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Ext. Reference

Technical Specification of Raw Material for ITER Blanket Shield Block

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1 General Requirements

All materials shall conform to the requirements of this specification (see Table 1) and those of the ITER Vacuum Handbook Section 5.

All materials shall be new and of specified quality.

The Supplier shall ensure that each material is properly identified, each block of material being assigned a unique traceable number.

Traceability of each material shall be maintained throughout all manufacturing processes. Traceability documentation which cross-references component parts to material certificates shall be included in the given documentation.

All the materials required to manufacture the components are provided by the supplier, which shall ensure that the required characterisation and testing is performed and that the related certificates issued.

2 Material Specifications

Table 1 provide the reference for material specification applicable to the SB procurement.

Table 1 SB Material Specifications

Components	Material/Grade	Specification
ITER Blanket Shield Block (SB)	"Material Specification for the Supply of 316L(N) – IG Austenitic Stainless Steel Forgings ESR forgings	316L(N)-IG ESR Forging for Blanket (G2VF8B v1.2)
SB Cover Plates	"Material Specification for the Supply of 316L(N) – IG Austenitic Stainless Steel Plates" Non ESR plates	316L(N)-IG plate for Blanket (33XXJM v1.2)
Central bolt Spirallock Insert Electrical Strap Spirallock Insert	"Material Specification for the Steel number 1.4980 (grade 660)"	Steel number 1.4980 (grade 660) bars for the BMCs (PS3ASG v1.0)
Locking Pin for Spirallock inserts	Grade 660_Specification for Blanket applications	Grade 660 for Blanket (FUMUHR v1.2)



Appendix 1. Technical Specification “316L(N)-IG ESR or VAR Forging for Blanket”

Appendix 2. Technical Specification “316L(N)-IG plate for Blanket”

Appendix 3. Technical Specification “Steel number 1.4980 (grade 660) bars for the BMCs”

Appendix 4. Technical Specification “Grade 660 for Blanket”

Technical Specification

316L(N)-IG ESR or VAR Forging for Blanket

This specification covers the supply of 316L(N)-IG Electro Slag Re-melted (ESR) or Vacuum Arc Re-melted (VAR) austenitic stainless steel forgings and drop forgings with a unit weight of no more than 10 tonnes as-delivered condition for the ITER Blanket System.

Approval Process			
	Name	Action	Affiliation
Signatory	Merola M.	01 Jun 2015:signed	IO/DG/COO/TED/INC
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Reviewers	Barabash V.	08 Jun 2015:recommended	IO/DG/COO/CIO/AS
	Jung C. Y.	02 Jun 2015:recommended	IO/DG/RCO/QAA
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<i>Change Log</i>			
316L(N)-IG ESR or VAR Forging for Blanket (G2VF8B)			
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v0.0	In Work	23 Apr 2013	
v1.0	Approved	24 May 2013	1st issue for PA implementation
v1.1	Approved	11 Sep 2013	Table 1 modified Boron content reduced from 0.0020 to 0.0010 to improve reweldability
v1.2	Approved	01 Jun 2015	Minor changes

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1 Scope

This specification covers the supply of 316L(N)-IG Electro Slag Re-melted (ESR) or Vacuum Arc Re-melted (VAR) austenitic stainless steel forgings and drop forgings with a unit weight of no more than 10 tonnes as-delivered condition for the ITER Blanket System.

These forgings shall be used for components for blanket system with final thickness less than 5 mm.

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 document is based on the product procurement specification RM 3321 in RCC-MR 2007 for forgings, plus additional requirements due to the ITER Blanket system operations.

The quantity 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 ESR 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 EN and ASTM Standards

EN 10222-1: 1998	Steel forgings for pressure purposes, Part 1: General requirements for open die forgings
EN ISO 6892-1:2009	Metallic materials, Tensile testing, Part 1: Method of test at room temperature
EN ISO 6892-2:2011	Metallic materials, Tensile testing, Part 2: Method of test 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 10228-2: 1998	Non-destructive testing of steel forgings, Part 2: Penetrant testing
EN 10204: 2004	Metallic products: Type of inspection documents
EN ISO 643: 2003	Steels – Micrographic determination of the apparent grain size
ASTM E 45-13	Standard test methods for determining the inclusion content of steel
ASTM A342-14	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.

3 Ordering Information and Deliverables

It is responsibility of the DA to specify the requirements for the size of forgings in the purchase order.

4 Manufacturing Process

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

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

Supplier shall propose a detailed manufacturing process, which shall be approved by the IO and DA. Forging ratio shall be greater than 3.

5 Chemical Requirements and Physical Characteristics

5.1 Required values

Chemical composition, as determined by ladle (cast) 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
Cu		0.30
B		0.0010
Ti		0.10
Nb#		0.10
Ta#		0.01
Co#		0.05

Radiation protection requirements

5.2 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) shall be less than or equal to 0.5 %.

