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Product Procurement Specification

for the supply of

316L(N)-IG austenitic stainless steel forgings for the ITER ports components

Abstract

This specification covers the supply of austenitic stainless steel forgings grade 316L(N)-IG for the ports of the ITER Vacuum Vessel.

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Revisions

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1.3	29 Sept 2009		IDM number was added to each page.

* – Working version, after formal agreement with ANB version 1.3 will be downloaded in IDM.

Table of Content

1 Scope

This specification covers the supply of 316L(N)-IG austenitic stainless steel forgings and drop forgings with a unit weight of no more than 10 tonnes as-delivered condition for the ports of the ITER vacuum vessel.

Generally 316L(N)-IG steel is grade 316L steel with narrower alloying element ranges and controlled impurities. The closest analogy is X2CrNiMo17-12-2 controlled nitrogen content austenitic stainless steel described in the RCC-MR Code, Edition 2007.

This specification is based on the product procurement specification RM 3321in RCC-MR 2007 for forgings, plus additional requirements arising from the features of the ITER vacuum vessel and ports components. The forgings are considered for equipment Class 2 (in accordance with RCC-MR classification).

The amount of stainless steel forgings 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) Manufacture of the total quantity of stainless steel forgings, grade 316L(N)-IG.
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) To 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 to in this specification:

2.1 Design and Construction Code:

RCC-MR, Edition 2007
RCC-MR, 2007, Section 2 – Materials, Chapter RM3321
Applicable requirements of RM 0100 of RCC-MR, Edition 2007 must be respected.

2.2 EN and ASTM Standards:

EN 10222-1: 1998	Steel forgings for pressure purposes, Part 1: General requirements for open die forgings
EN 10002-1: 2001	Tensile testing at ambient temperature
EN 10002-5: 1991	Tensile testing at elevated temperature
EN 10228-4: 1999	Non-destructive testing of steel forgings, Part 4: Ultrasonic testing of austenitic and austenitic-ferritic stainless steel forgings
EN 10204: 2004	Metallic products: Type of inspection documents
EN ISO 643: 2003	Steels – Micrographic determination of the apparent grain size

ASTM E 45-05 (2005) Standard test methods for determining the inclusion content of steel
ASTM A342-04 Standard Test Methods for Permeability of Feebly Magnetic Materials

Other equivalent national or international standards and codes proposed by DA may be acceptable with prior written IO approval, provided conformity assessment to all criteria is satisfied. Conformity assessment will be submitted to Agreed Notified Body for agreement.

3 Melting Process

The steel shall be made using electric furnace or by any other technically equivalent process.

For vacuum application and to meet requirements for structure and inclusion contents in this specification the melting of steel should be completed by a suitable secondary metallurgy treatment and possibly re-melting step. The refining processes are argon-oxygen decarburization (AOD), vacuum oxygen de-carbonised (VOD). The remelting processes are electro-slag remelting (ESR) and vacuum arc remelting (VAR).

Supplier shall propose refining method, which shall be agreed with DA and IO.

4 Chemical requirements and Physico-chemical characteristics

4.1 Required values

Chemical composition, as determined by ladle and product analyses, shall comply with the requirements given in Table 1.

Table 1. Chemical composition

Element	**Alloying elements and impurities content, wt. %.**	
	min	max
C		0.030
Mn	1.60	2.00
Si		0.50
P		0.025
S		0.010
Cr	17.00	18.00
Ni	12.00	12.50
Mo	2.30	2.70
N	0.060	0.080
B		0.0020
Cu		0.30
Co		0.05
Nb		0.01
Ti		0.10
Ta		0.01

4.2 Chemical analysis

The Steelmaker shall supply a ladle analysis certified by the Mill Manager or his duly accredited representative. A product analysis is made per part for parts listed in RM 0141. A product analysis is made per heat.

This analysis may be performed on metal discards taken from mechanical test specimens. Chemical analyses and crosschecks shall be performed in a laboratory of Steelmaker choice, according to that laboratory's usual method. These analyses shall be performed in compliance with the requirements of RMC 1000.

4.3 Ferrite content and magnetic permeability

The ferrite content evaluated using the Schaeffler diagram modified by Pryce and Andrews (Figure RMC 1341.2, Section 3, RCC-MR 2007) and measured on a solution annealed product must be less than 0.5 %, (see note[1]).

The ferrite content shall be measured per lot in the mechanical test specimen sampling zone. Method of testing is RMC 1340 of RCC-MR, Edition 2007 or by method agreed between Supplier and Contractor (IO and DA).

