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74-35

SPECIFICATION FOR VACUUM TUBES FOR MAGNETS IN THE WEST EXPERIMENTAL AREA OF THE 300 GeV PROTON SYNCHROTRON

1. INTRODUCTION

The European Organization for Nuclear Research (CERN) in Meyrin (Geneva) is constructing a 300 GeV Proton Synchrotron (SPS). For the magnets in the West experimental area of the SPS an all-metal vacuum containment will be used consisting of non-circular and circular tubes and operating at pressures which could be as low as 10^{-7} Torr.

This specification concerns the tubes for the bending and quadrupole magnets of this experimental area.

2. GENERAL INFORMATION

2.1 Scope of tender

The tenderer is invited to make an offer for the supply, testing and delivery to CERN of tubes according to the enclosed tender form and in line with the detailed specifications given in this document. The offer shall include the following items for which separate prices shall be given.

i) Stainless steel sheets including transportation cost from steel maker to manufacturer.

ii) Fabrication of tubes according to drawings including the cost of tools, dies, fixtures etc.

iii) Test to be performed according to this specification.

iv) Cleaning according to this specification.

v) Packing, transport and insurance.

CERN reserves the right to propose or select a different steel supplier in case an over-all economy can be achieved. The exact procedure will be discussed with the successful tenderer.

All conditions relating to delivery time, manufacturing programme and progress reports, additional work or modifications etc. are contained in the tender documents. For completeness the quantities involved and the options considered are tabulated below.

TABLE I

Pos	Tube size mm O.D. x wall x length	Firm order No of tubes	Options No of tubes
1	98 x 1.5 x 3293	68	40
2	98 x 1.5 x 1463	6	-
3	98 x 1.5 x 1063	34	-
4	89 x 1.5 x 1063	36	-
5	78 x 1.5 x 3308	10	6
6	78 x 1.5 x 1808	25	5
7	98 x 1.5 x 3400	15	30
8	89 x 1.5 x 1852	10	-
9	78 x 1.5 x 3400	10	-
10	134/68 x 2.5 x 3632) Race	16	10
11	134/78 x 2.5 x 3232) track	48	-

2.2 Options

CERN reserves the right to order within 1 (one) year from the date of placing the contract additional vacuum tubes in quantities up to the numbers given in column 4 of Table I under the same general conditions as the first firm order.

2.3 Prototypes

The manufacturer shall not start any large scale production of the tubes until acceptance tests have been carried out to CERN's satisfaction on one prototype tube of each type to be made by the manufacturer. For acceptance, the prototypes shall meet all requirements of the present specification.

3. TECHNICAL SPECIFICATION

3.1 Design features

The tubes referred to in this specification will be located between the poles of electro-magnets. The distance between poles together with the cross-section occupied by the proton beam and the wall thickness of the tube determine the size and manufacturing tolerances of the tubes which are given in the drawings no. 8088.2032.3 and 8088.2033.3 attached to this document.

These tubes are also part of a completely metal sealed vacuum system and must be manufactured according to UHV standards, e.g. having He leak tight welding seams, smooth (degreased) inner surfaces with low outgassing rates.

3.2 Materials

It is considered that the most suitable material for the vacuum chamber is an austenitic nickel-chromium steel, of low carbon content and high stability, strengthened by the addition of nitrogen. This type of steel corresponds to grade AISI 316 LN or DIN 1.4429, the composition of which is shown below.

C	0.03 % (max.)
Si	1.0 % (max.)
Mn	2.0 % (max.)
Cr	16.5 - 18.5 %
Ni	12.0 - 14.5 %
Mo	2.5 - 3.0 %
N	0.15 - 0.20 %

3.2.1 Physical properties

The vacuum chamber must cause a minimum of disturbance in the control of the beam of particles by the magnets. For the cross-sections and wall thicknesses specified, the magnetic permeability μ should be 1.003 to 1.004 at field strengths in excess of 1000 Oe. This applies to the whole structure of the tubes, including the weld itself and the weld transition (heat affected) zone irrespective of strain induced during fabrication. The stainless steel grade AISI 316 LN does normally have this property.