The relative magnetic permeability of the finished forgings shall be measured at room temperature after solution annealing. The value measured shall be lower than or equal to 1.03 as determined by an acceptable Test method per ASTM A342. Test method used shall be reported.

One specimen per lot shall be taken from a position close to mechanical test specimens.

Measurements made with other physical methods (e.g. permascope, magnetoscope, etc.) can be accepted provided information is supplied about the type and trade mark of apparatus proposed and information about the calibration. For these methods one test will be required per forging.

5.3 Structure

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

5.3.1 Grain size

The grain size number determined in accordance with EN ISO 643 shall be equal or greater than 3. The determination is performed on test samples taken from the immediate vicinity of the mechanical test specimens.

5.3.2 Non-metallic inclusions

Amount and definition shall meet the requirements of the ITER Vacuum Handbook; definitions shall meet the standard ASTM E45:

- Microinclusions (indigenous inclusions detectable by microscopical test methods): method D is applicable of ASTM E45-10. Severity level number shall be at most 1 for inclusions types A, B and C and at most 1.5 for D.
- Macroinclusions (exogenous inclusions from entrapped slag or refractories): they are strictly forbidden and are cause for rejection.

The test sample shall be taken from one edge of each forging.

6 Manufacture**6.1 Manufacturing programme**

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

- identification of melting process,

- drawing of parts as-forged or drop-forged, profiles for heat treatment, non-destructive examination and delivery,
- conditions for intermediate heat treatments and for final heat treatment for mechanical properties,
- 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 program shall be agreed with DA and IO.

6.2 Delivery condition

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

6.2.1 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.

6.2.2 Machining – surface conditions

The parts shall be machined to its as-delivered profile. The surface roughness Ra shall be 6.3 µm or finer. Method of testing shall be proposed by Supplier and agreed with DA and IO.

7 Mechanical Properties

7.1 Required values

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

Table 2. Mechanical properties

Test temperature, °C	Tensile Strength, MPa	Yield Strength (0.2%), min, MPa	Elongation, (5d) min, %
Room	525 -700	220	45
250	min 415	135	-

7.2 Sampling and testing

Test samples shall be taken after the forging has been subjected to solution heat treatment. Test sample shall be cut from either:

- the forging itself,
- or from a prolongation or excess material integrally attached to the part,

The samples shall be appropriately marked. The size of test samples shall be such that they can provide enough test specimens for all tests and re-tests.

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 the thickness is > 40 mm,
- mid-thickness if the thickness is ≤ 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 ≤ 40 mm.

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

Test specimens shall have a circular section. Their normal diameter shall be 10 mm. For forgings less than 20 mm thick, the cylindrical test specimen may be replaced by a specimen with a rectangular section.

The tension test shall be performed in compliance with EN ISO 6892-1:2009 at room temperature and or EN ISO 6892-2:2011 at elevated temperature.

The following values shall be recorded:

- yield strength at 0.2% offset, in MPa,
- yield strength at 1% offset, in MPa,
- tensile strength, in MPa,
- percentage elongation after fracture,
- percentage reduction of the area after fracture.

The percentage of area reduction and yield strength at 1% offset and elongation at elevated temperature shall be given for information.

Definition of lot:

A lot shall comprise parts of similar Diameter (dia) Thickness (e), Cross-Section (S) and, as defined below:

$$(\text{dia max.})/(\text{dia min.}) \leq 1.1 \quad (\text{e max.})/(\text{e min.}) \leq 1.1 \quad (\text{S max.})/(\text{S min.}) \leq 1.25$$

Special case: the dimensions given above do not apply to hollow, circular parts 80 mm thick or less and weighing 500 kg or less.

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.

7.3 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. No more than one retreatment shall be allowed.

8 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.

8.1 Penetrant examination

100% liquid penetrant inspection of each forging shall be undertaken in accordance with the requirements of EN 10228-2. The use of an ITER approved liquid penetrant is mandatory for all surfaces exposed to vacuum as specified in the ITER Vacuum Handbook.

The acceptance criteria shall be agreed at the time of the enquiry and order.

9 Volumetric Examination

100% of ultrasonic inspection of each product shall be provided in accordance with EN 10228: Part 4. The acceptance criteria, which depend on the thickness, shall be those defined in the standard EN 10228-4. The quality class 3 is adopted for forgings used for structural application.

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.

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.

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.

10 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.

Examination criteria shall be those defined in chapter “Surface examination – surface defects”.

No repairs by welding by the Forging Mill shall be permissible.

11 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.

12 Marking

The Supplier shall specify the identification and marking method used.

Marking shall include:

- manufacturer name or symbol
- grade of material
- forging number or unique identification number related to quality history
- 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.