The relative magnetic permeability of the finished forgings shall be measured at room temperature after solution annealing. The value measured shall be lower than 1.03 (see note[1]) (for fields of over 80000A/m (1000Oe) as per Test method 2 or measured with a low μ permeability indicator as per method 3 of ASTM A342. Specimen for testing shall be cut as described in the previous paragraph.

4.4 Structure

A micrographic examination, with photographs, shall be performed parallel to the main direction of extension. The structure must be homogeneous.

4.4.1 Grain size

The grain size number as determined in accordance with EN ISO 643 shall be greater than 2. The grain size homogeneity shall be ±1 around the true average value. The grain size is determined on a test sample taken close to the mechanical test specimens.

4.4.2 Non metallic inclusions

Amount and definition shall meet standard ASTM E45-05.

- Microinclusions (indigenous inclusions detectable by microscopical test methods): method D is applicable. Severity level number shall be at most 1 for types A, B and C and at most 1.5 for D. The tolerance for acceptance may be a half-class above the set limit to the extent of 2% of the fields counted.
- Macroinclusions (exogeneous inclusions from entrapped slag or refractories): they are strictly forbidden and are cause of rejection.

[1] Note:
Recommendation – the measured values shall be as low as possible in a practical way,

Test shall be done from one edge of forging.

5 Manufacture

5.1 Manufacturing programme

Before the beginning of manufacturing operations, the Foundry shall draw up a manufacturing programme. This programme shall include the following:

- identification of melting process,
- drawing of parts as-forged or drop-forget, profiles for heat treatment, non-destructive examination and delivery,
- conditions for intermediate heat treatments and for final heat treatment,
- position of acceptance test samples on the part,
- dimensional drawing with position of test specimens on samples.

The various heat treatments, sampling and non-destructive examination operations shall be presented in chronological order.

The produced parts shall be multi-directionally cross-forged. The program shall be agreed with DA and IO. The overall ratio of reduction as determined in RM 0380 shall be greater than 3.

5.2 Delivery condition

Forged parts shall be delivered in the solution heat treated condition then machined to the as-delivered profile.

5.2.1 Solution heat treatment

Solution heat treatment shall consist of holding at a temperature between 1050°C and 1150°C followed by water cooling. The thermal cycles shall be recorded and the records kept shall be presented in the test report.

5.2.2 Machining – surface conditions

The parts shall be machined to its as-delivered profile. The surface condition determined in accordance with RMC 7200 shall meet the following requirement: roughness Ra shall not exceed 6.3 microns.

6 Mechanical properties

6.1 Required values

Mechanical strength requirements shall to comply with values are given in Table 2.

Table 2. Mechanical properties

Tensile properties			
Test temperature, °C	**Tensile Strength, min, MPa**	**Yield Strength (0.2%), min, MPa**	**Elongation, (5d) min, %**
Room	525-700	220	45
200	423	144	-

6.2 Sampling

6.2.1 General

Test samples shall be cut:

- either from the part itself,
- or from a prolongation or excess material integrally attached to the part, after the part has undergone solution heat treatment; it shall be appropriately marked.

The size of the test samples shall be such that they can provide enough test specimens for all test and retests. Insofar as the shape of the parts so allows, test specimens shall be cut out in such a way that their axis is oriented perpendicular to the main forging direction and the distance between the axis and the nearest treated surface (skin) is:

- 20 mm if thickness is > 40 mm,
- Mid-thickness if the thickness is $\leq$ 40 mm.

The distance between the test-pertinent area of the test specimen and the other treated surfaces shall not be less than:

- 40 mm if the thickness is > 40 mm,
- The thickness if this is $\leq$ 40 mm.

If the shape of the parts does not permit this, values as close as possible to those given above shall be obtained.

6.2.2 Drop-forget parts

Mechanical test samples shall be cut out from one or more parts in a lot or, when this is impossible (for instance, very small parts) and subject to the approval of the Contractor, from a test bar of the same heat of steel simultaneously treated in the same heat treatment charge. This test bar shall first have been subjected to forging operations considered to be representative of those undergone by the parts.

The position of test specimen in the parts or the test bar shall be given in the mechanical test report in accordance with previous chapter “General”.

6.3 Testing in solution heat treated condition

Tests shall be performed on test specimens which were not subjected to heat treatment after sampling.

6.3.1 Definition a lot

- General case

A lot shall comprise parts of similar shape, cross-section and diameter, as defined below:

$$Ø_{max}/ Ø_{min} \leq 1.1 \; ; \; e_{max}/ e_{min} \leq 1.1 \; ; \; S_{max}/ S_{min} \leq 1.25$$

- Special case

The dimensions given above do not apply to hollow, circular parts 80 mm thick or less and weighting 500 kg or less.

