

Material Specification		
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Product Procurement Specification
for the supply of
austenitic stainless steel plates and forgings
for PF-1 poloidal coil ITER

PROCUREMENT ARRANGEMENT:1.1.P3A.RF.01

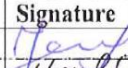
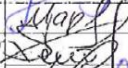


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1 Scope

This specification covers austenitic stainless steel hot rolled plates between 5 mm and 30 mm thick and forgings between 30 mm and 135 mm thick for the structural elements of the ITER PF-1 poloidal coil.

The amount of stainless steel plates and 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 plates and forgings grade.
- 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:

ASTM A 370 Test Methods and Definitions for Mechanical Testing of Steel Products,
ASTM A 479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels,
ASTM A 484/A 484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings,
ASTM A 480/A 480M-09B, 'General requirements for flat rolled stainless
ASTM A 511-04 Standard Specifications for Stainless Steel Mechanical Tubing,
EN 10088-2:2005, 'Stainless steels - Part 2: Technical delivery conditions for sheet/plate and strip for general purposes'
ASTM A 700 Standard Practices for Packing, making, and Loading Methods for Steel Products for Domestic Shipment,
ASTM A 751-95 Specification for Test Methods, Practices and Terminology of Chemical Analysis of Steel Product
ASTM A262-02A(2008) Standard Practices for Detecting Susceptibility to Inter-granular Attack in Austenitic Stainless Steel,
ASTM A 342, 'Test Method for Permeability of feebly magnetic Materials'
ASTM E 45-05(2005) Standard Test Methods for Determining the Inclusion Content of Steel,
ASTM E 112-96(2004)e1 Test Methods for Determining Average Grain Size,
ASTM E 8M Standard Test Methods for Tension Testing of Metallic Materials [Metric],
ASTM A 745, 'Standard Practice for ultrasonic Examination of austenitic Steel Forgings'
ASTM E 813 Standard Test Method for JIC, A Measure of Fracture Toughness,
ASTM E 0309-95(2006) Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation

ASTM E 0426-98(2007) Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys
ASTM E1820 Standard Test Method for Measurement of Fracture Toughness,
ASTM E 1450 Standard Test Method for Tension Testing of Structural Alloys in Liquid helium,
JIS Z 2284-1998 Method of Elastic-plastic Fracture Toughness JIC Testing for Metallic Materials in Liquid Helium.
JIS Z 2283 Method of Low Cycle Fatigue Testing for Metallic Materials in Liquid Helium.
JIS Z 2277-2000, "Method of Tensile testing for Metallic Materials in liquid Helium".
ISO 8249-2000 "Welding - Determination of Ferrite Number (FN) in austenitic and duplex ferritic austenitic Cr-Ni stainless steel weld metals".
ASTM E606-92 Standard Practice for Strain-Controlled Fatigue Testing
ASTM E739-91 Standard Practice for Statistical Analysis of Linear or Linearized Stress-Life (S-N) and Strain-Life (ϵ -N) Fatigue Data
ASME Section III, NB-2000
ASME Section V, Article 5 Ultrasonic Examination Methods for Materials and Fabrication
ASME Section V, Article 2 Radiographic testing
ASME Section V, Article 6 Liquid Penetrant Examination
ASME Section V, Article 9 Visual Examination
ISO 9712:2005, 'Non-destructive Testing – Qualification and Certification of Personnel'

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.

3 Melting process

The melting shall include a AOD or VOD process. The forgings shall be multi-directionally forged. The hot rolled plates and forgings shall be solution annealed and descaled. The descale process shall achieve a smooth finish. Imperfections that may be present shall be of such a nature or degree for the type and quality ordered that they will not adversely affect the machining of finished parts.

4 Definitions

A heat is a single melt of material used to cast one or several ingots

A lot for product analysis and other tests shall consist of all forgings, bars, and plates with the same geometric shape and production route made from the same ingot. The permitted variations in thickness, width, length and flatness are defined in Annex A3 of ASTM A 480/A 480M-09B.

A form is defined as a single example of a lot

5 Chemical requirements and physico-chemical characteristics

5.1 Chemical composition

The chemical composition 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
Cr	16.00	18.50
Ni	10.00	14.00
C		0.030
Si		1.00
Mn		2.00
Mo	2.00	3.00
N		0.10
P		0.030
S		0.020
Co		0.10
Nb		0.05
B		0.03
Fe		remainder

The material shall conform to the requirements of ASTM A480/A480M-09B for hot rolled plates, ASTM A 484A/484M for forgings and ASTM A511-04, which outlines manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

If the requirements of this specification are in conflict with the requirements of ASTM A480/A480M-09B, ASTM A484A/484M and A511-04, the requirements of this specification shall prevail.

