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Technical Specification

Procurement Specification for supply NiCr19Fe19Nb5Mo3_NB_Bolts

The Purpose of this document is to define a Procurement Specification for the supply of material NiCr19Fe19Nb5Mo3 [No. 2.4668] (similar to Alloy 718) Bars for Bolts of the Neutral Beam Components.

This document has been done from the document ITER_D_AHMGDY (v2.6) [Product Procurement Specification for the supply of NiCr19FeNb5Mo3 [No. 2.4668] (similar to Alloy 718) Bars for Bolts of the ITER VVGS]

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Table of Contents

1	PURPOSE	3
2	SCOPE	3
3	DEFINITIONS	4
4	REFERENCES DOCUMENTS.....	4
4.1	DESIGN AND CONSTRUCTION CODE	4
4.2	EN AND ASTM STANDARDS	4
5	MELTING PROCESS.....	4
6	CHEMICAL REQUIREMENTS AND PHYSICO-CHEMICAL CHARACTERISTICS.....	5
6.1	REQUIRED VALUES.....	5
6.2	CHEMICAL ANALYSIS	5
6.3	STRUCTURE.....	6
6.3.1	<i>Grain size</i>	6
6.3.2	<i>Non-metallic inclusions</i>	6
7	MANUFACTURE.....	6
7.1	MANUFACTURING PROGRAMME	6
7.2	DELIVERY CONDITION – THERMAL TREATMENT	7
7.2.1	<i>Heat Treatment</i>	7
7.2.2	<i>Machining – Surface conditions</i>	7
8	MECHANICAL PROPERTIES.....	7
8.1	REQUIRED VALUES.....	7
8.2	SAMPLING	8
8.3	TESTING	8
8.3.1	<i>Definition of a lot</i>	8
8.3.2	<i>Number and content of the tests series for mechanical properties</i>	8
8.3.3	<i>Test procedure</i>	8
8.4	RETREATMENT.....	9
9	SURFACE EXAMINATION – SURFACE DEFECTS.....	9
10	VOLUMETRIC EXAMINATION.....	9
10.1	DEGREE AND TIME OF EXAMINATION	9
10.2	PROCEDURES.....	10
10.3	SCANNING PLANE AND DEGREE OF EXAMINATION.....	10
10.4	EVALUATION OF INDICATIONS	10
10.5	RECORDABLE CONDITIONS AND EVALUATION CRITERIA	10
11	DIMENSIONAL CHECK - TOLERANCES.....	10

12 MARKING10

13 CLEANLINESS-PACKAGING-TRANSPORTATION11

14 ACCEPTANCE.....11

15 DOCUMENTATION AND TEST REPORT11

16 LICENSING11

17 QUALITY SYSTEM REQUIREMENTS.....13

18 ACCESS OF INSPECTORS.....13

1 Purpose

The Purpose of this document is to define a Procurement Specification for the supply of material NiCr19Fe19Nb5Mo3 [No. 2.4668] (similar to Alloy 718) Bars for Bolts of the Neutral Beam Front Components (NB Vessels, Drift-Duct, Passive Magnetic Shield (PMS), Absolute valve, VVPSS Box, Fast Shutter and Trolley support).

This document has been done from the document ITER_D_AHMGDY (v2.6) [Product Procurement Specification for the supply of NiCr19Fe19Nb5Mo3 [No. 2.4668] (similar to Alloy 718) Bars for Bolts of the ITER VVGS]

2 Scope

This specification covers NiCr19Fe19Nb5Mo3 (No. 2.4668) structural hardening nickel-chromium-iron alloy (known as Alloy 718) hot rolled or forged bars with a diameter less than or equal to 160 mm for the NB Components . The bars are considered for mechanical parts which are not intended to be pressure resistant (not bearing pressure). They shall be used for the manufacturing of bolting components.

This specification is based on the standard EN 10269:2013 plus requirements of product procurement specification RM 4123 of RCC-MR 2007 for hot rolled or forged bars for mechanical application of alloy No. 2.4668 and additional requirements arising from the features of the NB Components.

The Safety parts (SIC-1) of the NB Components are classified as RCC-MR Class 2 or RCC-MR Support Class S1 (RH 1300) for the PMS Accordingly, the materials of the Safety parts (SIC-1) of the NB Components shall satisfy requirements for Class 2 components defined in Section 2 – Materials in RCC-MR 2007 where it is applicable.

