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

This specification covers weldable austenitic stainless steel X2CrNiMo17-12-2 (1.4404) (RCC-MR 2007, Section-2, RM 3342) seamless pipes of thicknesses between 2.0 and 50.0 mm, for piping or other uses.

2. References

RM 3342 Product procurement specification: class 1, 2 and 3 austenitic stainless steel seamless pipes

Chemical composition and impurity requirements for materials (REYV5V_v2_3)

3. Melting process


The steel shall be made using an electric furnace or by any other technically equivalent process. Melting of the steel should be completed by a suitable secondary refining processes like Argon oxygen decarburization (AOD) or Vacuum oxygen decarbonized (VOD).

4. Chemical requirements

Chemical composition, as determined by the product analyses, shall comply with the following requirements (Table 1). The Steelmaker shall supply a ladle analysis certified by the Mill Manager or his duly accredited representative.

Table 1: Chemical composition requirement

Chemical composition,	Content in Wt. %
X2CrNiMo17-12-2	
<i>Elements</i>	<i>Range or Max</i>
Fe	balance
C	0.030
Mn	2.00
Si	1.00
P	0.030
S	0.015
Cr	16.50-18.50
Ni	10-13

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Mo	2 – 2.5
N	0.11
Cu	1.00
Additional ITER specific requirements [6] and [93]:	
Co	0.05
Nb	0.01
Ta	0.01


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

5. Intergranular Corrosion test and Ferrite content

- 5.1 It shall be performed in accordance with **RMC 1310**, on a test ingot made at the time of casting. In case this is not possible, one test shall be performed per heat of metal.
- 5.2 The sensitising treatment shall be performed at the heating temperature of $650^{\circ}\text{C} \pm 10^{\circ}\text{C}$.
- 5.3 The corrosion test result shall be considered satisfactory if (1) during sound testing the test specimen gives a clear metallic sound, and (2) provided no cracks or tears are detected during the bend tests. Should any doubt remain, the absence of intergranular corrosion shall be confirmed by micrographic examination.
- 5.4 Only for pipe thicker than 5mm: The ferrite content as measured on a part of tube using the Schaeffler diagram modified by Pryce and Andrews (Fig. RMC 1341.2, placed at the end of this annexure) must be less than 1%.

6. Manufacturing programme

- 6.1 Prior to commencement of manufacturing operations, the pipe manufacturer shall draw up a manufacturing programme which shall include in chronological order the various manufacturing stages. All intermediate and final heat treatment, finishing and non-destructive examination operations shall be mentioned.
- 6.2 Manufacture of pipes
 - 6.2.1 The rounds and/or billets which are to be used for manufacturing pipes shall be taken from ingots where sufficient top and bottom end discard has been removed. If required, all cracks shall be carefully removed. The overall ratio of reduction shall not be less than 3.

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62.2 In any case, it shall be such that an austenitic grain size number of at least 2, as determined in accordance with **EN ISO 643: Steels- Micrographic determination of the apparent grain size**, is obtained on the finished part. The grain size homogeneity shall be ± 1 around the true average value.

65.2.3 Furthermore, the manufacturer shall guarantee that the manufacturing processes he uses do not impair the intergranular corrosion strength of the steel.

6.2.4 The pipes shall be hot finished and small diameters and thicknesses may be cold drawn; this shall be specified in the manufacturing programme.

7. Delivery condition- Heat Treatment

7.1 Pipes shall be subjected to solution heat treatment at a temperature between 1050°C and 1150°C prior to delivery.

7.2 The conditions for solution heat treatment, as well as the furnace atmosphere, shall be specified in this manufacturing programme. The holding temperature shall be recorded and the feed speed shall be monitored continuously. Diagrams shall be kept at the disposal of the Surveillance Agents.

8. Surface condition

Unless specified otherwise, maximum average surface roughness (defined in accordance with ISO 4278:2000) shall be 6.3 μm Ra for all metallic components. The measurement shall be performed by a stylus probe type instrument.

9. Mechanical properties

9.1 Sampling

91.1 Test samples shall be taken from pipes in the as-delivered condition (after solution heat treatment). Samples shall be taken from pipe ends.

9.1.2 When the dimensions of the pipe so permit, tension and impact test specimens shall be taken perpendicular to the pipe axis.


9.1.3 Their test-pertinent area shall be as close as possible to the internal skin. For impact test specimens, the notches shall be perpendicular to the skin.

9.1.4 In all other cases, the tension and impact test specimens shall be taken longitudinally, i.e. with their centreline parallel to the axis of the pipe. Their test-pertinent area shall be as close as possible to the internal skin.

9.1.5 Flattening and flare tests shall be performed on tubular sections taken from pipe ends.

9.1.6 In the event of retests, samples shall be taken close to the original samples.

9.2 Number and content of tests

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9.2.1 Tests for mechanical properties shall be performed per heat or per lot.