13 Summary and Frequency of Required Tests

Table 3. Frequency of tests

Test		Frequency of test	Comments
Chemical composition		1 test per heat 1 test per lot	
Determination of Ferrite content – evaluation using Schaeffler diagram		Calculated using the results of chemical analysis for heat	Always calculated using the results of chemical analysis
Magnetic permeability		1 test per lot	Samples taken close to mechanical test specimens
Structure	Photographs	1 test per lot	Samples taken close to mechanical test specimens
	Grain size	1 test per lot	Samples taken close to mechanical test specimens
	Non-metallic inclusions	Per each forging	Samples taken close to mechanical test specimens
Surface examination conditions		Per each forging	-
Liquid penetrant examination		Per each forging	-
Ultrasonic examination		Per each forging	See specification for details
Dimensional check		Per each forging	In accordance with drawing

Tensile test	Forging's weight (w)	Number of tests	Frequency of test
Test temperature – Room Temp	$w \leq 500$ kg	1	Per lot

Test temperature – 250°C		1	
Test temperature – Room Temp	w > 500kg	2	Per lot
Test temperature – 250°C		2	

Note: each part with an as-delivered unit weight of more than 1000 kg shall constitute a lot.

14 Cleanliness, Packaging and Transportation

Requirements shall be specified in the purchase order.

15 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.

16 Documentation and test report

The Supplier shall provide the Inspection Certificate type 3.1 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,
- test and retest results together with required values.

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.

17 Quality Assurance Requirements

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

A manufacturing and Inspection plan (MIP) shall be provided for each forging in accordance with [Requirements for Preparing and Implementing a Manufacturing and Inspection Plan \(22MDZD\)](#).

Technical Specifications (In-Cash Procurement)

316L(N)-IG plate for Blanket

This specification covers 316L(N)-IG austenitic stainless steel hot rolled quarto plates between 5 mm and 100mm thick for the ITER Blanket System.

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1 Scope

This specification covers 316L(N)-IG austenitic stainless steel hot rolled quarto plates between 5 mm and 100 mm thick for the ITER Blanket System.

These plates shall be used for components of the ITER facility, where the surface of plates parallel to the direction of rolling forms the vacuum boundary.

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 document is based on the product procurement specification RM 3331 in RCC-MR 2007 for plates, plus additional requirements due to the ITER Blanket System operation.

The quantity of stainless steel plates 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 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 EN and ASTM Standards

EN 10088-2: 2005	Stainless steels. Technical delivery conditions for sheet/plate and strip of corrosion resisting steels for general purposes
EN 10028-1: 2001	Flat products made of steels for pressure purposes, Part 1: General requirements
EN ISO 6892-1:2009	Metallic materials, Tensile testing, Part 1: Method of test at room temperature
EN ISO 6892-2:2011	Metallic materials, Tensile testing, Part 2: Method of test at elevated temperature
EN 10307: 2001	Ultrasonic testing of austenitic and austenitic-ferritic stainless steels flat products of thickness equal to or greater than 6 mm
EN 10204: 2004	Metallic products: Type of inspection documents
EN 10029: 2010	Hot rolled steel plates 3 mm thick or above -Tolerances on dimensions, shape and mass
EN ISO 643: 2003	Steels – Micrographic determination of the apparent grain size
ASTM E 45-13	Standard test methods for determining the inclusion content of steel

ASTM A342-14 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.

3 Ordering Information and Deliverables

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

4 Manufacturing Process

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

To meet structure and inclusion contents in this specification, the melting of steel shall be completed by a suitable secondary metallurgy treatment. The refining processes are argon-oxygen decarburization (AOD) or vacuum oxygen de-carbonised (VOD).

Supplier shall propose a detailed manufacturing process, which shall be approved by the IO and DA.

5 Chemical Requirements and Physical Characteristics

5.1 Required values

The chemical composition determined by ladle (cast) 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
Ti		0.10
Nb#		0.10
Ta#		0.01
Co#		0.05

Radiation protection requirements

5.2 Chemical analysis

The Steelmaker shall supply a ladle analysis certified by the Mill Manager or his duly accredited representative. In addition they shall provide a product analysis taken from each rolled sheet or strip.

5.3 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) shall be less than or equal to 0.5 %.

The relative magnetic permeability of the finished plates shall be measured at room temperature after solution annealing. The value measured shall be lower than or equal 1.03 as determined by an acceptable Test method per ASTM A342. Test method used shall be reported.

One specimen per heat treated sheet or strip shall be taken from position close to mechanical test specimens.

Measurements made with other physical methods (e.g. permascope, magnetoscope, etc.) can be accepted provided information is supplied about the type and trade mark of apparatus proposed and information about the calibration. For these methods one test will be required per sheet or strip.

5.4 Structure

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

5.4.1 Grain size

The grain size number determined in accordance with EN ISO 643 shall be equal or greater than 2. The grain size homogeneity shall be ± 1 around the true average value. The presence of a few grains of index 1 or 0 is tolerated.

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

5.4.2 Non-metallic inclusions

Amount and definition shall meet the standard ASTM E45.

