



PRODUCT STANDARD

HEAT EXCHANGERS

HYDERABAD

HE 5 1533

Rev. No. 00

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WELDED TITANIUM TUBES - GRADE 2

1.0 General:

This specification governs the quality of Welded Titanium Tubes, Grade 2 in annealed condition.

2.0 Application:

For use in surface condensers, evaporators and heat-exchangers.

3.0 Condition Of Delivery:

Annealed.

4.0 Compliance With Standards:

The tubes shall comply with requirements of:

ASME SB-338 Gr. 2 (Latest applicable code as on date of enquiry)

5.0 Dimensions & Tolerances:

5.1 Sizes:

The tube shall be supplied as per wall thickness, Outer diameter and dimension specified in the purchase order.

5.2 Tolerances:

5.2.1 On OD and Wall Thickness:

Outside diameter, mm	Diameter	Permissible variation
Over Upto & Incl	Tolerances, mm	in wall thickness, percent
- 25	± 0.102	± 10
25 38	± 0.127	± 10
38 50	± 0.152	± 10
50 63	± 0.178	± 10
63 90	± 0.254	± 10

Note: Tolerances on outside diameter apply only to tubes as finished at the mill before subsequent swaging, expanding, bending, polishing or other fabricating operations.

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5.2.2 On straightness:

The tubes shall be free of bends or kinks and the maximum bow shall not exceed Values shown below.

Length, Metres		Maximum Curvature
Over	Upto & Incl	Depth of arc, mm
0.9	1.8	3.2
1.8	2.4	4.8
2.4	3.0	6.4
3.0	--	6.5 in any 3 metres

5.2.3 On Specified Lengths of Tubes :

Specified Lengths of Tubes, Metres	Tolerance, + mm
Upto 7	3.0
Over 7 upto 10	6.0
Over 10 upto 13	9.0
Over 13	12.0

5.3 Seam Height:

The projection of weld seam inside the tube shall not be more than 0.10 mm.

5.4 Squareness of Cut:

The angle of cut of the end of any tube may depart from square by not more than 0.016 mm/mm of diameter.

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6. MANUFACTURE:

The tube shall be made from annealed & flat rolled product by an automatic arc welding process or without any filler material. Welded tubing shall be heat treated by at least a stress relief after forming and welding.

7. FREEDOM FROM DEFECTS:

The finished tube shall be clean and free of foreign material shall be smooth ends free of burrs and shall be free of injurious external and internal imperfections. Minor defects may be removed, provided the dimensional tolerances of clause 5 are not exceeded.

8. SURFACE ROUGHNESS:

For the inner surface, with the exception of weld seam, the roughness in longitudinal direction shall be allowable within Ra=2 microns or Rz=10 microns.

9. CHEMICAL COMPOSITION:

The analysis of the tube material and the permissible variation in the composition of the finished tube from the limits specified shall be as follows:

Element	Percent, Maxm, Meter	Permissible Variation
Nitrogen	0.03	+ 0.02
Carbon	0.08	+ 0.02
Hydrogen	0.015	+ 0.002
Iron	0.30	+ 0.15
Oxygen	0.25	+ 0.03
Residuals. Each	0.1	+ 0.02
Residuals, total	0.4	--
Titanium	--	Reminder --

- Note:
1. Lower hydrogen values may be obtained by negotiation with the manufacturer.
 2. Percentage of residuals, each need not be reported unless the concentration level is Greater than 0.1% each, or 0.4% total.
 3. A residual is an element present in a useful or an alloy in small quantities inherent to The manufacturing process but not added intentionally.
 4. Ingot hydrogen need not be reported .Final product hydrogen shall be reported.

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10. TEST SAMPLES:

10.1 Heat analysis:

An analysis of each heat shall be made by the tube manufacturer to determine the percentage of the elements.

10.2 Product analysis

10.2.1 An analysis of one length of flat rolled stock or one tube shall be made of each heat to cross check the analysis of the material.

10.2.2 If the original test for the product analysis fails, retests of two additional lengths of flat rolled stock or tubes shall be made. Both retests, if for the element in question shall meet the requirements of the specification, otherwise all remaining material in the heat or lot shall be rejected or at the option of the producer, each length of flat rolled stock or tube may be individually tested for acceptance. Length or flat rolled stock of tubes which do not meet the requirements of this specification shall be rejected.