It is noted from RM 0115, applicable for RCC-MR Class 2 components and from RH 2200, applicable for RCC-MR Class S1 components that the manufacturer (in this case IO, as the NB components, here above listed, are defined at level of Build-to-Print PA) may propose materials outside the scope of Reference Material Specifications (Section 2 of RCC-MR). This is the case for this material procurement specification.

The amount of the structural hardened nickel-chromium-iron alloy bar 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 nickel-chromium-iron alloy bar grade NiCr19Fe19Nb5Mo3 (No. 2.4668).
- 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.

3 Definitions

For a complete list of ITER abbreviations see: ITER_D_2MU6W5 - ITER Abbreviations
Include here all those relevant to this document.

4 References documents

4.1 Design and Construction Code

- RCC-MR, Edition 2007
- RCC-MR, 2007, Section 2 – Materials, Chapter RM 4123

4.2 EN and ASTM Standards

- EN 10269:2013 Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties
- EN ISO 643:2003 Steels – Micrographic determination of the apparent grain size
- ASTM E 45-10 Standard test methods for determining the inclusion content of steel
- 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 148-1:2010 Metallic materials — Charpy pendulum impact test — Part 1: Test method
- EN ISO 6506-1:2006 Metallic Materials – Brinell hardness test – Part 1: Test method
- EN ISO 3452-1:2013 Non-destructive testing — Penetrant testing — Part 1: General principles
- EN 10228-4:2016 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

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

5 Melting process

The nickel alloy shall be made using electric furnace or by any other technically equivalent process, preferably in vacuum induction furnace. It then shall be processed by vacuum re-melting or under electrically conductive slag re-melting.

6 Chemical requirements and physico-chemical characteristics

6.1 Required values

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

Table 1: Chemical composition

Element	Content in wt. %	
	Min	Max
C	0.020	0.08
Si		0.35
Mn		0,35
P		0.015
S		0.015
Al	0.30	0.70
Cr	17.0	21.0
Co*		0.20
Cu		0.30
Mo	2.80	3.30
Ni	50.00	55.00
Nb	4.70	5.50
Ti	0.60	1.20
B	0.002	0.006
Ta**		0.05
Nb + Ta***	4.70	5.50
Fe	Remaining	

* Cobalt max of 0.20 wt. % is due to radioprotection requirement.

*** Ta content is not specified in EN 10269, but in EN 10302 sum of Nb + Ta is specified (4.70 - 5.50).

**Ta content shall be limited to max 0.05wt. %, as recommended in AMS 5662M¹. (¹ Aerospace Material Specification, AMS 5662M, SAE Aerospace Group, July 2004.)

The product analysis shall not deviate from the specified values of the cast analysis by more than the values given in Table 2 of EN 10269:2013.

6.2 Chemical analysis

A cast/ladle analysis is performed on a sample taken from the ingot processed by vacuum re-melting or under electrically conductive slag.

The Steelmaker shall supply a cast/ladle analysis certified by the Mill Manager or his duly accredited representative.

A product analysis shall be taken from each lot. Chemical analyses and crosschecks shall be performed in a laboratory of the steel manufacturer's choice, according to the laboratory's usual method.

6.3 Structure

A micrographic examination per lot, with photographs, shall be performed at magnification x 200. The structure must be homogeneous.

6.3.1 Grain size

The grain size index of the aged material determined in accordance with EN ISO 643 shall be between 5 and 8. The presence of a few isolated grains of index of 4 is tolerated for bars whose diameter is greater than 16 mm. The determination is performed on test samples taken from the immediate vicinity of the mechanical test samples. Test shall be done per lot.

6.3.2 Non-metallic inclusions

Amount and definition shall meet standard ASTM E45-10:

- Micro-inclusions (indigenous inclusions detectable by microscopical test methods): method D is applicable. Severity level number shall be at most 2 for types A, B, C and D inclusions.
- Macro-inclusions (exogenous inclusions from entrapped slag or refractories): they are strictly forbidden and are cause of rejection.

Test shall be done per lot.

7 Manufacture

7.1 Manufacturing Programme

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

- a) identification of melting process,
- b) ingot weight and type,
- c) diameters of bars during treatment and diameters as delivered,
- d) conditions for intermediate heat treatments and for final heat treatment,
- e) dimensional drawing with position of test specimens on samples.

As a rule, the overall ratio of reduction shall not be less than 3.

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

The program shall be agreed with Domestic Agency (DA) and IO.