In all cases the parts of the lot shall be from the same heat of steel. They shall undergone the same processing cycle and shall be from the same furnace charge or shall been subjected to the same heat

treatment run. A lot shall be limited to 5000 kg. However, each part with an as-delivered unit weight of more than 1000 kg shall constitute a lot. In addition, each part listed in RM 0141 shall constitute a lot.

6.3.2 Number and content of tests

One series of tests shall be performed per lot for parts weighting 500 kg or less and two series of tests shall be performed for parts weighting more than 500 kg. A test series shall comprise:

- tension testing at room temperature,
- tension testing at high temperature.

6.3.3 Test procedure

6.3.3.1 Tension testing at room temperature

- **Test specimen**
  Test specimens shall have a circular section. Their normal diameter shall be 10 mm and their dimensions as specified in Appendix D of EN 10002-1. For details see RMC 1211 of RCC-MR 2007.

- **Test method**
  The tension test shall be performed in compliance with EN 10002-1.
  The following values shall be recorded:
  - yield strength at 0.2% offset, in MPa,
  - yield strength at 1% offset, in MPa,
  - ultimate tensile strength, in MPa,
  - percentage elongation after fracture,
  - percentage reduction of area after fracture.

- **Results**
  Results obtained shall meet the requirements given in Table 2 (percentage of reduction of area and yield strength at 1% offset shall be given for information purposes). If this is not the case and the test specimen has a physical defect (which does not affect the usefulness of the product) or if unsatisfactory test results are due to incorrect mounting of the specimen or a testing machine malfunction, the test shall be repeated using another specimen. If the results of the second test are satisfactory, the part and /or the lot shall be accepted; if not, the following paragraph shall apply.
  When unsatisfactory results cannot be attributed to any of the above mentioned causes, two retests may be performed for each unsatisfactory result obtained. The second set of test specimen shall be taken from an area close to the one were defective samples originated from. If the results of the retest are satisfactory, the lot shall be accepted; if not, it shall be rejected, see chapter “Retreatment”.

6.3.3.2 Tension testing at high temperature

- **Test specimen**
  The nominal diameter shall be 10 mm. The dimensions are as specified in EN 10002-5. For details see RMC 1212 of RCC-MR 2007.

- **Test methods**
  The tension test shall be performed in compliance with EN 10002-5. The rate of stressing shall not exceed 80MPa per minute up to yield strength. For details see RMC 1212 of RCC-MR 2007.

- **Results**
  Yield strength at 0.2% offset obtained shall meet the requirements given in Table 2. If this not a case, the paragraph "Results" of chapter "Tension test at room temperature" shall be followed.

6.4 Retreatment

Lots rejected on the basis of unsatisfactory results for one or more mechanical tests may be retreated (solution heat treatment). Retreatment conditions shall be described in the test report.
In such cases, test specimens shall be taken in the same conditions as specified in chapter 6.2. Test performed shall be the same as those described in chapter 6.3.
No more than one retreatment shall be allowed.

7 Surface examination – surface defects

Surfaces shall be thoroughly examined during all phases of production and machining to check the soundness of metal.
The part shall be sound and free of scale, strings, tears, nicks or other injurious defects.
A visual examination shall be performed on all parts and this shall be followed by a liquid penetrant examination in accordance with RMC 4000.

The following recordable conditions and examination criteria shall be applied for liquid penetrant examination.
Except in the particular case described below, any defects with one dimension of 1 mm or more shall be considered a recordable condition.
The following indications shall be unacceptable:

- linear indications,
- rounded indications with one dimension grater than 3 mm,
- 3 or more indications aligned less than 3 mm apart edge to edge,
- 5 or more grouped indications within a rectangular area of 100 cm^2, whose greater dimension shall not exceed 20 cm, taken in the most unfavourable location relative to the indication being evaluated.

In the particular case of parts to be deep machined (removal of over 30% of the wall thickness), the condition regarding grouped indications shall be applied taking into account defects with one dimension greater than 0.5 mm.
When the examination described above indicate the presence of unacceptable defects on the part, the instruction of chapter "Removal of unacceptable areas" shall apply.

8 Volumetric examination

An ultrasonic volumetric examination shall be performed for all forgings.

8.1 Degree ant time of examination

This examination shall be performed when the profile of the part permits satisfactory test performance. It shall be performed in the following order of preference:

- after final machining,
- after heat treatment for mechanical properties, whether subsequent machining is performed or not.

Parts or portions of parts which cannot be examined after heat treatment due to the geometry of the part shall be examined at the latest intermediate stage possible.
In the case of small formed parts, the examination may be performed on semi-finished products.

