PROTOTYPE BEAM SCREENS FOR LHC DIPOLE MAGNETS
FROM CO-LAMINATED STAINLESS STEEL
IN 16 METRE LENGTHS

This technical specification replaces LHC-VAC/NK(TS-96-20) and LHC-VAC/NK(TS-96-20bis).
CONTENTS

1. INTRODUCTION

2. SCOPE OF THE TENDER

3. MATERIALS ISSUED BY CERN

4. TECHNICAL REQUIREMENTS
   4.1. Slotting
   4.2. Forming
   4.3. Welding
   4.4. General

5. CLEANING AND PACKING

6. SCHEDULE

7. CONTACT PERSONS

ATTACHMENTS:
   Technical details
   Slot pattern - N. Kos 07/04/97
   VV010064PL.NK, 24-05-96
   06LHCVHNSA01644
1. INTRODUCTION

CERN is preparing the production of dipole beam screens for the Large Hadron Collider. The beam screens will be inserted in the cold bores of the dipole magnets to intercept synchrotron radiation and carry the image currents which are generated by the circulating beams. The beam screens will have a length of ≈16 metres.

The prototype beam screens will be manufactured from Ugine UNS21904 stainless steel, co-laminated on the inside surface with 50 µm of OFE copper. The stainless steel will provide high strength in combination with ultra low magnetic permeability at low temperatures. The copper coating on the inner surface with its high electrical conductivity will minimise image current losses and resistive wall impedances.

Pumping slots will allow gas molecules to be pumped out of the beam screen aperture and onto the cold bore inner surface. The beam screen is positioned in the cold bore by means of supports every 1.7 metres. The supports assure the perfectly centred position in the cold bore. They are designed to minimise thermal heat transfer between the beam screen and the cold bore.

Two cooling tubes will be welded onto both sides of the beam screen to remove the power from absorbed synchrotron radiation and image currents. The temperature of the beam screen will be higher than the temperature of the cold bores (5K-20K versus 1.8 K).

The perforated beam screen will ensure a good vacuum while minimising the heat load to the 1.8 K cryogenic system.

2. SCOPE OF THE TENDER

Manufacturing of 30 prototype beam screens for LHC dipole magnets with a length of 16000 ± 100 mm each.

The manufacturing will consist of the following steps:
- Manufacturing the required tooling for slotting and forming.
- Slotting the flat co-laminated strip with a regular slot pattern.
- Forming the flat strip into beam screens.
- Closing the screens longitudinally by means of one laser weld.

In consultation with CERN, some of the beam screens may be manufactured without slots. At least 20 beam screens will, however, be made with slots.

A dimensional report shall be included for every manufactured prototype (see 4.4).

Attaching the Ø4.5 mm cooling tubes will not be part of the contract.

3. MATERIALS ISSUED BY CERN

For the requested prototypes, CERN will free-issue ≈750 metres of copper/stainless steel co-laminated strip (coil lengths 100, 300 and 350 metres). The chemical composition of the stainless steel is given in the table below.

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Grade</th>
<th>Cr [%]</th>
<th>Ni [%]</th>
<th>Mn [%]</th>
<th>N [%]</th>
<th>C [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ugine</td>
<td>UNS21904</td>
<td>20</td>
<td>7</td>
<td>9</td>
<td>0.38</td>
<td>0.03</td>
</tr>
</tbody>
</table>
The nominal values for the mechanical properties at room temperature are:

- Tensile strength $R_m \approx 840$ MPa
- Yield strength $R_{p0.2} \approx 600$ MPa
- Elongation $A_{10} > 35 \%$

4. TECHNICAL REQUIREMENTS

4.1 SLOTTING
- The pumping slots will be punched from the copper side. Care will be taken that the copper layer does not get damaged or scratched during re-coiling after punching (use of protective interleaf paper).
- The use of punching lubricants is subject to prior approval from CERN.
- A representative punched sample will be made available to CERN for approval of the punching process.

