
	Manufacturing, testing and supply of vacuum vessels for HNB3 (Beam Line Vessel and Beam Source Vessel) and DNB <i>Annexure-4G_Materials_Plates for HNB3 Vessel</i>	INDUS Ref No
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1. Scope

This specification covers weldable X2CrNiMo17-12-2 controlled nitrogen content austenitic stainless steel plate between 5 mm and 100 mm thick, for use at temperatures of up to 550°C. This also includes the requirements of thin sheet for the lip seal.

2. References

RCC-MR 2007; Section-2; **RM 3331** Product procurement specification: class 1, 2 and 3 X2CrNiMo17-12-2 controlled nitrogen content austenitic stainless steel plate from 5 mm to 100 mm thick for use at high temperature

RCC-MR 2007; Section-2; **RM 3333** Product procurement specification class 1, 2 and 3 austenitic stainless steel plates and strips

Chemical composition and impurity requirements for materials **(REYV5V_v2_3)**

3. Specific requirements from IVH

3.1 Where hot or cold rolled plate material is used, it is recommended for all vacuum classes, that a surface parallel to the direction of rolling forms the vacuum boundary. This is due to the possibility of long leak paths caused by the stratification of inclusions.

3.2 Hot or cold rolled plate material produced with conventional smelting and refining processes such as Argon-Oxygen Decarburization (AOD), Vacuum Arc decarburization (VOD)) shall not be used where the transverse cross section across the vacuum boundary (wall thickness) is less than 25mm.

3.3 Where Hot or cold rolled plate material is used with the transverse cross section crossing the vacuum boundary (wall thickness less than 25 mm), ESR or VAR low inclusion rate material shall be used which meets the inclusion limits as specified in **Clause 6 of Annexure 4**. The component shall also be proven by leak testing in an environment which conforms as closely as possible to the operating conditions (as per Annexure 10: Leak Testing) with due consideration taken of the effects of possible leaks along laminations on the response time for the test method.

4. Melting process

The steel shall be made using an electric furnace or by any other technically equivalent process. Requirements of **Clause 3 above** shall be fulfilled.

5. Chemical requirements

Chemical composition, as determined by product analyses taken from each rolled sheet or strip, shall comply with the following requirements. The Steelmaker shall supply a ladle analysis certified by the Mill Manager or his duly accredited representative. These analyses shall be performed in compliance with the requirements of **RMC 1000**.


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Table 1: Chemical composition requirement

Chemical composition, X2CrNiMo17-12-2 controlled nitrogen	Content in Wt. %
<i>Elements</i>	<i>Range or Max</i>
Fe	balance
C	0.030
Mn	1.60 - 2.00
Si	0.50
P	0.030
S	0.015
Cr	17.00 - 18.00
Ni	12.00 – 12.50
Mo	2.30 – 2.70
N	0.060-0.080
Cu	1.00
B	0.0020
Additional ITER specific requirements [6] and [93]:	
Co	0.05
Nb	0.01
Ta	0.01
Ti	0.10

Control of Co, Nb and Ta is identified as Protection Important Activity (PIA). Therefore, the compliance with above requirements have to be closely monitored.

6. Ferrite Content

The ferrite content evaluated using the Schaeffler diagram modified by Pryce and Andrews (Fig. RMC 1341.2, placed at the end of this annexure) and measured on a solution heat treated product must be less than 1%.

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The ferrite content shall be measured at the surface of each heat treated rolling sheet or strip, at one quarter width at the top and bottom, close to the mechanical test specimens.

7. Structure

- 7.1 A micrographic examination, with photographs, shall be performed parallel to the rolling direction on each rolled strip or sheet.
- 7.2 The structure must be homogeneous.
- 7.3 The grain size number as determined in accordance with **RMC 1000 / EN ISO 643: Steels- Micrographic determination of the apparent grain size**, shall be greater than 2. The presence of a few grains with size number 1 and 0 is tolerated. The grain size homogeneity shall be ± 1 around the true average value.
- 7.4 This determination shall be made on one of the test samples taken from the immediate vicinity of the mechanical test samples.
- 7.5 Non-metallic inclusions amount and definition shall meet standard **ASTM E45-05**.
- 7.6 Micro inclusions (indigenous inclusions detectable by Micro Examination methods): Method D is applicable. Severity level number shall be at most 2 for 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.
- 7.7 Macro inclusions (exogenous inclusions from entrapped slag or refractories): they are strictly forbidden and are cause of rejection.
- 7.8 In case of plate materials utilized for the "T" type of welds, cleanliness of material specifically for $S < 0.01$. Additionally, Tensile test to be verified across the thickness direction.

8. Manufacturing programme

- 8.1 Prior to commencement of manufacturing operations, the supplier shall draw up a manufacturing programme. This chapter shall include the following:
 - a) Identification of melting process,
 - b) Ingot weight and type
 - c) Identification of main hot-working operations
 - d) In the case of continuous casting, the discard parameters, weight of blooms, etc.,
 - e) Top and bottom end discard percentages,
 - f) Position of the plate in the ingot, in particular the final rolling direction in relation to the ingot axis,
 - g) Indication of main rolling direction,
 - h) Conditions for intermediate heat treatments and for solution heat treatment (in particular, temperature, holding time and cooling method),

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- i) Position of acceptance test samples on the plate,
- j) Dimensional drawing with position of test specimens in these samples.

