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Materials Technical Specification
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Technical Specification

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**Stainless steel forged blanks
for ultra-high vacuum applications**

1.4429

X2CrNiMoN17-13-3

AISI 316LN

This document specifies the CERN technical requirements for 1.4429 (X2CrNiMoN17-13-3, AISI 316LN) stainless steel blanks for ultra-high vacuum applications (UHV) at CERN requiring vacuum firing at 950°C.

Original : English

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1. NORMATIVE REFERENCES

Unless stated in the present CERN specification or agreed by a written mention in the order, the material shall be in accordance with the following referenced documents. The latest edition applies.

EN 10021	General technical delivery requirements for steel products
EN 10222-1	Steel forgings for pressure purposes – Part 1: general requirements for open die forgings
EN 10222-5	Steel forgings for pressure purposes – Part 5: Martensitic, austenitic, and austenitic-ferritic stainless steels
ASTM E112	Standard test methods for determining average grain size
ASTM E45	Standard test methods for determining the inclusion content of steel
EN 10002-1	Metallic Materials – Tensile Testing – Part 1: Method of Test at Ambient Temperature
ISO 6892-1	Metallic materials – Tensile testing – Part 1: Method of test at room temperature
ISO 6506-1	Metallic materials – Brinell hardness test – Part 1: Test method
EN 60404-15	Magnetic materials – Part 15: Methods for the determination of the relative magnetic permeability of feebly magnetic materials
EN 10228-2	Non-destructive testing of steel forgings – Part 2: Penetrant testing
EN 10228-4	Non-destructive testing of steel forgings – Part 4: Ultrasonic testing of austenitic and austenitic-ferritic stainless-steel forgings
EN 10204	Metallic products: Types of inspection documents

2. REQUIREMENTS

The stringent requirements of this material specification for products intended for UHV purposes, impose to apply an adapted steelmaking and manufacturing process, aimed at meeting the structure and inclusion limits outlined in the document.

2.1 STEELMAKING AND MANUFACTURING PROCESS

1.4429 ingots shall be produced including a mandatory step of electro slag remelting (ESR).

The manufacturing process shall include solution annealing treatment.

The blanks shall be multi-directionally and redundantly forged. Minimum forging reduction ratio shall be 10.

2.2 CHEMICAL COMPOSITION

The product analysis shall comply with the requirements in EN 10222-5 and with the special CERN requirements indicated here below.

Element	Product analysis (% by mass)
Cr	16.00 – 18.50 ¹
Ni	12.00 – 14.00 ¹
C	0.030 max.
Si	1.00 max.
Mn	2.00 max.
Mo	2.00 – 3.00 ¹
N	0.14 – 0.20 ¹
P	0.030 max. ¹
S	0.010 max. ¹
Fe	Remainder

Special requirements:

Cobalt shall be present only as a trace or to a maximum content of 0.10%, including measuring tolerance.

The nitrogen content between 0.14% and 0.20% is imperative.

Content of impurity elements (P, S, B) shall reach the lowest achievable level.

Elements not listed in this table shall not be intentionally added to the steel without the agreement of CERN.

2.3 STRUCTURE

The structure after solution annealing shall be completely austenitic and homogenous. Segregations, as well as presence of intermediate phases, such as Sigma, Chi, Laves..., are not allowed in the final product.

The equivalent grain size number according to ASTM E112 shall be, in average, equal or greater than 3. The grain size shall be homogeneous within the range of ± 0.5 equivalent grain size number around the true average value.

2.4 INCLUSIONS CONTENT

Amount and definition shall meet standard ASTM E45.

- Micro-inclusions (indigenous inclusions detectable by microscopical test methods): method A is applicable. Severity level number shall be at most 2 for all types.

¹ CERN requirement.

- Macro-inclusions (exogenous inclusions from entrapped slag or refractories): they are strictly forbidden and are cause for rejection.

2.5 MECHANICAL PROPERTIES

At room temperature, after solution annealing:

Tensile strength	R _m	min.	600 N/mm ²
0,2% proof strength	R _{p0.2%}	min.	300 N/mm ²
Elongation at break	A ₅	min.	35%
Brinell hardness	HBW		150-190

If verification of additional properties is required (i. e. impact energy or proof of strength and tensile strength at elevated temperatures), the results shall conform EN 10222-5.

If elevated temperature testing has been requested the testing temperature should be agreed at the time of enquiry and order. Otherwise, the test shall be carried out at 250 °C.

2.6 MAGNETIC PROPERTIES

The relative magnetic permeability at room temperature after solution annealing shall be lower than or equal to 1.005 for fields of over 80 000 A/m (equivalent to 1000 Oe).