3.3 Dimensional tolerances and fabrication methods

All dimensional tolerances permitted on the finished tubes are set out in the drawings attached to this document.

The required tolerances, in particular on the wall thickness, preclude the possibility of obtaining solid-drawn tubing. The tubes will, therefore, be fabricated from sheet metal and welded, and the tolerances will apply to the thickness of the sheet material prior to forming.

For circular tubes the tolerances on the diameter consist of 2 parts:

a) The tolerance due to errors in the developed length. This tolerance is composed of the sheet metal cutting tolerance, which is of the order of ± 0.2 mm if normal precautions are taken, and of the shrinkage during welding which has been shown at CERN to be of the order of 0.2 to 0.4 mm for a TIG weld which just penetrates the sheet metal thickness. Taking these two fabrication errors into account and making a partial compensation of the shrinkage, the tolerance on the tube diameter should be within ± 0.1 mm.

b) The tolerance due to errors in roundness which should not exceed the 0.5 mm shown on the drawings.

For the tubes having the "race track" shaped cross-section similar remarks apply as indicated under a) and b) with the added tolerance on the permissible twist on these tubes.

It is very important that these tolerances be strictly respected because these tubes have to fit into long, narrow magnet gaps with only little clearance, and the tube ends must be welded to transition pieces and bellows, and this demands that the shape of the tube ends, and particularly their developed lengths, be correct. Note that the fabrication tolerance on the developed length can be relaxed if the tenderer prefers to calibrate the tube ends over a length of 50 mm to the required tolerance.

The welds on the non-circular tubes must be located in the long axis plane of the tubes and must be of the highest quality.

CERN has some preference for fabrication methods in which transverse welds in the tubes are not required. However, it must be stressed that the primary consideration is the most economic production of tubes of the desired profile which meet the technical requirements for dimensions, mechanical strength and vacuum soundness. Accordingly, CERN does not impose a method of fabrication, although expressing a preference for those which have given satisfactory results on experimental basis.

3.4 Welding

The quality of the weld in any application involving high vacuum is critical. The weld area must be regular, continuous, non-porous and the heat-affected areas on either side of the weld zone must be restricted to a minimum.

As mentioned earlier, there should be the least possible disturbance to the magnetic permeability and the mechanical properties arising out of the welding process.

With regard to magnetic permeability in stainless steel this is primarily a function of composition, in so far as it affects the stability of the austenite structure. Briefly, it is well known that some steels which are fully austenitic at room temperature, when suitably heat-treated, may revert to a mixed austenite-ferrite structure if they are brought to melting temperature or near to it (as in the weld pool) and cooled quickly. The presence of ferrite brings the magnetic permeability of the weld and of its transition layers to a level unacceptable for the present application. This feature has been one of the main criteria for selecting a steel composition which ensures austenite stability under all conditions likely to be experienced during welding or fabrication. Hence, this condition should be implicitly fulfilled by making use of a steel, which meets the specifications set out under section 3.2.

In order to ensure homogeneity of composition, filler rods should not be used in welding tubes from stainless steel.

With respect to the welding technique, experience at CERN has shown that a carefully controlled TIG process, with inert gas shielding on both sides of the weld-bead, produces satisfactory welds. Processes such as "Argonarc" operated as stated above, and used under conditions ensuring minimum weld-spread, are acceptable.

All welds shall be equivalent to or better than the IIW Standard Quality no. 1 (colour code: black). Furthermore, all welds must penetrate the wall thickness leaving no pits or cracks on the inside tube surface which will later be subjected to an ultra-high vacuum and must therefore meet the surface finish described in the following section.

3.5 Surface conditions and finish

The importance of care and cleanliness in handling the tubes at all stages of production cannot be overemphasized. The manual handling of the tubes should be limited to a minimum and the internal surfaces should, at no time, be in contact with oily or greasy objects, unless some thorough cleaning operation is scheduled to follow with a minimum delay.