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

8.3 For plates less than 80 mm thick, point b, c, e of the manufacturing program is not required.

9. Delivery condition

- Plate Thickness from 5mm to 100mm: The plate shall be delivered in the solution heat treated, pickled and passivated condition.
- Plate <3mm thickness: These plates and strips shall be delivered after cold-rolling in the solution heat-treated, pickled and passivated condition. They may or may not be subjected to a cold skin-rolling pass.

10. Solution heat treatment

Solution heat treatment shall consist of holding at a temperature between 1050°C and 1150°C followed by water cooling and possibly air cooling for small thicknesses. The thermal cycles involved in the heat treatment shall be recorded and the records kept at the disposal of the Surveillance Agents.


11. Pickling - passivation, surface condition

- 11.1 The pickling-passivation treatment shall be performed in compliance with the requirements of **Annexure-8: Pickling and passivation**. No trace of oil or grease must remain on the surface of the metal in the as-delivered condition.
- 11.2 The surface condition of the plates evaluated in accordance with **RMC 7200** must on average be at least that defined by **scale N9 of LCA-CEA plate No. 3**, that is, a roughness of <6.3 µm, as measured by a stylus probe type instrument.

12. Mechanical properties

12.1 Sampling

- 12.1.1 Test samples shall be taken after the plate has been subjected to solution heat treatment. They shall be appropriately marked and shall show the final rolling direction.
- 12.1.2 The size of the test samples shall be such that they can provide enough test specimens for all tests and retests.
- 12.1.3 Test samples shall be taken halfway between the edge and the plate centreline. Specimens shall always be taken closer to the edge of the sample than a distance equal to the thickness of the plate.

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12.1.4 The longitudinal axis of test specimens shall be parallel to the rolling skins and perpendicular to the final rolling direction.

12.1.5 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 test specimen thickness shall be equal to the thickness of the plate (specimen with rectangular cross-section).

12.2 Testing in the solution heat treated condition

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

12.3 Number and content of tests

12.3.1 The number of tests to be performed is given in Table-2 below.


Table-2: Number of tension tests

				Top end			Bottom end			Number of specimens	
Name of test	Test temperature (°C)	Weight of plate or rolled strip	Thickness	Full thickness	Mid-thickness	Quarter thickness	Full thickness	Mid-thickness	Quarter thickness	Per heat	Per rolling sheet or strip
Solution heat treated											
Tension	Room	≤ 3000 kg	≤ 10 mm	1							1
			10 mm < e ≤ 30 mm		1						1
			> 30 mm			1					1
	Room	> 3000 kg	≤ 10 mm	1			1				2
			10 mm < e ≤ 30 mm		1			1			2
			> 30 mm			1			1		2
	According to the Equipment Specification	Regardless of weight	≤ 10 mm	1							1
			10 mm < e ≤ 30 mm		1						1
			> 30 mm			1					1

12.3.2 The following are performed for each rolled sheet or strip:

- one series of tests at room temperature at the end corresponding to the top end of the ingot for sheets and strips weighing a maximum of 3000 kg,
- two series of tests at room temperature, one at each end of the sheet, for sheets or strips weighing more than 3000 kg.

12.3.3 For each heat of metal, the yield strength at 200 C shall be checked. This check shall be performed at the temperature given by the Equipment Specification selected from

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those indicated in table **RM 3332.51** on a test specimen sampled, if possible, from the end corresponding to the top end of the ingot

12.4 Tension testing at room temperature

124.1 Test specimen:

Test specimens shall have a circular section. Their normal diameter shall be 10 mm and their dimensions as specified in **RMC 1211**. For plates less than 20 mm thick, the cylindrical test specimen may be replaced by a specimen with a rectangular section, as stipulated in **RMC 1211**.

121.4.2 Test method:

The tension test shall be performed in compliance with **RMC 1211**. The following values shall be recorded:

- (i) Yield strength at 0.2% offset, in MPa,
- (ii) Yield strength at 1% offset, in MPa,
- (iii) Ultimate tensile strength, in MPa,
- (iv) Percentage elongation after fracture,
- (v) Percentage reduction of area after fracture.


12.4.3 Results

Results obtained shall meet the requirements given in Table-3 below:

Table-3: Tensile test requirements at room temperature

Yield strength at 0.2% offset, in MPa, $R_{p0.2}$	220
Yield strength at 1% offset, in MPa, R_{p1}	To be recorded For Information
Ultimate tensile strength, in MPa, R_m	525-700
Percentage elongation after fracture, A% (5d)	45
Percentage reduction of area after fracture	To be recorded For Information

12.4.4 If the requirements of **clause 12.4.3** are not fulfilled 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 strip or sheet shall be accepted; if not, the following paragraph shall apply.