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

The test sample shall be taken from one edge of each rolled sheet or strip.

6 Manufacture

6.1 Manufacturing programme

Prior to the commencement of manufacturing operations, the material Supplier shall draw up a manufacturing programme.

The program shall be agreed with DA and IO.

6.2 Delivery condition

The plates shall be delivered in a solution heat treated, pickled and passivated condition, equivalent to 1D finish according to EN 10088-2.

6.2.1 Solution heat treatment

Solution heat treatment shall consist of maintaining a temperature of between 1050°C and 1150°C followed by water cooling and possible air cooling for smaller thicknesses. The thermal cycles shall be recorded and the records kept shall be presented in the test report.

6.2.2 Surface conditions

The surface shall be pickled.

No trace of oil or grease must remain on the surface of the metal in the as-delivered condition.

The surface roughness Ra of the plates evaluated shall be on average 6.3 µm. Method of testing shall be proposed by Supplier and agreed with DA and IO. Roughness measurement in accordance with EN ISO 4288 can be used.

7 Mechanical Properties

7.1 Required values

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

Table 2. Mechanical properties

Test temperature, °C	Tensile Strength, MPa	Yield Strength (0.2%), min, MPa	Elongation, (5d) min, %
Room	525 - 700	220	45
250	min 415	135	-

7.2 Sampling and testing

Test samples shall be taken after the plate has been subjected to solution heat treatment. They shall be appropriately marked and show the final rolling direction.

The size of test samples shall be such that they can provide enough test specimens for all test and retests. Test samples shall be taken halfway between the edge and the axis of the plate centreline. Specimens shall not be taken closer to the edge of the sample, than a distance equal to the thickness of the plate. The longitudinal axis of the test specimens shall be parallel to the rolling skins and perpendicular to the final rolling direction.

The longitudinal axis for tension test specimens is located as follows:

- for plates 30 mm thick or less, at mid-thickness,
- for plates thicker than 30 mm, at quarter thickness,
- for plates less than 10 mm thick, the thickness of the test specimen shall be equal to the thickness of the plate (specimen with rectangular cross-section).

Table 3. Number of and content of test – sampling

				Top end			Bottom end			Number of specimens	
Name of test	Test temperature, °C	Weight of plate	Thickness, t	Full thick-ness	Mid-thick-ness	Quarter thick-ness	Full thick-ness	Mid-thick-ness	Quarter thick-ness	Per heat	Per sheet
Solution heat treated											
Tensile	Room	≤ 3000 kg	< 10 mm	1							1
			10 mm ≤ t ≤ 30 mm		1						1
			> 30 mm			1					1
	Room	> 3000 kg	< 10 mm	1			1				2
			10 mm ≤ t ≤ 30 mm		1			1			2
			> 30 mm			1			1		2
	250	Regardless of weight	< 10 mm	1						1	
			10 mm ≤ t ≤ 30 mm		1					1	
			> 30 mm			1				1	

Test specimens shall have a circular section. Their normal diameter shall be 10 mm and their dimensions as specified in EN ISO 6892-1:2009. For plates less than 20 mm thick, the cylindrical test specimen may be replaced by a specimen with a rectangular section.

The tension test shall be performed in compliance with EN ISO 6892-1:2009 at room temperature and EN ISO 6892-2:2011 at elevated temperature.

The following values shall be recorded:

- yield strength at 0.2% offset, in MPa,
- yield strength at 1% offset, in MPa,
- tensile strength, in MPa,
- percentage elongation after fracture,
- percentage reduction of the area after fracture.

The percentage of area reduction; yield strength at 1% offset and elongation at elevated temperature shall be given for information.

7.3 Retreatment

Rolled sheet or strip rejected on the basis of unsatisfactory results for one or more mechanical tests may be retreated (solution heat treatment as per 6.2.1) Retreatment conditions shall be described in the test report. Not more than one retreatment shall be allowed.

8 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.

After cutting to the delivery dimensions, the edges shall be visually examined. The absence of cleavage or lamination (for example comprised by a fine layer of inclusions drawn out during rolling) shall be checked. If in doubt, a liquid penetrant examination shall be performed.

8.1 Penetrant examination

100% liquid penetrant inspection of each plate shall be undertaken in accordance with the requirements of EN 10228-2. The use of an ITER approved liquid penetrant is mandatory for all surfaces exposed to vacuum as specified in in the ITER Vacuum Handbook.

The acceptance criteria shall be agreed at the time of the enquiry and order.

9 Volumetric Examination

All plates shall be examined. An ultrasonic examination shall be performed in compliance with EN 10307.

The examination shall be carried out, in accordance with the scanning plan and the criteria given in standard EN 10307, quality class S3 for plate body and quality class E4 for plate edges.

10 Repair Welding

No repairing of defects by welding is accepted for the products.

11 Summary and Frequency of Required Tests

The number of tensile tests is specified in Table 3.