10.3 Lot:

Number of tubes in a lot heat treated by continuous process shall be as below:

Size of tube	Size of lot
25.4 mm or less in outside diameter`	not more than 125 tubes
Less than 40 mm but over 25.4 mm	not more than 75 tubes
In outside diameter.	

The term lot applied to all tubes prior to cutting of the same nominal diameter and wall thickness which are produced from the same heat. When final heat treatment is in a batch type furnace, a lot shall include only those tubes of the same size and the same heat which are heat treated in the same heat furnace charge. When the final heat treatment is in a continuous furnace a lot as defined above shall include tubes of the same size and heat, heat treated in the same furnace at the same temperature, time at heat and furnace speed.

One tensile, flattening, flaring test per lot shall be conducted.

11. MECHANICAL PROPERTIES:

When tested in accordance with ASTM A 370, the test pieces shall show the following properties in the annealed condition.

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11.1 Tensile Strength:

Tensile Strength : 345 N/mm² min.
Yield Strength, 0.2% offset : 275 – 450 N/mm²
Elongation in 50 mm gauge length : 20% min.

11.2 Flattening Test:

The tube shall be capable of withstanding without cracking, flattening under a load applied gradually at room temperature until the distance between the load platens is H mm. H is calculated as follows:

$$H = \frac{(1 + e) t}{e + t / D}$$

Where

H = the min. Flattened height, mm.
t = the nominal wall thickness, mm.
D = the nominal tube diameter, mm and
e = 0.07 for all diameters

The tube shall be subjected to a reverse flattening test in accordance with Annex 2 of ASTM A370. A section of tube, approximately 102 mm long, which is still longitudinally 90° either side of the weld, shall be opened and flattened with the weld at the point of maximum bend. No cracking is permitted.

11.3 Flaring Test:

Tubes upto 88 mm outside diameter and upto 4 mm in wall thickness and thinner and section of tube approx. 102 mm shall withstand being flared with a tool having 60° included angle until the inner diameter of the tube at the mouth of the flare has been expanded by 20% min. The flared end shall show no visible cracking or rupture.

Flaring tests for larger sizes of tubes shall be as agreed upon between the manufacturer and BHEL.

12. NON DESTRUCTIVE TESTS:

Unless otherwise specified each tube shall be subjected to the following tests by the manufacturer.

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12.1 Eddy current Or Ultrasonic Test:

In order to accommodate the various types of nondestructive electric testing equipment and techniques in use, and manufacturing practices employed, any one of the following calibration standards may be used, at the option of the producer, to establish a minimum sensitivity level for rejection.

Note: 1. If specified on the order, both Eddy Current and Ultrasonic tests shall be conducted.

2. After Eddy Current test, untested ends of tubes shall be cut and removed.

12.1.1 Drilled Hole:

A hole not larger than 0.787 mm or less in which shall be drilled radially and completely through tube wall, care being taken to avoid distortion of the tube while drilling.

12.1.2 Longitudinal Notch:

A notch 0.787 mm or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 10% of the nominal wall thickness of the tube, or 0.102 mm, whichever is greater. The length of the notch shall be compatible with the testing method.

Any tube showing an indication in excess of that obtained from the calibration standard shall be set aside and be subjected to rework, retest or rejection. A tube thus set aside may be further examined for confirmation of the presence of a defect and may be resubmitted for inspection if no defect is found. Any tube may also be resubmitted for inspection if reworked so as to remove the defect within the specified diameter and wall thickness tolerance specified in clause 5.2.1. Rework by weld repair is not permitted.

12.2 Hydrostatic test:

Each tube so tested shall withstand, without showing bulges, leaks, or other defects, an internal hydrostatic pressure that will produce in the tube wall a stress of 50% of the minimum specified yield strength at room temperature. This pressure shall be determined by the following equation.

$$P = SEt / (Ro - 0.4t)$$

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Where

P = Minimum hydrostatic test pressure, N/mm²

S = Allowable fiber stress of one half the minimum yield strength, N/mm²

t = Wall thickness, mm

Ro = Outside tube radius, mm

E = 0.85 for welded tube

12.2.1 The maximum hydrostatic test pressure shall not exceed 17.2 N/mm² for sizes 76 mm OD and under, or 19.3 N/mm² for sizes over 76 mm OD. Hydrostatic pressure shall be maintained for not less than 10 seconds.