7.2 Delivery condition – Thermal treatment

7.2.1 Heat Treatment

The bars intended for manufacture of bolting can be delivered:

- Either after being subjected to solution annealing between 950°C and 1010°C followed by air cooling,

- Or after aforementioned solution annealing treatment followed by a structural hardening treatment including:

- 8 hours exposure at 720°C (+/-10°C) followed by a cooling down to 620°C period (in the furnace) at the approximate rate of 50°C/h,
 - 8 hours exposure at 620°C (+/-10°C) followed by air cooling.

The holding time for precipitation hardening shall be at least 18 hours.

The thermal cycles shall be recorded, and the records kept shall be presented in the test report. Delivery heat treatment shall be specified in purchase order.

7.2.2 Machining – Surface conditions

The bar is machined based on its as-delivered profile. The surface quality class shall be better specified in purchase order. The surface condition shall correspond to the requirements relating to the various non-destructive examinations required.

8 Mechanical properties

8.1 Required values

Mechanical properties requirements shall meet the values given in Table 2.

Material shall be tested after solution annealing and structural hardening treatment (see 7.2.1).

Table 2: Mechanical properties

Test temperature, °C	Tensile Strength, Rm, MPa, min	Yield Strength Rp0.2, MPa, min	Elongation after fracture, A (5d), % min	Impact energy (ISO-V) at 20°C KV ₂ J min	Brinell Hardness, min
Room	1230	1030	14	20	340
200	-	934	-		

Note: Percentage of reduction of area and proof strength, 1% plastic extension at room temperature and elevated temperature, tensile strength, elongation at elevated temperature and shall be given for information purposes.

8.2 Sampling

All test samples shall be cut from bar prolongations; they shall be cropped as delivered after heat treatment. The size of the test samples shall be such that they can provide enough test pieces for possible retests.

The axis of the test pieces shall be parallel to that of the bars and located at a distance from the skin defined as follows (as indicated in EN 10269):

- for $\varnothing \leq 25$ mm, in the axis of the bar,
- for $25 \leq \varnothing \leq 160$ mm, 12.5mm from the skin.

The active area of the test pieces shall be located at a distance from the end of the bar at least equal to the diameter of the bar.

8.3 Testing

8.3.1 Definition of a lot

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

$$\varnothing_{\max}/\varnothing_{\min} < 1.1 ; e_{\max}/e_{\min} < 1.1 ; S_{\max}/S_{\min} < 1.25$$

These parts originated from the same re-melting heat, shall have been subjected to the same manufacturing cycle and be part of the same heat treatment cycle. The lot shall not exceed 2000 kg.

8.3.2 Number and content of the tests series for mechanical properties

Number and types of test are shown in Table 3.

Table 3. Number and types of tests

Name of test	Sampling direction	Test temperature (°C)	Number of test per lot
Tension	Long	Room	1
Tension	Long	200	1
Charpy V-notch impact	Long	20	3
Brinell hardness		Room	All bars

8.3.3 Test procedure

Tension testing

The tensile tests at room temperature shall be carried out in accordance with EN ISO 6892-1 at room temperature and in accordance with EN ISO 6892-2 at elevated temperature.

A proportional test piece of gauge length $L_0 = 5.65 \sqrt{S_0}$ (S_0 = cross-sectional area of the parallel length of the test piece) shall be used.

Test specimens shall have a circular section. One tensile test shall be conducted per lot.

Charpy V-notch impact tests for bars $\varnothing \geq 16$ mm

The impact test shall be carried out in accordance with EN ISO 148-1 at 20°C on V-notched test pieces and by using a 2 mm striker (KV2). For each lot 3 specimens shall be broken.

Hardness tests

The Brinell hardness test shall be performed in compliance with EN ISO 6506-1. A 10 mm diameter ball shall be used.

8.4 Retreatment

Lots rejected on the basis of unsatisfactory results for one or more mechanical tests may be retreated (heat treatment for mechanical properties). 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 8.2.

Test performed shall be the same as those described in chapter 8.3.

No more than one retreatment shall be allowed.

9 Surface examination – surface defects

100% of surfaces shall be thoroughly examined during all phases of production and machining to check the soundness of the metal. Parts shall be sound and free from scales, cracks nicks or other defects detrimental to their use or (class E as per EN 10221 as noted in EN 10269).

A visual examination shall be supplemented for by a liquid penetrant examination in accordance with EN ISO 3452-1:2013 on all parts.

The recordable conditions and examination criteria shall be applied for liquid penetrant examination.