Table 4. Frequency of tests

Test		Frequency of test	Comments
Chemical composition		1 test per heat	
		1 test per plate (sheet or strip)	
Determination of Ferrite content – evaluation using Schaeffler diagram and measurement on a heat		Calculated using the results of chemical analysis	Always calculated using the results of chemical analysis
Magnetic permeability		1 test per sheet or strip	Samples taken close to mechanical test specimens
Structure	Photographs	1 test per sheet or strip	Samples taken close to mechanical test specimens
	Grain size	1 test per sheet or strip	Samples taken close to mechanical test specimens
	Non-metallic inclusions	1 test per sheet or strip	Samples taken close to mechanical test specimens
Surface examination conditions		1 test per plate	-
Ultrasonic examination		1 test per plate	See specification for details
Dimensional check		1 test per plate	In accordance with drawing

12 Dimensional Check - Tolerances

The dimensions of the plates shall comply with requirements of the purchase order. The tolerances for thickness, length, width, flatness, edge camber and out-of squareness shall comply with EN 10029.

13 Marking

The Supplier shall specify the identification and marking method used.

Each plate shall be legibly identified with the following information:

- manufacturer name or symbol,
- grade of material,
- plate number or unique identification number related to quality history,
- direction of rolling,
- dimensions: plate thickness, width and length, type of finish,
- heat (cast) 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.

14 Cleanliness, Packaging and Transportation

Requirements are specified in the purchase order.

15 Acceptance

Material Test Reports shall 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.

16 Documentation and Test Report

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

The following reports shall be drawn up by the Supplier after each individual test and prior to the delivery of the part:

- ladle and product analyses,
- 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 and roughness,
- record of heat treatment.

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,
- test and retest results together with required values.

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.

17 Quality Assurance Requirements

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

A manufacturing and Inspection plan (MIP) shall be provided for each plate in accordance with [Requirements for Preparing and Implementing a Manufacturing and Inspection Plan \(22MDZD\)](#).

Technical Specification

Steel number 1.4980 (grade 660) bars for the BMCs

Material Specification for the supply of X6NiCrTiMoVB25-15-2 [No. 1.4980] (similar to ASTM steel 660, UNS Number S66286) precipitation hardened steel bars for bolting for the ITER Blanket System

Approval Process			
	Name	Action	Affiliation
Signatory	Eaton R.	01 Aug 2014:signed	IO/DG/DIP/TKM/INC/BKT
Co-signatories	Barabash V.	01 Aug 2014:signed	IO/DG/DIP/PSE/PEI/SEAS
Reviewers	Chappuis P.	04 Aug 2014:recommended	IO/DG/DIP/TKM/INC/BKT
	Jung C. Y.	01 Aug 2014:recommended	IO/DG/SQS/QA
	Raffray R.	06 Aug 2014:recommended	IO/DG/DIP/TKM/INC/BKT
Approver	Merola M.	18 Aug 2014:approved	IO/DG/DIP/TKM/INC
Document Security: Internal Use RO: Barabash Vladimir			
Read Access	RO, project administrator, LG: Blanket add right persons, LG: Blanket Materials, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: IC_OMPE_WG, AD: Auditors, AD: ITER Management Assessor		

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1 Scope

This specification covers grade **X6NiCrTiMoVB25-15-2 (No. 1.4980) (which is European analogue of ASTM steel 660, UNS Number S66286)** structural hardening austenitic stainless steel hot rolled or forged bars with diameter not greater than 160 mm for the Blanket Module Connections (BMCs) for the ITER Blanket System. The products are intended for bolting.

This specification is based on the European Standard EN 10269:2013 and includes some additional requirements established for the ITER application.

The amount of the steel bars to be procured shall be specified by the supplier 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:

- Manufacture of the total quantity of stainless steel bar grade X6NiCrTiMoVB25-15-2 (No. 1.4980).
- Organization of quality at works.
- Elaboration of all procedures required for the manufacturing, inspection (including analysis), packaging, storage and delivery.
- Time schedules and documentation.
- To perform all the inspections and tests during and after manufacturing envisaged in this specification.
- Storage, packaging and delivery.

2 Referenced documents

The following Codes and Standards shall be referred to in this specification (latest editions of standards shall be used):

- EN 10269:2013 Steels and Nickel Alloys for Fasteners with specified elevated and/or low temperature properties
- EN ISO 6892-1:2009 Metallic materials — Tensile testing — Part 1: Method of test at room temperature
- EN ISO 6892-2:2011 Metallic materials — Tensile testing — Part 2: Method of test at elevated temperature
- EN ISO 148-1, 2009 Metallic materials — Charpy pendulum impact test — Part 1: Test method
- EN 10221:1995 Surface quality classes for hot-rolled bars and rods –Technical delivery conditions
- EN 10204: 2004 Metallic products: Type of inspection documents
- EN ISO 6506-1:2005 Metallic Materials – Brinell hardness test.
- EN ISO 377: 2013 Steel and steel products – Location and preparation of samples and test pieces for mechanical testing
- EN ISO 14284: 2002 Sampling and preparation of samples for the determination of chemical composition
- EN ISO 643: 2012 Steels - Micrographic determination of the apparent grain size.
- ASME Edition 2013, Section V, Article 5, Ultrasonic Examination Methods for Materials
- ASME Edition 2013, Section III, Subsection NG, chapter NG-2584

In case of change of edition year or issuing standard which supersede above mentioned, the use of new standards is allowed only in case of demonstration of equivalency with prior written IO approval.

