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SPECIFICATION FOR THE FLEXIBLE METAL BELLOWS, TRANSITION PIECES, AND FLANGES FOR THE 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 operating at pressures which could be as low as 10^{-7} Torr.

This vacuum containment will consist of circular and race-track shaped tubes, welded to which will be bellows assemblies, each consisting of two transition pieces, one flexible bellows, and one flange.

The present technical specification covers the supply of metal bellows assemblies and transition pieces and the assembly of these pieces with the vacuum flanges to be supplied by CERN.

2. TECHNICAL SPECIFICATION OF THE BELLOWS ASSEMBLIES

2.1 Design features

The configuration of the proton beam calls for an effective free space inside the bellows which must be available along the beam line.

The length of each bellows is determined by the required lateral and angular off-sets and, further, by the over-all design (allocated space). In order to reduce the number of types of bellows, certain lengths have been standardized for various magnet chambers.

The number of convolutions, the pitch (distance between two adjacent convolutions), and the gauge (wall thickness) are all related to the parameters outlined above, together with the material (see Section 2.2) and the method of fabrication of the bellows. The tenderer is free to suggest minor changes in the proposed number of convolutions, pitch, or gauge.

2.2 Material

All bellows must be "non-magnetic". This applies to the whole of the bellows structures (including all welds), where the magnetic permeability should not exceed 1.01 at field strengths in excess of 1,000 Oe.

Based on the extensive experience with vacuum chambers at CERN, it is considered that the most suitable material is an austenitic nickel-chromium steel, of low carbon content and high stability. The composition of the steel used for the vacuum tubes, to which the bellows assemblies have to be welded at CERN, corresponds to that of grade AISI 316 L alloyed with 0.15–0.20% nitrogen. For the bellows and the transition pieces, a stainless steel of grade AISI 304 L or 316 L would be acceptable.

Because of the required leak-tightness (see Section 3.2.2) the selected steel must be "clean" and homogeneous, i.e. free from microscopic channels, fissures, gas cavities, sponginess, excessive segregation, or non-metallic inclusions.

Since welds are potential sources of leakage in high vacuum systems, excellent welding properties and cleaness must be ensured.

2.3 Method of fabrication

In order to ensure less fragility, better access for cleaning, and lower cost, it is considered that the best solution is to have corrugated bellows rather than completely welded types. Furthermore, it is imperative that any longitudinal weld on the corrugated bellows should be of the butt-weld type (not overlap welded).

With respect to the welding technique, a carefully controlled TIG, plasma, or electron beam (EB) welding process, in general gives satisfactory results. The welding technique must, however, before being finally adopted, be subject to consultation with, and agreement in writing from, CERN.

With regard to the shaping of the bellows, mechanical forming or hydro-forming, or a combination of these two methods, may give acceptable results. Accordingly, the tenderer is also on this point free to suggest his own fabrication method, which must likewise be accepted by CERN prior to the grant of the contract.

2.4 End cuffs of bellows

Lip welding has been adopted for the joints between the lip of the bellows and the transition pieces. This type of weld gives less virtual leaks, i.e. air pockets, compared to other joint configurations, and it also gives access for welding operations from the outside of the chamber. Furthermore, the lip-welded type of joint involves less risk of having real leaks in the form of long microscopic channels, which, in particular, may lead to excessively long response times during leak detection.

Mechanically bordered lips of the bellows must be heat-treated (annealed) before being welded to the end pieces in order to ensure freedom from weld cracks in the transition zone of the weld.

2.5 Transition pieces

The enclosed drawings show the various transition pieces and the corresponding types of joints by which they are welded to the bellows. The bellows manufacturer must take full responsibility for fabrication, cutting and trimming of various lengths, as well as bordering and adjustment of the edges on all end pieces before welding.

The surface finish of the inside of the end pieces must be equivalent to the roughness $R_a = 0.2 - 0.3\ \mu$ (or finish AISI 2 D).

2.6 Attachment of bellows to transition pieces

Irrespective of the welding method (TIG, plasma, or EB) used for connecting the bellows to the transition pieces, it is of importance that a high precision weld jig be used and attention be paid to all conditions, including cleaness (see also 2.10), during this operation. The tenderer is free to suggest his preferred procedure, also with regard to leak testing of the items at intermediate stages of fabrication. Such procedures, before being finally adopted, will also be subject to consultation with, and agreement in writing from, CERN.

2.7 Attachment of transition piece to flanges

Flanges will be supplied by CERN, finish machined as shown in drawings attached to this specification. Irrespective of the welding procedure for connecting the transition pieces to the flanges, attention must be paid to all conditions, including cleaness (see also 2.10), during this operation. The tenderer is free to suggest his preferred procedure etc. as indicated in paragraph 2.3 and 2.6.

2.8 Handling of components during fabrication

The importance of care and cleanliness in handling the bellows, transition pieces, and flanges at all stages of production cannot be overemphasized. Even small traces of grease, oil, or heavy organic compounds, can seriously impair the quality of the welds as well as the pump-down efficiency of the vacuum system, once installed.