The following indications shall be unacceptable:

- linear indications,
- rounded indications with one dimension greater than 3 mm,
- 3 or more indications aligned less than 3 mm apart edge to edge.

10 Volumetric examination

An ultrasonic volumetric examination shall be performed for all bars with $\varnothing \geq 50$ mm.

10.1 Degree and time of examination

This examination shall be performed after heat treatment and machining to delivery dimensions.

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.

10.2 Procedures

Ultrasonic examination procedures and conditions specified in standard EN 10228-4 shall apply. Probe frequency shall normally be 2 MHz. Use a dual element probe and inspecting may be possible only until half of the diameter along the circumferential movement of the probe.

10.3 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 EN 10228-4 shall be performed.
Scanning coverage with normal probes Type is 1a.

10.4 Evaluation of indications

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

10.5 Recordable conditions and evaluation criteria

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 or dual probe. The quality class 3 shall be adopted.

For thickness above or equal to 75 mm, concerning the loss of back echo, the recordable attenuation range is $R \leq 0.12$ with no acceptability limit.

11 Dimensional check - tolerances

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

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

12 Marking

Marking shall include:

- manufacturer name, trade mark or symbol,
- material number or name,
- cast number,
- lot (batch) number,
- identification number related to the origin of the delivery.

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

13 Cleanliness-Packaging-Transportation

Requirements are specified in the purchase order.

14 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.

15 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 bars:

The report shall contain the following information:

- cast (ladle) and product analyses,
- melting process method,
- records of micrographic examination, inclusions and grain size,
- 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 bar reference number,
- identification of the Supplier,
- identification of the purchase order number,
- name of the Inspection Agency, where applicable.

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.

16 Licensing

The **Protection Important Activities** are identified by the Nuclear Operator. The list of the Protection Important Activities is based on the chapter 10 of the RPrS [Preliminary Safety Report (RPrS) ITER_D_3ZR2NC v3.0] and the application of the INB Order which applies to all the lifecycle of a nuclear facility [Order dated 7 Feb 2012 relating to the general technical regulations applicable to INB. ITER_D_7M2YKF v1.6].

The PIAs for the NB Injector are defined in the Surveillance plan for PBS 53 ITER_D_U65RWF. During design phases, the safety demonstration is considered as PIA; the procurement of the materials for the bolts the Drift Duct which are ensuring the confinement barrier is a safety demonstration.

IO shall manage this activity as follow:

PIA	Defined requirement	External interveners	Nature of the surveillance	Frequency of the surveillance	Actor of the surveillance	Formalization of the surveillance	Records management	Record location
Safety Demonstration related to safety demonstration	Compliance with the defined requirements for each PIC [(LAMFG2) Application of the procedure (LAMFG2)	All	Review of the document	For each document	TRO	Review in IDM	Standard IO rule (22K5JQ)	IDM folder 2N78DT

The Contractor shall provide a Quality plan at the kick off meeting. This QP shall remind the safety function of the DD BELLOWS bolts. The DD BELLOWS bolts is SIC1 and the safety function associated is the confinement.

DD Bellows items classified SIC are also classified PIC. The development of the DD BELLOWS bolts shall comply with the Order dated 7 February 2012 relating to the general technical regulations applicable to INB [13].

The Suppliers and Subcontractors must be informed that:

- *ITER is a nuclear facility identified in France by the number-INB-174;*
- *The Order 7th February 2012 title I and II replace Order 10th August 1984 since the 1st July 2013;*
- *The Order 7th February applies to all the components important for the protection (PIC) and the activities important for the protection (PIA).*
- *The compliance with the INB-order must be demonstrated in the chain of in the chain of contractors and subcontractors.*
- *In application of article II.2.5.4 of the Order 7th February 2012, contracted activities for supervision purposes are also subject to a supervision done by the Nuclear Operator (IO).*

A specific management system has to be implemented by any Supplier and Subcontractor working on protection important activities, on the basis of activities defined and executed by the Supplier and Subcontractor.

The Contractor shall refer to the document: ITER_D_SBSTBM - Provisions for Implementation of the Generic Safety Requirements by the External Intervenors which is a declination of the French order 2012.

17 Quality system requirements

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

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

The quality control 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 control system.

Failing this, the Supplier shall undertake all necessary actions to establish and maintain quality control in the subcontractors' premises.

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

18 Access of Inspectors

Representatives of the IO, DA, ANB, ASN 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 subcontractor the progress and status of the work forming the subject matter of the procurement and to witness specified tests.