4.2 FORMING
- The beam screens will be continuously formed from a single strip in a dry (non-lubricated) process.
- In order to stabilise the profile and improve straightness and twist tolerances, it is allowed to make 4 longitudinal indentations on the inside of the corners of the beam screen. These indentations will be in the form of a radius and will not be deeper than 0.2 mm.
- It is known from previous prototypes that forming of the beam screen from perforated strip can result in an undulated surface of the flat part of the perimeter between the two inner slot rows. The use of a sufficient amount of roller sets and the application of an appropriate forming sequence will be necessary to avoid such undulations. The flatness of the external flat surface between the inner slot rows should be better than 0.1 mm per 100 mm length (see drawing 06LHCVHNSA01644).

4.3 WELDING
- Welding of the beam screens shall be done with laser to minimise the heat affected zone. The bulk of the Cu-clad stainless steel, and hence the copper itself, is not allowed to be heated above 350°C in order to maintain the electrical properties of the copper.
- It has been shown that full penetration welding in the presence of Cu results in hot cracking. The copper shall therefore be mechanically removed prior to welding over a width of 1.0 mm on both sides of the weld. Care will be taken not to remove too much SS in order to maintain the rigidity of the section.
- Measures will be taken to eliminate as much as possible the deposit of welding projections on the inside of the beam screen. Care will be taken that these measures will not scratch or contaminate the copper surface.

4.4 GENERAL
- The ultra low magnetic permeability of the stainless steel, including the welds, must as far as possible be maintained during manufacturing.
- The manufacturing must be compatible with Ultra High Vacuum cleanliness standards. The copper surface of the material shall only be handled or touched with clean gloves.
- The section of the beam screen shall be measured in-line after the welding. The measured data will be included in the dimensional report.
- See the technical details attached for further information.
5. CLEANING AND PACKING

The pre-punched beam screen strip will be degreased inline before the forming. The cleaning fluid is subject to approval from CERN.

The forming process will be dry. Care shall be taken to avoid contamination with finger prints, dirt, grease and oil.

The finished beam screens will not undergo any cleaning treatment after forming and welding.

The beam screens shall be individually packed in polyethylene bags and transported to CERN in a crate sufficiently rigid to guarantee that they will not plastically deform during handling and transport.

6. PROVISIONAL SCHEDULE

May 1997 - Free-issue of co-laminated strip
October 1997 - Delivery of the beam screens

7. CONTACT PERSONS

Technical matters:

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Fax: (41) 22 767 7605
## TECHNICAL DETAILS

### CERN supplied co-laminated strip

<table>
<thead>
<tr>
<th>Material grade</th>
<th>UNS21904 (high Mn austenitic stainless steel). Cu-clad on the inside surface with OFE copper.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>142±0.1 mm (to be confirmed).</td>
</tr>
<tr>
<td>Thickness</td>
<td>1.00±0.02 mm ss + 0.05±0.01 mm Cu (1.05±0.03 total).</td>
</tr>
<tr>
<td>Inner coil diameter</td>
<td>525 mm</td>
</tr>
</tbody>
</table>

### Finished beam screens

<table>
<thead>
<tr>
<th>Length</th>
<th>16000±100 mm (at 20°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface quality</td>
<td>( R_a ) internal Cu-surface ( \leq 0.2 \mu m ), free from fingerprints, debris, scratches and oxidation (as delivered). ( R_a ) external ss-surface ( \leq 0.8 \mu m )</td>
</tr>
<tr>
<td>Straightness tolerance</td>
<td>( &lt;0.5 \text{ mm/m} ) (target value)</td>
</tr>
<tr>
<td>Twist</td>
<td>( &lt;0.5^\circ/\text{m} ) (target value)</td>
</tr>
<tr>
<td></td>
<td>( &lt;1^\circ ) between the ends (target value)</td>
</tr>
<tr>
<td>Pumping slots</td>
<td>8 rows of longitudinal slots with rounded ends</td>
</tr>
<tr>
<td>Slot width</td>
<td>1.5 ± 0.2 mm</td>
</tr>
<tr>
<td>Slot length</td>
<td>8 ± 0.2 mm</td>
</tr>
<tr>
<td>Slot positions</td>
<td>as drawing attached</td>
</tr>
<tr>
<td>Weld preparation</td>
<td>Cu removed on both sides to avoid hot cracking.</td>
</tr>
<tr>
<td>Welding</td>
<td>Full penetration laser welds with minimum austenite content.</td>
</tr>
</tbody>
</table>