12.3 Pneumatic Test:

Each tube so tested shall withstand an internal air pressure of 0.69 N/mm² minimum for 5 seconds minimum without showing evidence of leakage. The test method used shall permit easy visual detection of any leakage. Such as by placing the tube under water or by using the pressure differential method. Any evidence of leakage shall be cause for rejection of that tube.

13. RETEST:

If the results of any mechanical tests of any lot do not conform to the requirements specified in the clause 11, results shall be made on additional tubes of double the original number from the same lot, each of which shall conform to the requirements specified.

14. QUALITY ASSURANCE REQUIREMENT:

The manufacturer shall conduct all the tests required to ensure that the tubes offered conform to the requirements of the applicable codes and standards, Manufacturer shall submit a detailed quality plan along with his offer as per the standard format which should include all the tests/checks to be carried out by them at the various stages of manufacturing the item. This quality plan shall be reviewed by BHEL and BHEL reserves the right to ask for any more checks, details if required at the time of Quality Plan finalization. The manufacturer shall manufacture the item as per the quality plan duly approved by BHEL.

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The supplier shall fill up the enclosed check list as per Annexure-A and submit the same along with the offer.

16. DOCUMENTS TO BE FURNISHED:

The following documents shall be furnished along with the offer:

1. A process chart clearly indicating the sequence of manufacturing.
2. Purchasing specification of strips.
3. Heat treatment details.
4. Welding procedure and weld details.
5. Packing box drawing
6. Quality plan.

17. INSPECTION AT SUPPLIERS WORKS:

BHEL / its representative shall have free access at all times until work on the contract of BHEL is being performed, to all parts of the manufacture's works. The supplier shall offer BHEL'S representative all reasonable facilities, without charge to satisfy the latter that the material is being furnished in accordance with this specification.

18. TEST CERTIFICATES:

Four copies of test certificates shall be supplied unless otherwise stated in the order. The test certificate shall bear the following information:

BHEL REFERENCES:

BHEL Order No.

HE 5 1533 (Rev. 00): Welded Titanium Tubes – Grade 2.



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Supplier's References:

- Supplier's Name
- Test Certificate No.
- Size & Quantity
- Identification Marks
- Process of Manufacture
- Heat Treatment and Batch Number

Test Results:

Results of chemical analysis, mechanical and non-destructive tests. If specified in purchase order, the test certificate shall be attested by BHEL representative / third inspection agency approved by BHEL.

19. PACKING AND MARKING

Packing shall be as per AA 0490002 **PRESERVATION PACKING AND MARKING HEAT EXCHANGER TUBES.**

20. REJECTION AND REPLACEMENT:

Material failing to confirm to this specification will be rejected. The supplier shall undertake to replace the rejected material at his own cost.

21. REFERRED STANDARDS:

Standards referred in this specification:

- 1) AA13002
- 2) ASTM A 370
- 3) AA 0490002

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ANNEXURE - A (Clause 15)

CHECK LIST FOR HE 5 1533 (To be filled by supplier)

- | | | |
|--|----|--------|
| (A) Name of Principal Supplier | >: | |
| (B) Name of Indian Agent | : | |
| 1. Grade of material as per specification | : | Yes/No |
| 2. Mechanical properties as per specification | : | Yes/No |
| 3. Bright annealing | : | Yes/No |
| 4. Seam height < 0.01 mm | : | Yes/No |
| 5. NDT Test Offered | : | Yes/No |
| i. Hydraulic test | : | Yes/No |
| ii. Pneumatic test | : | Yes/No |
| iii. Eddy current test | : | Yes/No |
| iv. Ultrasonic test | : | Yes/No |
| v. Air-air differential pressure test | : | Yes/No |
| 6. Test | | |
| 1. Flattening test | : | Yes/No |
| 2. Flaring test | : | Yes/No |
| 7. Finish of tubes | | |
| Inside side surface Ra= 2 microns or | : | Yes/No |
| Rz=10 microns | | |
| 8. Brief write up on manufacturing | : | Yes/No |
| Process enclosed. | | |
| 9. Quality plan on BHEL formal enclosed. | : | Yes/No |
| 10. Details of previous experience enclosed | : | Yes/No |
| (For new supplier's only). | | |
| 11. Lifting beam offered. | : | Yes/No |
| 12. Packing box drawing enclosed. | : | Yes/No |
| 13. End guides included (Both cuds). | : | Yes/No |
| 14. Deviation taken (please clearly specify, if any) | : | Yes/No |

Date:

Signature & Seal of Manufacturer

Place: