Favre, R. Folch, Ph. Gayet, B. Goddard, D. Güsewell, F. Haug, C. Hauviller, N. Hilleret, A. Ijspeert, E. Jensen, J.M. Jimenez, H.P. Kindermann, A. Lasserre, I. Laugier, P. Lebrun, D. Leroy, E. Mahner, L. Marques Antunes Ferreira, M. Modena, L.R. Oberli, J.P. Orlic, A. Park, G. Passardi, O. Pirotte, A. Poncet, K. Potter, P. Proudlock, M. Rabany, J.M. Rieubland, A. Rijllart, F. Rodriguez-Matheos, P. Rohmig, L. Rossi, R. Saban, P. Sacré, F. Savary, W. Scandale, R. Schmidt, L. Serio, C.H. Sicard, N. Siegel, A. Siemko, P. Sievers, G. Spigo, P. Strubin, L. Tavian, T. Taylor, L. Thorndahl, D. Tommasini, T. Tortschanoff, R. Trant, R. Veness, J. Vlogaert, B. Vullierme, L. Walckiers, L.R. Williams, C. Wyss, R. van Weelderen.

Subject: Soldering flux for main bus bars

1. INTRODUCTION

Corrosive residues of soldering fluxes have been recognised as one of the main causes of leaks in vacuum and cryogenic environment of previous CERN and non-CERN machines.

At the Design Review of the LHC Arc Interconnections in April 2000, the use of soldering flux was addressed. Shortly after a ruling was made that no halogen additives in soldering flux are to be allowed. [See MARIC meeting held on 19 April 2000]. The problem of corrosive flux with stainless steel was also revisited in the Memorandum "Chlorine containing Brazing Fluxes" [1].

As a consequence, an informal working group was created to find the best adapted flux for soldering in the cryogenic and vacuum environments of the LHC, focussing on the interconnects of the main bus bars. Representatives from various groups were involved. [EST-SM / LHC-CRI, ECR, MMS, VAC]

2. REQUIREMENTS

The following requirements and constraints were identified:

- The residues of the flux must be non-corrosive with copper, as well as austenitic stainless steels and their welds. No visible traces of corrosion should appear after accelerated corrosion testing according to norm ISO 9455-12, adapted to stainless steel.
- The electrical resistance of the soldered junction of the main bus bars must be lower than 0.6 nΩ, in order to respect the thermodynamic budget of the LHC.
- The mechanical resistance of the LHC interconnections splices must be greater than 750 N, in order to withstand forces developed in the interconnections.

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3. CLASSIFICATION OF FLUXES

The following table lists possible fluxes for the soldering of the main bus bars according to the standard EN29454-1.

Class	Flux type	Flux basis	Flux activation	Tested example	Tests (§ 4)		
					a	b	c
1.1.1.	Resin	Colophony	No activator	Kester 135	X	X	X
1.1.2.	Resin	Colophony	Halide activated	QF 380	X	X	
				Fontargen 600	X	X	X
				Castolin 197C	X	X	
				PF600	X	X	
1.1.3.	Resin	Colophony	Non-halide activated	ESF33	X	X	X
2.2.3.	Organic	Non-water soluble	Non-halide activated	Warton 380	X	X	X
3.1.2.	Inorganic	Salts	Without ammonium chloride	Castotin 157	X		

4. TESTING

The tests applied to the fluxes (see table) are detailed below.

a) Corrosion tests:
The corrosion of thin austenitic stainless steel sheets was especially addressed.
Comparative corrosion tests were performed according to ISO9455-12, by the CETIM-CERMAT / F. These tests have shown that 1.1.2 and 3.1.2 type fluxes are potentially corrosive towards austenitic stainless steel. Only fluxes belonging to class 1.1.1, 1.1.3 and 2.2.3 class did not show corrosion following the cited accelerated test.

b) Mechanical tests:
Shearing tests on soldered bus-bar samples at room temperature have shown that all fluxes meet the requirements, provided that the copper supports are cleaned following a dedicated and reproducible procedure [4]. Additional tests at room temperature after thermal cycling between room temperature and 4.2 K have confirmed these results for the non-corrosive fluxes of classes 1.1.1, 1.1.3 and 2.2.3. Shearing tests are currently being performed at 4.2 K to be representative of the joint working conditions.

c) Electrical resistance tests:
The three non-corrosive fluxes (see § 4.a), and one corrosive flux for comparison, were tested.
Tested samples have been manufactured and prepared following a detailed procedure [2], including the cleaning of the copper supports [4].
The electrical resistance of the splice was measured at 4.2 K and all the fluxes were found to fulfill the requirements.
The selected flux will be extensively tested for confirmation.

5. CONCLUSIONS

Based on the successful mechanical and electrical tests for the least corrosive flux according to its standard classification and the results of the standardised corrosion tests, fluxes belonging to class 1.1.1 or recognised as equivalent[1] in terms of type, basis, activation, safety against corrosion and performances, are recommended as the safest choice for the soldering of the main bus bars in the LHC interconnections. However, their use must be associated with a stringent cleaning procedure [4]. To be qualified, any other flux of the same class shall be submitted at least to the series of tests detailed in the present report.

After reaching the above conclusion for the main bus bars, this choice has been extended to the flux used for the soldering metal filler of the bus bars.

The Working Group suggests that all the locations, inside the cold mass or in the cryostat where soldering or soldering fluxes are used, are carefully identified and considered in a similar way. If any risk of corrosion exists, a similar series of tests should be carried out in order to identify the appropriate flux. For less severe applications in terms of environment and cleaning possibilities, the use of an activated flux possibly containing halides might be appropriate.

REFERENCES:

[1]: Memorandum LHC-VAC/GS (00-22), G. Schneider, 15 May 2000, "Chlorine Containing Brazing Fluxes"
[2]: "Manufacturing of the main superconducting cable loops for low temperature electrical testing" (In progress).
[3]: Standards: EN29454-1 and ISO9455-12
[4]: "Main superconducting Bus bars inductive soldering", Procedure in progress.
[5]: LHC Project Note, "On the soldering flux induced corrosion of the stainless steel components", CERN, to be published.

SOLDERING FLUX WG PARTICIPANTS

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[1] Of this class, only the soldering flux Kester 135 has been fully tested.

Annex 3: CD-Rom “CERN Official Documents”