All mechanical cold-working operations should exclude the use of lubricants or coatings which could not with certainty be removed after the process. This applies, in particular, to the forming of bellows as well as all bordering and pulling operations.

In addition, manual handling of all items concerned should be limited to a minimum. Especially the internal surfaces of finished items should never be in contact with oily or greasy objects (including bare hands), unless some thorough cleaning operation is scheduled to follow immediately.

2.9 Marking of components

Each bellows assembly shall be identified by a number etched on the atmospheric side of the component as indicated on the assembly drawing. This number will serve as a reference on the certificate of inspection.

2.10 Final 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. It is understood that all bellows assemblies and transition pieces should be clean and ready for subsequent welding or immediate use when dispatched from the manufacturer.

For the purpose of the tender, the following final cleaning procedure shall be assumed. This cleaning procedure, applied to stainless-steel parts, was found to give low outgassing rate 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 2.11).

2.11 Packing

After the final leak test the bellows assemblies shall be wrapped in aluminium foil and sealed individually into gas-tight containers (poly-ethylene bags or equivalent) in order to avoid any danger of contamination during transportation.

All individual containers or packages shall be marked for identification of their content. Further, the test certificate must be attached to each container or package (see also Section 3.3.2).

The tenderer will be responsible for safe delivery of the bellows assemblies with packing intact to the CERN site.

3. TESTS

3.1 Acceptance tests for material(s)

Within the specification set out under Section 2.2, the tenderer is free to suggest his own choice of materials.

However, if the tenderer chooses a different material from that recommended (AISI 316 L), then before such materials can be used in production, the following information and samples must be provided:

3.1.1 The contractor must provide the complete nominal compositions of the materials and one detailed analysis of each specific melt of the relevant grades. He must also present data on the physical and mechanical properties, including strain-stress curves of annealed and cold-worked materials at room temperature in compliance with the requirements listed under Section 2.2.

3.1.2 Samples of the materials must be provided for each melt and each batch of rolled sheet as follows:

3.1.2.1 For the bellows:

1 strip, approximately 250 mm × 500 mm, of each proposed thickness, cold worked to the degree proposed for blank sheet to be used for bellows production,

3.1.2.2 For transition pieces:

1 sheet, approximately 250 mm × 500 mm, of 1.5 mm stainless steel annealed or cold worked to the degree proposed for blank sheet to be used for production.

3.1.3 With the samples submitted by the tenderer, CERN will carry out the following acceptance tests:

3.1.3.1 The magnetic permeability will be measured in a force-balance at field strength from 1,000 to 6,000 Oe. All these specimens must show a magnetic permeability in the range 1.003 to 1.01. Sample lengths of the steel will be TIG, plasma, or EB welded and specimens for the magnetic permeability tests will be cut or machined from areas within the weld, at the weld transition, and outside the weld affected zones.

3.1.3.2 Tensile tests will be carried out on the sheet samples.

3.1.3.3 The surface roughness of the sheets will be checked.

3.2 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.

3.2.1 The prototype bellows assemblies will be checked with respect to dimensional accuracy, surface roughness, mechanical properties, and quality of welds (movements and spring rates).

3.2.2 Following the final cleaning and drying, the prototypes shall be leak tested. This test shall consist of a so-called "global leak test" using a mass-spectrometer leak detector with a detection limit lower than 2×10^{-10} std cm^3/s of helium, 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). 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 slight over-pressure for at least 10 minutes.

3.2.3 Following these tests the manufacturer shall dispatch the prototypes to CERN. When CERN is satisfied that all prototypes also have passed possible complementary performance tests, to be carried out at CERN, the contractor shall be given written notification that the series production of bellows assemblies and adaptors can start.

3.3 Factory tests on series-produced components

3.3.1 The tests on the series-produced bellows assemblies shall be carried out at the manufacturer's premises. The test procedures shall conform with those set out in Sections 3.2.1 and 3.2.2 (acceptance tests on prototypes).

3.3.2 A test certificate must accompany each component that has been proved leak-tight. The certificate must give the identification of the piece as well as the actual sensitivity of the leak detector, date of control, and name or code number of the operator. The certificate must be attached to the outside of the container or package of each component.

3.3.3 If a bellows assembly is repaired, the complete procedure according to Sections 2.10 and 3.3.1 must be repeated on this item, including the issue of a supplementary test certificate.

3.4 Acceptance tests at CERN

CERN reserves the right to carry out, or repeat, any of the tests described in Sections 3.2 and 3.3 at all stages during the guarantee period. Any bellows assembly 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.

APPENDIX

Access to information

If any part of the manufacture is to be undertaken by subcontractors, CERN must be informed of the nature of the subcontracts and of all technical details relating thereto.

CERN demands the right of access to all technical information available to the manufacturer in the course of production.

CERN further reserves the right of access to the manufacturer's premises during the entire period of production, which covers also the testing and fabrication of samples or prototypes prior to full-scale manufacture. This right of access must be granted also to the premises of subcontractors.