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Where 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 taken close to those which were defective. If the results of the retests are satisfactory, the rolled strip or sheet shall be accepted; if not, it shall be rejected (clause 12.8)

12.5 Tension testing at high temperature (200 C)

12.5.1 Test specimen:

The nominal diameter shall be 10 mm and their dimensions as specified in RMC 1212. For plates less than 20 mm thick, the cylindrical test specimen may be replaced by a specimen with a rectangular section, as stipulated in RMC 1212

12.5.2 Test method:

The tensile test is performed in compliance with RMC 1212.

12.5.3 Results:

Yield strength at 0.2% offset, in MPa, $R_{p0.2}$	144 (at 200 C)
Yield strength at 1% offset ($R_{p1\%}$)	To be recorded for information
tensile strength (R_m)	To be recorded for information

12.5.4 If the requirements of 12.5.3 are not fulfilled, then follow 12.4.4.

12.6 Bend test (Only applicable for plate / strips with thickness <3mm)

12.6.1 Test specimens and test method:

The choice of test specimen and the test conditions shall be as specified in RMC 1262. The diameter of the mandrel shall be $0.5 \times e$ (e being the thickness of the plate or strip). The bend angle shall be 180°.

12.6.2 Results


The outer face of the bend shall show no signs of cracks, tears or blister, failing which the requirements of 12.4.4 shall apply.

12.8 Retreatment

12.8.1 Rolled sheets or strips rejected on the basis of unsatisfactory results for one or more mechanical tests may be retreated (solution heat treatment).

12.8.2 Retreatment conditions shall be described in the test report.

12.8.3 In such cases, test samples and specimens shall be taken in the same conditions as specified in 12.1 and 12.2. The tests performed shall be the same as those described in 12.3 to 12.6.

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12.8.4 No more than one retreatment shall be allowed.

13. Surface examination - Surface defects

13.1 Plates shall be visually examined. Their surfaces shall be plane, uniform and free from wrinkles, buckles, blowholes, tears, cracks and inclusions. After cutting to as-delivered dimensions, the edges shall be visually examined in accordance with **RMC 7100**. There shall be no cleavage or lamination (for example, a layer of fine inclusions drawn out during rolling).

13.2 If in doubt, a liquid penetrant examination shall be performed in accordance with **RMC 4000**.

14. Volumetric examination

14.1 An ultrasonic examination shall be performed in compliance with **RMC 2400**, which states the conditions for application of **NF EN 10307**:

14.2 The examination shall be carried out with the scanning 100% plan and the levels S2 and E3 criteria given in standard NF EN 10307.

15. Removal of unacceptable areas

15.1 Removal by grinding:

15.2 The Supplier may remove surface defects by grinding, provided that:

- The remaining thickness is within the tolerances specified by the drawing
- The cavity blends smoothly in with the surrounding surface,

15.3 After removal, the surface is subjected to liquid penetrant examination in accordance with **RMC 4000**. The following criteria shall apply in the case of liquid penetrant examination:


- Only indications greater than 1 mm shall be considered a recordable condition.
- The following are unacceptable:
 - linear indications,
 - non-linear indications with one dimension greater than 2 mm.

16. Repair welding

Rolling Mill shall not be authorized to perform repair welding.

17. Dimension Check

The dimensions of the plates, sheets or strips shall comply with those specified on the drawing or in the purchase order.

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18. Marking

The Supplier shall specify the identification and marking methods used, in compliance with **RC 1300**. Samples delivered with the part shall be marked in accordance with the provisions of the purchase order.

19. Cleanliness - Packaging – Transportation

Requirements shall be specified in the purchase order, taking particular account of the requirements of **Annexure 13**.

20. Test reports

20.1 In addition to the inspection certificate type 3.1 in accordance with NF EN 10204, the following reports shall be drawn up by the Supplier after each individual test and, in any case, prior to delivery of the part:

20.1.1 Ladle and product analyses

20.1.2 Intergranular corrosion test

20.1.3 Record of all the heat treatment

20.1.4 Micrographic examination, grain size

20.1.5 Ferrite Content

20.1.6 Mechanical tests,

20.1.7 Non-destructive examinations,

20.1.8 Dimensional check.

20.2 These reports shall include:

20.2.1 Heat number and plate, sheet or strip reference number,

20.2.2 Supplier's particulars,

20.2.3 Purchase order number,

20.2.4 Name of the inspection agency, where applicable,

20.2.5 Test and retest results together with required values.


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Figure RMC 1341.2: Schaeffler diagram, modified Pryce and Andrews – determination of the δ ferrite content

Nickel equivalent: $Ni\ eq. = Ni + 21\ C + 11.5\ N + 0.5\ Mn$

Chromium equivalent: $Mo < 2\ %: Cr\ eq. = Cr + Mo + 3\ Si$

$Mo \geq 2\ %: Cr\ eq. = Cr + 2\ Mo + 3\ Si$