8.2 Procedures

Ultrasonic examination procedures are specified in RMC 2310 and RMC 2320 and conditions specified in standard EN 10228-4 shall apply.
Probe characteristics shall normally be as follows:

- straight beam examination: frequency 2 MHz,
- angle beam examination: frequency 1 MHz, refraction angle depends on the part geometry.

A lower frequency may be used for thick parts if the structure so requires.

8.3 Scanning plane and degree of examination

The entire volume of the part shall be subject to ultrasonic examination. 100% scanning coverage defined in §12.4 of standard EN 10228-4 shall be performed. Part type is 1, 2, 3 or 4.

8.4 Evaluation of indications

Indications shall be evaluated in accordance with the requirements of RMC 2310 and RMC 2320.

8.5 Recordable conditions and examination criteria

- **Straight beam examination**
  The ranges considered and the acceptance criteria which depends on the thickness of the part examined, shall be those defined by the standard EN 10228-4 for normal probe. The quality class 2 shall be adopted.
  For thickness above or equal 75 mm, concerning the loss of back echo, the recordable attenuation range is $R \leq 0.12$ with no acceptability limit.

- **Angle beam examination**
  Any indications with echo amplitude $\geq$ 50% of the reference echo shall be recorded.
  Any indication whose echo amplitude is greater than the reference echo amplitude shall be unacceptable.

9 Removal of unacceptable areas

The Forging Mill may eliminate surface defects by grinding, provided the dimensional tolerances of the part in the as-delivered condition are respected.

After grinding, a liquid penetrant examination shall be performed in accordance with RMC 4000.
Examination criteria shall be those defined in chapter “Surface examination – surface defects”.
No repairs by welding by the Forging Mill shall be permissible.

10 Dimensional check

The dimensions shall be checked in accordance with the requirements of procurement drawings.
The main dimensions shall be recorded.
The values shall be within the tolerances given on the drawing.
In case of drop forgings, this examination shall be performed by representative sampling.

11 Marking

The Supplier shall specify the identification and marking method used, in compliance with RC 1300.

Marking shall include:
- manufacturer name or symbol,
- forging number or unique identification number related to quality history,
- grade of material,
- heat number.

Markings or codes which provide clear reference to documents containing the information required for production control will always be acceptable.

Samples delivered with the part shall be marked in accordance with provisions of the purchaser order.

12 Cleanliness-packaging-transportation

Requirements shall be specified in the purchase order, taking particular account of the requirements of RF 6000.

13 Acceptance

Material Test Report and certificate 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.

Certification
A certificate, that material was manufactured, sampled, tested and inspected in accordance with requirements of the material specification and has been found to meet those requirements shall be supplied to the purchaser.

14 Documentation and test report

The Supplier shall provide the Inspection Certificate type 3.1 in accordance with EN 10204:2004.

The Inspection Certificate is accepted only provided the Material Manufacturer has an appropriate quality-assurance system, certified by a competent body established within the European Community and having undergone a specific acceptance for materials.

Inspection certificate type 3.2 in accordance with EN 10204:2004 can be provided by Supplier after agreement with IO, providing justification that Accepted Notified Body or another Authorised Third Party Organisation followed the testing as specified in accordance with EN 10204:2004.

The following reports shall be drawn up by the Supplier after each individual test and, in any case, prior to delivery of the part:
- ladle and product analyses of chemical composition, where applicable,
- melting process method,
- records of micrographic examination, inclusions and grain size,
- ferrite content and permeability,
- results of mechanical property tests,
- non-destructive examination,
- dimensional check,
- record of heat treatment.

These reports shall include:
- material designation and marking,
- the heat number and part reference number,
- identification of supplier,
- identification of purchase order number,
- name of inspection agency, where applicable,
- test and retest results together with required values,
- 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.

15 Quality system requirements

The Supplier shall implement an adequate and currently operational quality system capable of ensuring that:

- contract requirements will be met,
- evidence of such compliance will be maintained.

The quality system implemented by the Supplier shall:

- be based on a recognized quality standard,
- encompass all activities performed in connection with the contract,
- be described in a manual to be submitted to the IO at the start of the work.

The Supplier shall ensure that each subcontractor implements an effective quality system. Failing this, the Supplier shall undertake all necessary actions to establish and maintain quality in subcontractors' premises.

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

16 Access of Inspectors

Representatives of the IO and of Third Party Inspector (TPI) shall at reasonable notice have the right to check at the Supplier's premises or at those of his sub-contractor the progress and status of the work forming the subject matter of the procurement and to witness specified tests.

The Supplier, via the concerned DA, shall hold at the disposal of the IO and TPI and make available to them such information and documents as are necessary to determine the progress and status of the work.