Material Specification

for the Supply of

CuCrZr - IG Alloy Seamless Tubes

for the ITER Divertor
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1 Scope

This specification covers the supply of tubes of low alloyed copper alloy type CuCrZr - ITER Grade for the ITER divertor.

This specification is applicable for the first set of the divertor Vertical Targets with CFC/tungsten armour.

The addition of “ITER grade (IG)” to name this alloy means that the chemical composition of standard CuCrZr alloy (UNS Number C18150 or CW106C in EN standards) is modified. However, the specified range of alloying elements and impurities are within the ranges of the standard grade.

The amount of the CuCrZr tubes to be procured shall be specified by the concerned Domestic Agency (DA) and shall include appropriate contingency to face unexpected difficulties, to remake rejected parts and to repair parts with insufficient quality.

The supply covers the following items:

a) Manufacturing of CuCrZr alloy tubes;
b) Organisation of quality at works. Elaboration of all procedures required for the manufacturing, inspection (including analyses), packaging, storage and delivery. Time schedules and documentation;
c) Perform all the inspections and tests during and after manufacturing envisaged in this specification;
d) Storage, packaging and delivery.

2 Referenced Documents

The following Codes and Standards shall be referred:

2.1 ASME Code

Section V, Article 9 Visual Examination,
Section V, Article 8 Eddy Current Examination of Tubular Products

2.2 ASTM Standards

E 112 Standard Test Methods for Determining Average Grain Size
E 21 Standard Test Methods for Elevated Temperature Tension Tests of Metallic Materials
B 251M Standard Specification for General Requirements for Wrought Seamless Cooper and Copper Alloy Tube
E 3 Method of Preparation of Metallographic Specimens
E 8 Test Method for Tension Testing of Metallic Materials
E 478 Test Method for Chemical Analysis of Copper Alloys
E 118 Test Method for Chemical Analysis of Copper Chromium Alloys
B 193 Test Method for Resistivity of Electrical Conductor Materials
E1004-02  Practice for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method
E-243  Electromagnetic (Eddy Current) Testing of Seamless Copper and Copper-Alloy Tubes.

2.3 **EN Standard**
EN 10204:2004  Metallic products: Type of inspection documents

Other equivalent national or international standards and codes may be acceptable with prior written ITER approval, provided all criteria are satisfied.

3 **Ordering Information**

It is responsibility of the DA to specify the requirements for the material purchase order.

4 **Manufacturing Process**

The CuCrZr-IG alloy shall be produced free of cuprous oxide, without use of metallic or metalloid deoxidizers.

The product shall be produced by hot-working or cold-working operations, or both. Unless otherwise specified, the product shall be finished by such cold working and annealing or heat treatment as necessary to meet the properties specified.

_Special Handling_ — Handling methods shall minimize tube-to-tube contact during processing, cleaning, annealing, and storage. Special handling procedures shall be provided to maintain the traceability of the tubes at all times.

Definition of lot (ASTM B846-11: Standard terminology for Copper and Copper Alloys)
- A collection of like product (i.e. same alloy, temper, and dimensions) produced under uniform conditions from which a sample is to be drawn for inspection or testing, or both.

5 **Heat Treatment**

All tubes must be delivered at solution annealed and aged condition:

- Anneal at 980°C +10 -0 °C for 20 +2 -0 minutes + water quench,
- Age at 475°C ± 5°C for 3 hours.

Other treatments may be proposed based on manufacturing procedure requirements of divertor vertical target.
6 Chemical Requirements and Physical Characteristics

6.1 Chemical composition

The chemical composition has to satisfy the requirement given in Table 1.

The chemical analysis shall be performed for each lot of material.
Maximum lot size shall be 500 kg.
As a minimum number, ten (10) chemical analyses have to be performed and reported for the overall amount of purchased materials.

<table>
<thead>
<tr>
<th>Alloy Designation</th>
<th>Cu</th>
<th>Cr</th>
<th>Zr</th>
<th>Impurities</th>
</tr>
</thead>
<tbody>
<tr>
<td>CuCrZr – ITER Grade alloy</td>
<td>base</td>
<td>0.60-0.90</td>
<td>0.07-0.15</td>
<td>Total: ≤ 0.15, including Co* ≤ 0.05, Nb* ≤ 0.10, Ta* ≤ 0.01, O – as low as possible, content shall be reported</td>
</tr>
</tbody>
</table>

* - Radioprotection requirements

6.2 Electrical conductivity

The electrical conductivity at 20°C shall be no less than 75 % IACS. The samples of CuCrZr alloy must be tested at solution annealed and aged condition. Test method ASTM B 193 or E1004-02 shall be used.