5.2 Chemical analysis

Chemical analyses and crosschecks shall be performed in a laboratory of the steel manufacturer's choice, according to the laboratory's usual method.

Chemical analyse shall be performed for every melt

5.3 Ferrite content

The material shall be located in the austenite region above the 0% ferrite line in the DeLong phase Diagram as specified in the standard JIS Z3199 or any equivalent standard. Any trace of δ -ferrite visible on micrographs, following a suitable etching, at a magnification of 500x and in particular alignments of this phase shall be cause for rejection.

5.4 Magnetic properties

The relative magnetic permeability of the finished forging or hot rolled plate shall be measured at room temperature after solution annealing. The value measured shall be lower than 1.05 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. The material shall be free of δ -ferrite and σ -phase.

5.5 Structure

A micrographic examination with photographs must be made parallel to the rolling direction of each rolled plate. The structure must be homogeneous.

5.5.1 Grain size

The equivalent grain size number according to ASTM E112-96(2004)e1 shall be, as a target and on average, greater than 4 for all measurement fields. The grain size shall be homogeneous within the range of ± 1 equivalent grain size number around the true average value.

The determination is performed on test samples taken from the immediate vicinity of the mechanical test specimens.

5.5.2 Non metallic inclusions

The amount and definition of inclusions per lot shall follow method D of ASTM E 45-05.

1) Microinclusions (indigenous inclusions detectable by microscopical test methods): method D is applicable. Severity level number shall be at most 2 for inclusion types A, B, C and D. The tolerance for acceptance may be a half-class above the set limit to the extent of 2% of the fields counted.

2) Macroinclusions (exogeneous inclusions from entrapped slag or refractories): they are strictly forbidden and are cause of rejection

5.5.3 Carbides and carbo-nitrides, Inter-Granular Corrosion

The absence of any trace of carbides (in particular carbides that form a continuous network) and carbo-nitrides, which is to be checked at a magnification of 500x on the final product, is required.

The material shall be tested per ASTM A262-02A(2008), Practice A. Photomicrographs shall be compared to Figure 1 of ASTM A262-02A(2008). Material, which does not conform to Figure 1, shall be tested per ASTM A262-02A(2008), Practice E. Practice E shall be used as a basis for rejection of the material in accordance with ASTM A262-02A(2008).

5.5.4 Process

The melting shall include a AOD or VOD process. The forgings shall be multi-directionally forged.

The hot rolled plates and forgings shall be solution annealed and descaled. The descale process shall achieve a smooth finish. Imperfections that may be present shall be of such a nature or degree for the type and quality ordered that they will not adversely affect the machining of finished parts.

6 Mechanical properties

6.1 Required values

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

Table 2. Mechanical properties

Tensile properties					
Temp.	Young's Modulus (GPa)	Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	Elongation at Failure (%)	Fracture Toughness, K_{IC} (MPa m ^{1/2})
300 K	>190	>170	>480	>35 (target: 40)	N/A
< 7 K	>205	>700	>1000	>35	>150

6.1.1 Test procedure

- **Tensile testing**

Tensile tests shall be performed at room temperature and at helium temperature. Young's modulus, yield strength (0.2% offset), ultimate tensile strength, and elongation at failure shall be reported.

At room temperature, the tensile tests shall be performed in accordance to the document Test Methods and Definitions ASTM E8M-04, while at cryogenic temperature, the tests shall be performed in accordance with ASTM E1450-09.

- **Results**

The results obtained shall meet the requirements given in Table 2 (the percentage of area reduction and yield strength at 1% offset shall be given for information). 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 rolled sheet 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 specimens shall be compared to the defective ones. If the results of the retest are satisfactory, the rolled sheet shall be accepted; if not, it shall be rejected, see chapter "Retreatment".

6.1.1.1 Fracture Toughness at 4.2 K

Fracture toughness shall be measured at cryogenic temperature. The measurement shall be carried out on two standard, half-size, 5-mm-thick specimens. The two specimens shall be taken midway between the parallel surfaces and in the longitudinal direction of a same, compacted jacket section. The direction of crack propagation shall be the longitudinal direction. The manufacturer shall first fatigue pre-crack the specimens, and then, machine side grooves in accordance with JIS Z 2284-1998.

