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1. Scope

- 1) This document defines the material to be used for engineering and production of compensation bellows being operated at cryogenic temperatures for the use in
 - magnet cryostats,
 - cryogenic supply systems,
 - cryogenic transport systems,
 - cryogenic current lead boxes,
 - auxiliary cryogenic systems within particle accelerators.
- 2) This document is NOT related to any materials for cryogenic tubing or flanges.
- 3) This document does NOT represent a replacement for any relevant technical standards in terms of 97/23/EC [1] or the AD2000 Code [2].
- 4) This document is NOT related to any other purpose as aforementioned.

2. Definitions

- 1) *Pressure equipment* in terms of this document is equipment being identified as such according to the European pressure equipment directive 97/23/EC [1].
- 2) *Cryogenic temperatures* in terms of this document are temperatures below 273K.
- 3) *Magnetic fields* in terms of this document are magnetic fields generated by any magnet system dedicated to ion optics.

3. Codes and Standards

- 1) The European pressure equipment directive 97/23/EC [1] defines the legal standards for components and assemblies being identified as pressure equipment.

2) The AD 2000 Code [2] defines the engineering, production and documentation standards in terms of pressure equipment.

4. Specification of Qualified Material

- 1) For the production of bellows for operation at cryogenic temperatures only sheet metal of the material X2CrNiMo17-12-2 (W. Nr. 1.4404), compliant with the properties as defined in chapters 4.1 to 4.5 and by [7], is qualified.
- 2) In case compensation bellows are applied as pressure equipment in terms of [1], all properties relevant for fulfilling the requirements of [1] and [2] for the particular pressure equipment class of the component the bellow is applied to, must be fulfilled and proven.

4.1. Chemical Composition

- 1) The chemical composition of the material must fulfil the definitions in Table 1.

Table 1: Chemical composition of qualified steel material

Chemical Element	Weight component in %
Cr	16.00 - 18.50
Ni	11.00 - 14.00
C	≤ 0.030
Si	≤ 1.00
Mn	≤ 2.00
Mo	2.00 - 2.50
N	≤ 0.050
P	≤ 0.030
S	≤ 0.010
Fe	Remainder

- 2) Special requirements are on the Cobalt content which may be present only as a trace or to a proportion of ≤ 0.20 % by weight, including the measuring tolerance.

4.2. Structural Properties

- 1) The structure after full quenching must be completely austenitic.
- 2) In accordance with the standard ASTM E112-96 [3], grain size d 40 Pm shall be accepted.
- 3) The amount and definition of inclusions must meet the standard ASTM E45-97e1 [4], method D. The class of inclusions must be at most 1.

4.3. Magnetic Properties

- 1) Materials applied in regions close to and in magnetic fields must show a $\mu_R \leq 1.005$ at room temperature after solution annealing.
- 2) If not specified, the necessity for the low μ_R must be agreed with the contracting entity.

4.4. Mechanical Properties

- 1) The following properties must be fulfilled at room temperature after solution annealing
 - Tensile strength $R_m \geq 600 \text{ N/mm}^2$
 - Yield stress $R_{p0.2\%} \geq 225 \text{ N/mm}^2$
 - Elongation at break $A_5 \geq 35\%$
 - Brinell hardness $HB \leq 180$
- 2) The following properties must be fulfilled after solution annealing at the cryogenic temperature of 4.2 K.
 - Impact toughness $KCV \geq 80 \text{ J/cm}^2$
- 3) In case the material shall be applied for pressure equipment in terms of [1] it must be pointed out, that the permitted load case in dependence of applied temperature range, as defined in [2] technical bulletin W10, must be adhered without reserve.

4.5. Manufacturing Process

- 1) The manufacturer must state in due time in advance in writing the method of processing or refining of the steel which is intend to apply for obtain the rate of inclusions specified under in paragraph 4.2.
- 2) The homogeneity of the steel must be ultrasonically inspected to detect continuity faults after the last hot working operation.
- 3) All steel sheets must be cold-rolled and annealed.
- 4) The finishing of steel sheets must be of the type "2D" according to EN 10088-2 [5].
- 5) The surface quality must be confirmed by a dye penetrant test.

4.6. Identification

- 1) Each sheet or tube shall be marked with
 - Lot Number
 - Name of supplier
 - Material Number.
- 2) The marking must be placed on one side only.
- 3) Before removal of any marking, the information must be documented within quality documentation such, that for traceability purposes a correlation with the sheet is guaranteed constantly.
- 4) The marking must be easy to remove with organic solvents, e.g. methanol or acetone.



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4.7. Packaging

- 1) The packaging of sheet metal must be such that surface condition and evenness of the material is preserved during any transportation process.

5. Quality Assurance and Documentation

5.1. Frequency and Types of Quality Tests

- 1) The chemical composition must be proven for every melting lot in use for production.
- 2) An analysis of structure and inclusions must be performed
 - for each ingot at a head-, centre- and foot position
 - by sampling for each lot of steel sheets in use for production.
- 3) Ultrasonic measurement must be performed on each thickness of steel sheets during production.
- 4) The mechanical properties must be proven for
 - for each ingot
 - by sampling for each lot of steel sheets in use for production.
- 5) The thickness of each steel sheet in use for production must be proven.
- 6) The magnetic permeability must be proven
 - for every ingot
 - by sampling for each lot of steel sheets in use for production.
- 7) The surface quality must be proven with a dye penetrant test by sampling for each lot of steel sheets in use for production

5.2. Documentation and Certificates

- 1) All quality documentation as listed above and as defined by [6] must be delivered for all material in use for production.
- 2) In case of pressure equipment in terms of [1], additionally all documentation as defined by [2] must be delivered for all material in use for production. In case the class of pressure equipment is less than I, the documentation must be delivered according to pressure equipment of a class I.

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6. References

- [1] Directive 97/23/EC, European parliament and the council of the European Union, <http://eur-lex.europa.eu>; 1997
- [2] AD 2000-Code; Verband der TÜV e. V.; Beuth Verlag GmbH; Berlin; Germany; 2009.
- [3] ASTM E112-96: Standard Test Methods for Determining Average Grain Size; ASTM International, West Conshohocken; USA; 2004
- [4] ASTM E45-97: Standard Test Methods for Determining the Inclusion Content of Steel; ASTM International, West Conshohocken; USA; 2002
- [5] DIN EN 10088-2; Stainless steels - Part 2: Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes; Deutsches Institut für Normung e.V., Beuth Verlag GmbH; Berlin; Germany; 2005
- [6] EN 10204; Metallic products: Types of inspection documents; Deutsches Institut für Normung e.V., Beuth Verlag GmbH; Berlin; Germany; 2005
- [7] TECHNICAL SPECIFICATION N° 525 - Ed. 3: SHEETS AND TUBING FOR SPECIAL CRYOGENIC APPLICATIONS STAINLESS STEEL TYPE X2CrNiMo17-12-2 (1.4404, AISI 316L); CERN - European Organization for Nuclear Research; Geneva; Switzerland; 1999