With regard to the surface finish of the tubes, as delivered, this should conform to that of a good quality cold-rolled sheet (i.e. equivalent to the AISI 2D grade or $R_a \approx 0.2 - 0.3\ \mu$). The internal surfaces of the welds should be smooth and free from pitting or cavities.

3.6 Marking of tubes

Each unity shall be identified by a code number (to be agreed on with CERN when the order is placed), stamped or electro-etched on the atmospheric side of the tube at each end. This number will serve as reference on the certificates of inspection (see also Particular Conditions in the tender documents).

3.7 Leak tightness

Each tube delivered to CERN by the contractor must be leak tight by standards of helium mass-spectrometer leak detection. The leak rate must be inferior to the detection limit of the leak detector used, i.e. it must be lower than 2×10^{-10} std cm^3/s, as defined by the American Vacuum Society, T.S. 2.1, dated 1.10.1963 (information on this tentative standard may be obtained from CERN upon request).

Under no circumstances must any leak be repaired by any other means than by TIG welding.

3.8 Cleaning

The precise methods of intermediate and final cleaning, depending on the adopted method of fabrication, cannot be specified at this stage, but they will be the object of consultation and agreement with CERN at an appropriate stage prior to the grant of the contract.

For the purpose of the tender, the following procedure shall be assumed for the cost estimates. This cleaning procedure, applied to stainless steel parts, was found to give low outgassing rates under vacuum in cases where there is no gross contamination and where the welds have been well protected by inert gas during welding operations:

- Degreasing by trichlorethylene by jet or immersion at room temperature.
- Rinsing in tap water at room temperature for at least 15 minutes.
- Rinsing in demineralized water at room temperature for at least 5 minutes.
- Drying by air at 150° C without contamination of inside surface.

After final cleaning, handling of vacuum exposed surfaces should be limited to a minimum and the wearing of clean nylon gloves is imperative (see also section 3.9).

3.9 Packing

After inspection and final cleaning, the tubes must be equipped with properly shaped plastic end-caps. These will prevent the tubes from being contaminated with dust etc. before packing and later during installation and protect the tube ends for later welding.

4. TESTS

4.1 Acceptance tests on prototypes

The acceptance tests on the prototypes shall be carried out at the manufacturer's premises in the presence of CERN inspectors. Following these tests the manufacturer shall dispatch the prototypes to CERN. When CERN is satisfied that the prototypes also have passed possible complementory performance tests, to be carried out at CERN, the contractor shall be given written notification within 2 weeks of the delivery of the prototype that the series production of tubes can start.

4.2.1 Dimensional control

Prototype tubes shall be checked with respect to dimensional accuracy (including linearity and angular twist on the non-circular tubes).

4.2.2 Leak testing

The prototype tubes shall be leak tested in the presence of a CERN inspector. This test shall consist of a so-called "global leak test" using a helium mass-spectrometer leak detector with a detection limit below 2×10^{-10} std cm^3/s of helium (see also section 3.7). The component to be tested is connected to the vacuum system of the leak detector and is surrounded by a plastic bag or a similar container into which helium is introduced and maintained at light over-pressure for at least 10 minutes.

4.3 Factory tests on series produced tubes

The tests on the series produced tubes shall be carried out at the manufacturer's premises. These must conform with conditions set out in section 4.2 (acceptance tests on prototypes).

4.4 Acceptance tests at CERN

CERN reserves the right to carry out, or repeat, any of the tests described in sections 4.2 and 4.3 at all stages during the guarantee period. Any tube which does not conform strictly to the specification will be rejected and returned to the contractor who will, without delay and at his own cost, effect all necessary repairs and tests until it is deemed acceptable by CERN.