The test shall be carried out in a nominal helium cryogenic environment in accordance with JIS Z2284 or an equivalent test code. The results shall satisfy the requirements given in Table 2.

6.2 S-N curve

S-N curves at cryogenic temperature for the material shall be obtained according to JIS Z 2283 or equivalent. Other applicable standards for the test, and for the statistical processing and presentation of the data are ASTM E606-92 and E739-91. An S-N curve shall be produced for every heat. The acceptance criterion shall be a fatigue limit of at least 500 MPa after a minimum of 30,000 cycles.

6.3 Retreatment

Rolled plates rejected on the basis of unsatisfactory results for one or more mechanical tests may be retreated. Retreatment conditions shall be described in the test report.

Not more than one retreatment shall be allowed.

7 Surface examination – surface defects

Plates shall be visually examined. Their surfaces shall be plain, uniform and free from wrinkles, buckles, blowholes, tears, cracks and inclusions.

8 Non-destructive testing

A combination of US testing (procedures following ASME V, Article 5), radiographic testing (procedures following ASME V, Article 2) and penetrant testing (procedures following ASME V, Article 6) shall be performed to confirm the compliance with the maximum acceptable embedded flaw of area 7mm^2 and no visible surface cracks.

All NDT (with the exception of the visual examination) can be carried out by Level 1 or 2 qualified personnel as per ISO 9712:2005 but the coordination and reports shall be responsibility of a Level 3 NDT expert. The period of validity of the NDT level certification of the personnel shall not exceed 5 years.

9 Marking

Each forging and plate shall be marked mechanically engraved with:

- manufacturer name or symbol,
- plate number or unique identification number related to quality history,
- grade of material,
- heat number;
- the direction of rolling.

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.

10 Packaging

The packaging shall be strong enough to preserve the surface condition and evenness during transport and shall comply with ASTM A 700.

11 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.

A certificate, that the 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.

12 Quality provisions

The Supplier shall provide a Quality Plan which will be submitted to IO prior to the start of fabrication. This Plan shall include at least the following items:

- Material certificates
- Manufacture procedure
- Quality control procedure
- Acceptance tests procedures
- NDT procedures
- Non-conformance procedures

Qualification of the mechanical properties at 4K is required. Once a correspondence between RT and 4K measurements is established, RT measurements may be used for the quality controls. The determination of the mechanical properties at 4K shall be performed on 1 specimen from each typical product form.

Quality controls shall be carried out in accordance with the Quality Plan comply at least with the Table 3.

Table 3: Quality controls

Test	Frequency
Chemical analysis	Every melt
Structural analysis (structure/inclusions)	Every lot at head, centre and foot By sampling on the steel plates and forgings
X-ray testing or Ultrasonic	Each thickness or shape on steel plates and forgings
Ultrasonic	Each thickness or shape on steel plates and forgings
Mechanical properties at RT	Every lot at head, centre and foot By sampling on the steel plates and forgings
Mechanical properties at 4K	Every lot at head, centre and foot By sampling on the steel plates and forgings
Dimensions	Every product
Magnetic permeability	Every plate and forging and by sampling on steel plates and forgings
Penetrant test	Every product
Intergranular corrosion	Every lot at head, centre and foot By sampling on the steel plates and forgings
Visual inspection	Every product
CVN at 4K	Each thickness or shape on steel plates and forgings

13 Documentation and test report

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

A certified report of the test results shall be furnished at the time of shipment. This document shall contain at least:

- Purchase order number
- Forging identification number
- Heat number
- Heat treatment cycle
- Material Class according to Table 1
- Chemical analyses
- Mechanical tests
- Macro and micrographs
- Ultrasonic/Radiographic testing
- Radiographic testing
- Magnetic properties
- Dimensional inspection

- Non conformances

All these certificates shall be drawn up in accordance with the prevailing standards.

These reports shall include:

- material designation and marking,
- the heat number and part reference number,
- identification of the Supplier,
- identification of the purchase order number,
- name of the Inspection Agency, where applicable,
- test and retest results together with required values,
- packaging data.

The homogeneity of the steel shall be ultrasonically inspected solely to detect continuity faults after the last hot working operation.

The details of the ultrasonic inspection will be agreed as part of the supply qualification as a function of the product. Ultrasonic testing shall be performed in accordance with an approved written procedure that shall be submitted for approval during qualification.

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.