9.2.2 The term "lot" applies to pipes produced from the same heat, having the same diameter, the same wall thickness, having been subjected to the same manufacturing cycle and forming part of the same furnace charge or the same set of heat treatments.

9.2.3 A lot shall be restricted as follows:

a. to 50 production lengths not exceeding 1000 m for pipes of diameter > 150 mm and wall thickness > 9 mm.

b. to 100 production lengths not exceeding 2000 m for pipes of diameter ≤ 150 mm and wall thickness ≤ 9 mm.

9.2.4 The number of tests to be performed, orientation of test specimens and test temperatures are given in **Table 2** below.

Table 2: Number and contents of tests

Name of test	Orientation of specimen	Test temperature (°C)	Number of specimens per type of test	
			Per heat	Per lot
Tension	(1)	Room	-	1
Tension (4)	(1)	According to the Equipment Specification	1	-
Charpy V-notch for thickness ≥ 12 mm (5)	(1)	Room	-	3
Flattening		Room	-	5 % (2)
Flare		Room	-	5 % (3)
(1) Transverse when the pipe is sufficiently thick, if not longitudinal (2) Limited to pipes whose \varnothing ext. ≤ 400 mm or whose thickness ≤ 15 % of \varnothing ext. (3) Limited to pipes whose \varnothing ext. ≤ 150 mm or whose thickness ≤ 9 mm. (4) This test shall be performed at one of the temperatures given in table RM 3342.51 , when specified in the equipment specification and the purchase order. This test shall be performed systematically for class 1 pipes. (5) Impact test is not performed when A% determined at room temperature ≥ 45.				

9.3 Tension testing at room temperature


9.3.1 Test specimen:

(i) When the wall thickness of the pipe is sufficient, a test specimen with a circular section 10 mm in diameter whose dimensions conform to **RMC 1211** shall be used.

(ii) When the wall thickness of the pipe is such that test specimens with a circular section 10 mm in diameter cannot be used, strips cut out from the pipe or tubular sections removed in accordance with **RMC 1211** shall be used for tension testing.

9.3.2 Test method:

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

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- (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,

9.3.3 Results:

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

Table-3: Tensile properties requirements

Yield strength at 0.2% offset, in MPa, $R_{p0.2}$	190
Yield strength at 1% offset, in MPa, R_{p1}	To be recorded For Information
Ultimate tensile strength, in MPa, R_m	490-690
Percentage elongation after fracture, A% (5d)	45 (Longitudinal) 40 (Transverse)
Percentage reduction of area after fracture	To be recorded For Information


- 9.3.4 If the requirements of **clause 9.3.3** are not fulfilled, and If this is not the case and the test specimen has a physical defect (which does not affect the usefulness of the product) or if unsatisfactory test results are due to incorrect mounting of the specimen or a testing machine malfunction, the test shall be repeated using another specimen. If the results of the second test are satisfactory, the part and/or the lot shall be accepted; if not, the following paragraph shall apply.

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 lot shall be accepted; if not, it shall be rejected (**Clause 13**).

9.4 Tension testing at high temperature

9.4.1 Test specimen:

When the wall thickness of the pipe is sufficient, a test specimen with a circular section 10 mm in diameter whose dimensions conform to **RMC 1212** shall be used.

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When the wall thickness of the pipe is such that test specimens with a circular section 10 mm in diameter cannot be used, strips cut out from the pipe or tubular sections removed in accordance with **RMC 1212** shall be used for tension testing.

94.2 Test method:

The tensile test is performed in compliance with **RMC 1212**.

9.4.3 Results:

Yield strength at 0.2% offset, in MPa, $R_{p0.2}$	137 (at 200 C)
Yield strength at 1% offset ($R_{p1\%}$)	To be recorded for information
tensile strength (R_m)	To be recorded for information

9.4.4 If the requirements of 9.4.3 are not fulfilled, then follow 9.3.4.

9.5 Flattening test

95.1 Test specimens and test method:

The size of the specimen and the test procedure are given in **RMC 1272**.

9.5.2 Results:

There shall be no cracks or tears on the surface of the pipe subsequent to the first stage of flattening.

At the second stage of flattening, the shell shall not show any delamination or any other significant heterogeneity.

If the results of a flattening test performed on a pipe are unsatisfactory, this pipe shall be retested, and tests shall be performed on two more pipes. If the results are unsatisfactory, all defective pipes shall be rejected. If more than 10% of the pipes prove to be defective, the entire lot shall be rejected.

9.6 Flare test


9.6.1 Test specimens and test method:

The size of the specimen and the test procedure are given in **RMC 1271**.

9.6.2 Results:

There shall be no cracks or tears on the surface of the pipe subsequent to testing. Results shall be interpreted in the same way as for a flattening test **(Clause 9.5.2)**.