2.7 SURFACE QUALITY

All surfaces shall be pre-machined, clean, and free from scale, paint and any other foreign matter that could adversely affect the sensitivity of the non-destructive testing or cause errors in interpretation.

The surface roughness, R_a, of the product shall not exceed 6.3 µm unless finer values are stated in the order documents or on the product drawings.

2.8 NON-DESTRUCTIVE TESTING

The homogeneity and internal soundness of the products shall be 100% inspected by penetrant testing (PT) and ultrasonic testing (UT). Testing shall be performed on the pre-machined surfaces of the solution annealed blanks and PT shall be performed before UT.

Test reports shall be submitted to CERN for acceptance prior to delivery and included in the inspection documents.

PT

PT shall be performed and reported in accordance with EN 10228-2.

All surfaces shall be examined with washable color or fluorescent penetrants.

Recording level and acceptance criteria shall be as per Quality Class 4 according to Table 1 in EN 10228-2.

UT

UT shall be performed and reported in accordance with EN 10228-4, and the specific aspects mentioned below:

- UT shall be performed in accordance with a written test procedure that shall be submitted to CERN for approval prior to the test;
- The test shall cover 100 % of the product volume including near-surface, with 100% scanning coverage as defined by § 12.4 of EN 10228-4;
- Testing by angle-beam probes is required in hollow shapes;
- Sensitivity setting for normal-beam probes shall be either a) Distance-amplitude curve (DAC) using flat-bottomed holes or b) Distance-gain-size (DGS) technique (disc-shaped reflectors);
- Sensitivity setting for angle-beam probes shall be following any of the techniques in § 11.3 of EN 10228-4;
- The applicable recording/acceptance criteria applied for normal-beam probes are different and more stringent than those defined in Table 5 of EN 10228-4. The local thickness of the product on the testing direction shall be considered (axial scanning, radial scanning and different parts of complex forgings may have different local product thickness). The recording/acceptance criteria shall be as follows depending on the local thickness of the product:

Local product thickness t (mm)	Recording level d _{eq} (mm)	Acceptance criteria for	
		Isolated discontinuities d _{eq} (mm)	Extended or grouped discontinuities d _{eq} (mm)
t ≤ 15 mm	0.8	1.2	0.8
15 mm < t ≤ 40 mm	1.2	1.6	1.2
40 mm < t ≤ 100 mm	1.6	2.0	1.6
100 mm < t ≤ 250 mm	2.0	3.2	2.0
250 mm < t ≤ 600 mm	3.2	5.0	3.2
t > 600 mm	Indication with an 80 % reduction of backwall echo	Indication with a total loss of backwall echo. A total loss of backwall echo shall be considered when its amplitude becomes less than 5 % of its initial value measured near the indication or less than or equal to grass	
d _{eq} = Equivalent diameter of flat-bottomed hole			

3. INSPECTION AND TESTING

3.1 GENERAL

Quality control shall be carried out in accordance with an Inspection and Test Plan (ITP) established between the manufacturer and CERN. CERN (or its representative) reserves the right to intervene during the different stages of fabrication.

3.1.1 TEST METHODS

Test	Applicable standard	Test unit
Chemical analysis	Using appropriate European Standards ²	Cast analysis and on final product
Structural analysis (structure/ inclusions)	Grain size: ASTM E112 Inclusions: ASTM E45, Method A	For each batch ³ and each size within the batch By sampling on the blanks
Mechanical properties	Tensile testing: EN 10002-1, ISO 6892-1, or equivalent Hardness testing: ISO 6506-1	For each batch ³ and each size within the batch By sampling on the blanks
Magnetic permeability	EN 60404-15 or equivalent	For each batch ³ and each diameter within the batch By sampling on the blanks
Non-destructive testing	PT: EN 10228-2 UT: EN 10228-4 and § 2.9.1	For each blank 100 % of the blank
Dimensions	According to the order documents or the product drawings	100% of the blanks

3.1.2 IDENTIFICATION

Each bar shall be marked with:

- Cast number;
- Manufacturer's name;
- Type of material;
- Traceability number between delivered lot and inspection documents.

The markings shall be chemically or mechanically engraved at each end.

3.2 INSPECTION CERTIFICATE

The certificate shall be based on specific inspection 3.1, according to EN 10204. All the certificates shall be drawn up in accordance with the prevailing standards and shall be submitted to CERN for approval prior to delivery.

² The choice of a suitable method for the analysis/test is at the discretion of the manufacturer. The manufacturer shall declare the test method used if required.

³ Each batch consists of products coming from the same cast. The products shall have been subject to the same heat treatment cycle in the same furnace. In the case of a continuous furnace or in process annealing a batch is the lot heat treated without intermission with the same process parameters.

4. PACKING

The packaging of the bars shall be strong enough to preserve the surface condition during transport.