6.3 Grain Size

Samples shall be tested in accordance with ASTM E 112 “Standard method for determining average grain size”. Micrographs shall be used to examine the structure of the material as well as to establish grain size.

It is responsibility of DA to establish grain size requirement for plate supplied. However after manufacturing heat treatment (which is defined by the method of joining of armour and stainless steel structure) the average grain size shall be less than 100 µm. An occasional grain size as large as 200 µm (< 10% of grains) is acceptable after the completion of the manufacturing process.

7 Mechanical Properties

Tensile test should be performed according to ASTM E 21 and ASTM E 8 (or EN 10002-1 and EN 10002-5).
The following values shall be recorded:
- Yield Strength (YS) at 0.2% offset, in MPa,
- Tensile Strength (UTS), in MPa,
- Total Elongation (TE) after fracture, %,

Samples shall be tested at solution annealed and aged condition. Table 2 shows the target values for properties after solution annealing and ageing treatment.

<table>
<thead>
<tr>
<th>Temperature of Test, °C</th>
<th>20°C</th>
<th>250°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength, MPa min</td>
<td>370</td>
<td>280</td>
</tr>
<tr>
<td>Yield Stress, MPa, min</td>
<td>240</td>
<td>200</td>
</tr>
<tr>
<td>Total Elongation, %, min</td>
<td>17</td>
<td>10</td>
</tr>
</tbody>
</table>

The tensile tests shall be performed on 3 samples for each lot of material. As a minimum number, ten (10) tensile tests have to be performed and reported for the overall amount of purchased materials.

8 Dimensions and Permissible Variations

Tolerances described in ASTM B251 are applicable, unless those specified by DA based on requirements of manufacturing process and joining technology method used for divertor component fabrication.

No trace of oil or grease shall be present on the metal when delivered. Roughness of the inner surface of tubes shall be \( \leq 1.6 \, \mu m \). Requirement for roughness of the outer surface depends on manufacturing method of joining CuCrZr tube and armour monoblock and shall be specified by DA and agreed with IO. The finished tubes shall be free of visible oxide, scale, splits, laps, cracks, seams, protrusions, gall marks, inclusions and other defects of a kind.

9 Non-destructive examination

9.1 Visual Examination

All external surfaces of tubes shall be examined by a visual examination in accordance with ASME Section V, Article 9. The surfaces shall be plane, uniform and free from wrinkles, buckles, blowholes, tears, cracks and inclusions.

9.2 Eddy Current Examination

100% of eddy current examination of each product shall be provided in accordance with ASME Section V, Article 8 and ASTM E243. Defects with a depth less than 10% of wall thickness are tolerated.
10 Acceptance

Material Test Reports have to be provided to the Purchaser prior to delivery. Material and certification shall be in compliance with this specification. Material cannot be accepted if it does not comply with this specification.

11 Documentation

The Supplier shall provide the Inspection Certificate type 3.1 in accordance with EN 10204, which include at least the following information:

- Description of the material designation and marking
- Lot number
- Identification of Supplier.
- Melting process method.
- Record of heat treatment.
- Dimensional check.
- Result of chemical analysis.
- Records of microstructure examination and grain size.
- Results of mechanical property tests at specified heat treatment
- Results of Electrical conductivity test.
- Indication from where the specimens have been taken for all specified analysis.
- Results of all analysis and inspections that should be done according this specification.
- Records of non-destruction examinations.
- Packaging data.

All documents shall be in the English language and all measures shall be given in the metric system SI. Each document shall be provided as an electronic file in PDF format.

12 Quality Assurance Requirements

The quality organisation shall comply with the requirements defined in Annex A of the Procurement Arrangement.

13 Packaging

Each tube shall be legibly identified with the following information. The marking shall be performed by impression stamping or other acceptable means specified by purchaser.

- Supplier name or symbol
- Grade of material
- Dimensions: tube diameter, thickness and length
- Tube number or unique identification number related to quality history
- Heat number
- Quantity

The supplier shall ensure that consignments comply with regulatory requirements applicable to transport and to the country of destination.