9.7 Retreatment

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- 9.7.1 Lots rejected on the basis of unsatisfactory results for one or more mechanical tests may be retreated (solution heat treatment).
- 9.7.2 Retreatment conditions shall be described in the test report.
- 9.7.3 In such cases, test samples and specimens shall be taken in the same conditions as specified in 9.1. The tests performed shall be the same as those described in 9.2 to 9.7.
- 9.7.4 No more than one retreatment shall be allowed.

10. Determination of austenitic grain size


- 10.1 The grain size number of shall be checked on one pipe per lot in accordance with RMC 1000.
- 10.2 Grain size number shall be equal to at least 2. The grain size homogeneity shall be ± 1 around the true average value.

11. Surface examination - Surface defects

- 11.1 Internal and external surfaces of pipes shall be sound, i.e. free of any injurious defects.
- 11.2 Straight pipes shall be delivered clean, free of oxidation. For piping, maximum final roughness shall be $6.3 \mu\text{m}$ (N9) for the inner and outer surfaces.
- 11.3 In all cases, surface roughness shall be checked in accordance with the requirements of RMC 7231.
- 11.4 Finish – Protection:
Pipes shall be delivered pickled and passivated.

12. Volumetric examination

- 12.1 Each straight pipe shall be subjected to ultrasonic examination in accordance with the requirements of RMC 2500, the following additional requirements being taken into account:
- (i) Ultrasonic examination shall be performed on pipes in the solution-heat treated condition,
 - (ii) Surface condition shall comply with the requirements of RMC 2100,
 - (iii) angle-beam examination shall be used to detect longitudinal and transverse defects in piping,
 - (iv) angle-beam examination shall be used to detect longitudinal defects in miscellaneous tubular parts.

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12.2 Results

Only those defects whose echo amplitude is lower than that of the echo produced by the notch in the standard pipe defined in **RMC 2534** shall be considered acceptable.

The pipe ends which cannot be properly examined on an automatic test bench shall be either discarded or examined manually on at least 100 mm. The manual examination method shall be of a precision at least equal to that of the automatic test bench; the reference pipe used for automatic examination shall be used to adjust precision.

13. Removal of unacceptable areas

13.1 As a general rule, those parts of pipes with unacceptable defects detected by either visual or non-destructive examination shall be discarded.

13.2 Surface defects may be removed by grinding provided that the remaining thickness is greater than the minimum specified thickness and provided that the usual precautions are taken (avoid overheating of the ground surface, use iron-free corundum grinding wheels).

13.3 For piping, liquid penetrant examination shall be performed after grinding, in accordance with the requirements below:

13.3.1 Criteria

(i) Indications of 1 mm or more shall be considered recordable conditions.

(ii) All defects which produce the following indications shall be unacceptable:


- linear indications,
- rounded indications with one dimension greater than 3 mm,
- 3 or more grouped indications less than 3 mm apart (edge to edge),
- 5 or more grouped indications within a rectangular area of 100 cm², whose greater dimension shall not exceed 20 cm, taken in the most unfavourable location relative to the indications being evaluated.

13.4 If major defects appear and they cannot be removed by grinding, the defective part of the pipe shall be discarded.

14. Dimensional check

14.1 Tolerances:

Pipe dimension and tolerances shall be stipulated in the procurement drawings and shall comply with the requirements of **NF EN 10216-5**. Whatever the diameter and the wall thickness of the pipe, the thickness tolerance shall comply with the class T2 of **NF EN 10216-5**.

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13.2 Dimension check

The minimum dimensional checks shall be for thickness, diameter and ovality check on five pipes per lot.

15. Hydrostatic test

Each pipe shall be subjected to hydrostatic testing during finishing operations, in accordance with the requirements specified in the purchase order.

16. Marking

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

17. Cleanliness - Packaging – Transportation

Procedures shall be specified in the purchase order and shall meet the requirements of **Annexure 13**

In addition:

- Pipe ends shall be cut square and blanked with plastic caps,
- All pipes shall be sealed in watertight polythene packing

18. Test reports

18.1 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 pipe:

18.1.1 Ladle and product analyses,

18.1.2 Intergranular corrosion where applicable,

18.1.3 Record of all the heat treatment

18.1.4 Mechanical tests,

18.1.5 Visual examination,


18.1.6 Non-destructive examination,

18.1.7 Determination of grain size

18.1.8 Dimensional check.

18.2 These reports shall include:

18.2.1 Heat number and pipe reference number,

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18.2.2 Supplier's particulars,

18.2.3 Purchase order number,

18.2.4 Name of the inspection agency,

18.2.5 Test and retest results together with required values.

19. Specific requirement about the Sulphur content

The sulphur content of the following welding area shall be between 100ppm and 150ppm to achieve a good penetration and to avoid hot cracking

For HNB Vessel: defined by 2.7 mm thickness/ DN200 in the Drawing 046910 – sheet 14 – view BZ-BZ - version H

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

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