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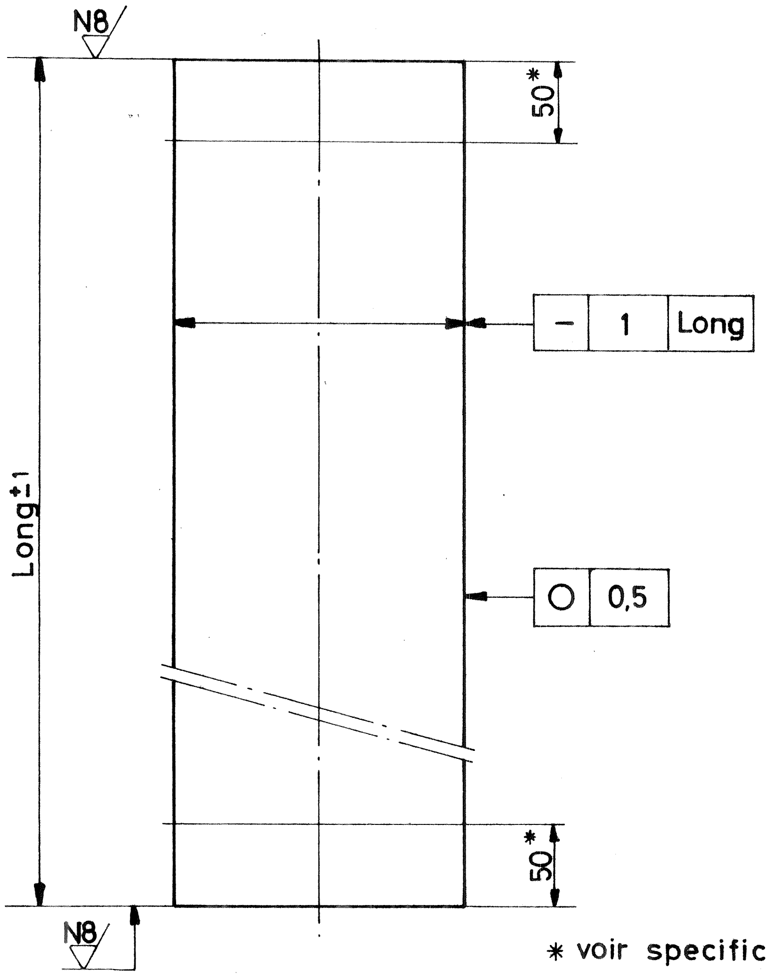

* voir specification

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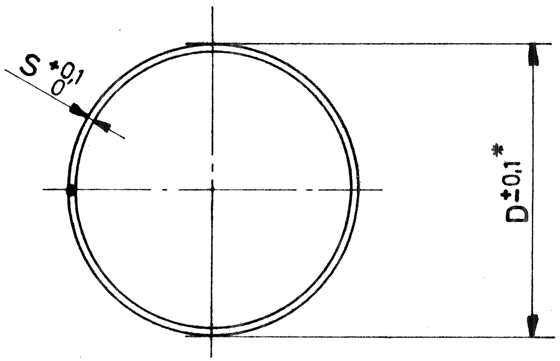
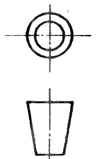


Rep	QUADRUPOLE	D	S	Longueur	Poids
1	QWL et QSL	ϕ98	1,5	3293	11,75 kg
2	QFL	ϕ98	1,5	1463	5,22 kg
3	QFS	ϕ98	1,5	1063	3,8 kg
4	QDS	ϕ89	1,5	1063	3,44 kg
5	QTL	ϕ78	1,5	3308	9,36 kg
6	QTS	ϕ78	1,5	1808	5,12 kg
7	SPS / BT	ϕ98	1,5	3400	12,13 kg
8	SPS / BT	ϕ89	1,5	1852	6 kg
9	SPS / BT	ϕ78	1,5	3400	9,62 kg



First angle projection
Projection européenne

Ensemble / Assembly
S/ensemble / S/assembly
Echelle / Scale

ENSEMBLE TUBE QUADRUPOLES

	Nom-Name	Date	Issue
Dessiné	CORCELLE	3.4.74	
Contrôlé			
			A
			B
			C

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