Other equivalent national or international standards and codes proposed by the supplier may be acceptable with prior written IO approval, provided conformity assessment to all criteria is satisfied.

3 Information to be presented by the purchaser

Mandatory information is presented in Chapter 7.1 of EN 10269:2013.

Additional requirements are presented in this specification.

The nominal dimensions and tolerances on dimensions shall be in accordance with the relevant dimensional standards listed in EN 10269. The surface condition shall be defined in the purchase order. The purchaser shall specify a surface quality class in accordance with EN 10221.

The weight of batch shall be limited by 1000 kg.

4 Melting process

The steel shall be made using electric furnace or by any other technically equivalent process and shall be vacuum-remelted or electro slag remelted.

5 Delivery conditions

The purchaser shall specify in his enquiry and order the delivery condition required.

Final components in design shall be in solution annealed and precipitation treated condition.

Purchaser may select material only in solution treated condition, but it shall be demonstrated that after final precipitation treatment mechanical properties of material in accordance with this specification will be met.

The heat treatments for mechanical properties are given in Table 4 (+AT+P) and in Table B.1 of the standard EN 10269 for grade X6NiCrTiMoVB25-15-2.

- Solution treatment - 970 to 990°C, hold 2 h, oil or water quench;
- Precipitation hardening treatment - 710 to 730°C, the minimum time for precipitation hardening shall be 16 hours.

The bars shall be machined to its as-delivered profile.

6 Chemical composition

The Steelmaker shall supply a ladle analysis certified by the Mill Manager or his duly accredited representative. The chemical composition determined by ladle and product analyses, shall comply with the requirements given in Table 1.

The product analysis shall not deviate from the specified values of the cast analysis as specified in EN 10269. For the product analysis one sample per cast (heat) shall be taken for determining the elements indicated with numerical values in Table 1.

Table 1. Chemical composition

Element	Alloying elements and impurities, wt. %	
	Min	Max
Fe	balance	
C	0.030	0.080
Si		1.00
Mn	1.00	2.00
P		0.025
S		0.015
Cr	13.50	16.00
Mo	1.00	1.50
Ni	24.00	27.00
Ti	1.90	2.30
V	0.10	0.50
B	0.003	0.010
Al		0.35
Co*		0.05
Ta*		0.01
Nb*		0.10

***Radiation protection requirements**

7 Structure and grain size

A micrographic examination, with photographs at 200X magnification, shall be performed parallel to the maximum direction of extension. The structure must be homogeneous.

The grain size number determined in accordance EN ISO 643 shall not be less than 3. The presence of a few grains of index 1 or 2 is tolerated. Test shall be performed per lot (test unit as for definition in EN 10269).

8 Manufacture

8.1 Manufacturing programme

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

- Identification of melting process.
- As-treated and as-delivered bar diameters.

- Conditions for intermediate heat treatments and for final heat treatment.
- 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 overall ratio of reduction generally shall not be less than 3.

9 Mechanical properties

9.1 Required values

The material shall conform to the mechanical property requirements specified in Table 2 after applying the heat treatments for mechanical properties given in Table 4 (+AT+P) and in Table B.1 of the standard EN 10269: solution annealing and precipitation hardening.

Table 2. Mechanical properties

	Tensile properties				
Test Temp. (°C)	Tensile Strength, (Rm) (MPa)	Yield Strength (Rp0.2%) min (MPa)	Elongation A, min (%)	Impact energy (ISO-V) (J) min	Brinell Hardness (HBW)
Room	900 - 1150	600	15	50	248 – 341
250	803 min	550	-	-	-

The yield strength at 1% offset (at RT and elevated temperature) shall be recorded for information purposes.

9.2 Sampling

Sampling and sample preparation shall be in accordance with the requirements of standard EN 10269: EN ISO 14284:2002 (chemical composition) and EN ISO 377:2013 (mechanical tests). If the product is not delivered in the solution annealed and precipitation hardened condition, the samples shall be treated.

Round test pieces shall be prepared for the tensile test at room temperature in accordance with EN ISO 6892-1 and for the tensile test at elevated temperature in accordance with EN ISO 6892-2.

Three longitudinal V-notched test pieces in accordance EN 10269 and in accordance with EN ISO 148-1 shall be prepared for the impact test.

9.3 Test methods

The test shall be performed on specimens taken from samples subjected to no heat treatment after sampling.

Frequency of testing

.

The test unit for the other tests shall be the batch of products or part thereof coming from the same cast and having been treated in the same batch and in the same heat treatment facility.

Refer to Table 12 of EN 10269:2013 for the quantity of test samples and test pieces depending on batch size. Note additional requirements for Brinell Hardness Tests.

Test methods – for details refer to requirements of EN 10269 (chapter 11) and the following standards:

- EN ISO 6892-1:2009 Metallic materials — Tensile testing — Part 1: Method of test at room temperature
- EN ISO 6892-2:2011 Metallic materials — Tensile testing — Part 2: Method of test at elevated temperature
- EN ISO 148-1:2009 Metallic materials — Charpy pendulum impact test — Part 1: Test method
- EN ISO 6506-1:2005 Metallic Materials – Brinell hardness test

A hardness test shall be performed on one bar from the batch (test unit).

10 Visual examination

All surfaces shall be thoroughly examined during all phases of production to check the soundness of metal.

The bars shall be smooth, plain, uniform, sound and free of scale, strings, tears, nicks or other injurious defects (class E as per EN 10221:1995).

11 Non-destructive ultrasonic examination

100% of ultrasonic inspection of each product greater than 13 mm nominal bolt size shall be done in accordance with ASME Section V, Article 5. The examination procedure and acceptance standard shall be in accordance with ASME Section III, NG-2584.

12 Dimensional check

The dimensions and tolerances shall be checked in accordance with the requirements of purchase order.

The main dimensions shall be recorded.

13 Marking

The Supplier shall specify the identification and marking method used, in compliance Chapter 12 of EN 10269:2013.

Marking shall include:

- Manufacturer name, trade mark or symbol.
- Steel name or number.
- Type of finish.
- Identification number related to quality history (including traceability if the cast number).
- Nominal diameter.
- Customer's order 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.

14 Cleanliness-packaging-transportation

Requirements are specified in the purchase order.

15 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.

16 Documentation and test report

The Supplier shall provide the Inspection Certificate type 3.1 in accordance with EN 10204:2004. The inspection certificate 3.1 shall include, in accordance with EN 10168, the codes described in EN 10269.

The following reports shall be drawn up by the Supplier after each individual test and prior to the delivery of the part:

- Ladle and product analyses.
- Melting process method.
- Records of micrographic examination and grain size.
- Results of mechanical property tests.
- Non-destructive examination.
- Dimensional check.

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.
- 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.

17 Quality system requirements

The quality organisation shall comply with the requirements defined in Annex A of the Procurement Arrangement as specified in the contract and purchase order.

18 Access of Inspectors

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

Technical Specification

Grade 660 for Blanket

This specification covers the supply of bars of Grade 660 (UNS Number S66286) for use for the ITER Blanket System.

Approval Process			
	Name	Action	Affiliation
Signatory	Merola M.	01 Jun 2015:signed	IO/DG/COO/TED/INC
Co-signatories			
Reviewers	Barabash V. Jung C. Y. Raffray R.	08 Jun 2015:recommended 03 Jun 2015:recommended 02 Jun 2015:recommended	IO/DG/COO/CIO/AS IO/DG/RCO/QAA IO/DG/COO/TED/INC/BKT
Approver	Merola M.	09 Jun 2015:approved	IO/DG/COO/TED/INC
Document Security: Internal Use RO: Barabash Vladimir			
Read Access	LG: Blanket add right persons, LG: Blanket Materials, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: EMAB, AD: Auditors, AD: ITER Management Assessor, project administrator, RO		

<i>Change Log</i>			
Grade 660 for Blanket (FUMUHR)			
<i>Version</i>	<i>Latest Status</i>	<i>Issue Date</i>	<i>Description of Change</i>
v0.0	In Work	29 Apr 2013	
v1.0	In Work	24 May 2013	1st Issue of specification for Blanket PA
v1.1	Approved	27 May 2013	Reference to ASTM E45 removed
v1.2	Approved	01 Jun 2015	Minor changes

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1 Scope

This specification covers the supply of bars of Grade 660 (UNS Number S66286) for application on the ITER Blanket System where threading is not required.

This specification is based on ASTM standard A638/A638M - 10 and includes additional requirements. The used terminology and definitions are as per A638/A638M -10 and A484/A484M-10.

The quantity of the material 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 total quantity of bars
- 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:

2.1 ASME Code

Section V, Article 9 Visual Examination,

2.2 ASTM Standards

A638/A638M - 10	Standard Specification for Precipitation Hardening Iron Base Superalloy Bars, Forgings and Forging Stock for High-Temperature Service
A484/A484M - 10	Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings
A751 - 08	Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
E112 - 10	Standard Test Methods for Determining Average Grain Size
E21 - 09	Standard Test Methods for Elevated Temperature Tension Tests of Metallic Materials

And including all relevant standards in ASTM A484/A484M – 10 and ASTM A638/638M-10.

2.3 EN Standard

EN 10204:2004 Metallic products: Type of inspection documents

Other equivalent national or international standards and codes may be acceptable subject to written approval by the ITER Organisation (IO), after demonstration that all the prescribed requirements are satisfied.

3 Definition, manufacture, heat treatment and delivery condition

3.1 Definitions

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

Definition of lot – see ASTM A484/A 484M: A lot for product analysis shall consist of all bars, shapes, or forgings made from the one heat with the same manufacturing process and the same applied heat treatment. For other tests required by the product specification, a lot shall consist of all bar products of the same size, with total weighing less than 500 kg and produced under the same processing conditions.

3.2 Manufacture, heat treatment and delivery requirements

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

Purchaser shall specify in the purchase order required product forms as described in Section 3 (Ordering Information) of ASTM A638/638M.

Final part in design shall be in solution and precipitation treated condition, Purchaser may select material only in solution treated, but it shall be demonstrated that after final precipitation treatment mechanical properties of this specification will be met

Samples cut from bars shall conform to the mechanical properties of Table 2 (section 6 of this specification) when heat treated.

Type 2 heat treatment in accordance with ASTM A638/A638M is selected:

- Solution treatment - $980 \pm 15^{\circ}\text{C}$, hold 1 h, oil or water quench
- Precipitation hardening treatment - 705 to 760°C , hold 16 h, air cool or furnace cool

4 Chemical Composition

The material shall conform to the chemical composition requirements prescribed in Table 1. Chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

One sample per heat shall be selected for chemical analysis.
For the product analysis, one sample per lot shall be taken.

Table 1 Chemical composition requirements

Element	Content in wt. %
Fe	balance
C	0.08 max
Mn	2.00 max
P	0.040 max
S	0.030 max
Si	1.00 max
Ni	24.00 – 27.00
Cr	13.50 – 16.00
Mo	1.00 – 1.50
Ti	1.90 – 2.35
Al	0.35 max
V	0.10 – 0.50
B	0.001 – 0.010
Nb#	0.10
Ta#	0.05
Co#	0.20

Radiation protection requirements

5 Grain size, microstructure and inclusions requirements

The microstructural examination to determine grain size is to be in accordance with ASTM E112. The grain size number shall be equal or greater than 2. Micrographic examination with photograph shall be performed and reported.

6 Mechanical Properties

6.1 Tensile Properties and hardness

The material shall conform to the mechanical property requirements specified in Table 2 after heat treatment as described in Section 3 of this specification.

Table 2 Requirement for tensile properties*

Temperature, °C	Tensile Strength, min, MPa	Yield Strength, 0.2% min, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Brinell Hardness
Room	895	585	15	18	248 min
250	803	549			

* Heat treatment Type 2: solution annealing + precipitation hardening treatment (Section 3 of this specification).

Two tensile tests at ambient and elevated temperatures and one hardness measurement shall be made if the lot consists of parts of the same nominal diameter.

Test shall be performed at room temperature in accordance with ASTM A370 (referred in ASTM A484) and at elevated temperature in accordance with ASTM E21.

7 Dimensions and Permissible Variations

The material shall conform to the permissible tolerances indicated in Purchaser's order and in compliance with A484/A484M -10.

8 Non-destructive examination

8.1 Visual Examination

All external surfaces 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 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.

10 Summary and Frequency of Required Tests

Table 3 Frequency of tests

Test	Frequency of test	Comments
Chemical composition	1 test per lot	
Grain size and micrograph	1 test per lot	Samples taken close to mechanical test specimens
Tensile properties	2 test per lot	2 specimens at each testing temperature (4 specimens in total)
Hardness	1 tests per lot	
Dimensional check	Per each bar	In accordance with purchase drawing
Visual examination	Per each bar	-

11 Documentation

The Supplier shall provide the Inspection Certificate type 3.1 in accordance with EN 10204:2004. The following reports shall be issued by the Supplier:

- Material designation and marking,
- Melting process method,
- Heat number,
- Identification of Supplier,
- Identification of order,
- Result of chemical analysis,
- Record of heat treatment,
- Records of microstructure examination, and grain size,
- Results of mechanical property tests (tensile, hardness),
- Records of visual examination ,
- Product number or unique identification number related to quality history.

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 Marking and Packaging

See ASTM A638 requirements:

Each bundle shall be properly tagged with metal tags showing the purchase order number, heat number, name of alloy (or grade).

Bars 25 mm and over in diameter, or in 25 mm and over in thickness between parallel sides, shall be stamped with the heat number, within approximately 50 mm of one end. Smaller sizes shall be boxed or bundled and identified with metal tags as described in above.

Additionally the following shall be reported:

- Specification number,
- Heat number,
- Heat treatment condition,
- Dimensions: diameter and length, total weight, type of finish.

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

13 Quality Assurance Requirements

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