Designation: B891/B891M – 19

Standard Specification for Seamless and Welded Titanium and Titanium Alloy Condenser and Heat Exchanger Tubes with Enhanced Surface for Improved Heat Transfer[1]

This standard is issued under the fixed designation B891/B891M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers seamless and welded titanium and titanium alloy tubing on which at least part of the external or internal surface has been enhanced by cold forming for improved heat transfer. The tubes are used in surface condensers, evaporators, heat exchangers, coils, and similar heat transfer apparatus in diameters up to and including 1 in. [25.4 mm]. The base tube wall thickness is typically at least 0.049 in. [1.245 mm] average, but lighter gauge may be negotiated with the manufacturer.

1.2 Tubing purchased to this specification will typically be inserted through close-fitting holes in tubesheets, baffles, or support plates spaced along the tube length such as defined in the Tubular Exchanger Manufacturer's Association (TEMA) Standard.[2] The tube ends will also be expanded, and may then be welded. Tube may also be bent to form U-tubes or be coiled or otherwise formed, although tight radii may require unenhanced length for the bends.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the order. Combining values from the two systems may result in non-conformance. Within the text, the SI units are shown in brackets. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order.

1.4 The following precautionary statement pertains to the test method portion only: Section 8, 9, 10 and S1 of this specification:*This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A1047/A1047M Test Method for Pneumatic Leak Testing of Tubing

B338 Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers

E426 Practice for Electromagnetic (Eddy Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys

E1316 Terminology for Nondestructive Examinations

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *base tube, n*—the seamless or welded tube conforming to Specification B338 prior to enhancing.

3.1.2 *finished tube, n*—the tube following enhancement and any heat treatment, forming, or other processing specified.

3.1.3 *enhanced tube or section, n*—all or sections of tube length that have been mechanically worked inside, outside, or both, to produce increased surface area for improved heat transfer.

3.1.4 *finned section, n*—sections of tube exterior length that have been mechanically worked to produce increased surface area for improved heat transfer; see Table 1 for nomenclature of finning details.

[1] This specification is under the jurisdiction of ASTM Committee B10 on Reactive and Refractory Metals and Alloys and is the direct responsibility of Subcommittee B10.01 on Titanium.

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[2] Available from Tubular Exchanger Manufacturers Association, Inc. 25 North Broadway Tarrytown, NY 10591, www.tema.org.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard

TABLE 1 ENHANCED TUBE NOMENCLATURE

D	Outside Diameter of Base Tube
Di	Inside Diameter of Base Tube
dr	Root Diameter of Finned Section – Outside of Tube
do	Outside Diameter of Enhanced Section – Outside of Tube
di	Inside Diameter of Enhanced Section – Inside of Tube
W	Wall Thickness of Base Tube
Wf	Wall Thickness in Enhanced Section
Fh	Height of Fin – Outside of Tube
Fm	Mean Fin Thickness – Finned Section Outside of Tube
P	Mean Rib Pitch – Enhanced Section Inside of Tube
Rh	Height of Rib – Enhanced Section Inside of Tube
Ha	Rib Helix Angle – Enhanced Section Inside of Tube
Tt	Transition Taper

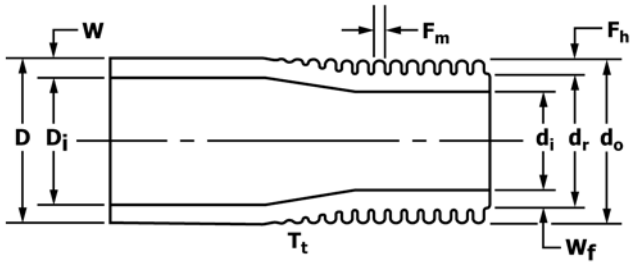

FIG. 1 Outside Finning Only

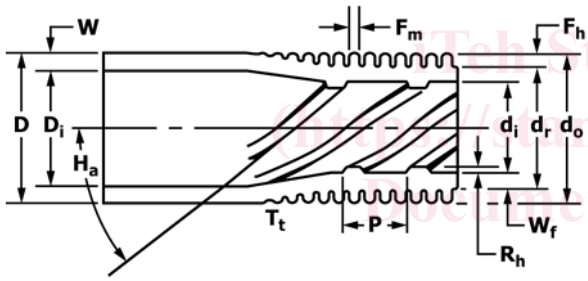

FIG. 2 Outside Finning and Inside Ribbing

3.1.5 *ribbed section, n*—sections of tube interior length that have been mechanically worked to produce increased surface area for improved heat transfer; see Table 1 for nomenclature of ribbing details.

3.1.6 *plain ends, n*—tube ends that have not been enhanced to allow for tube expansion for which properties are essentially identical to the base tube.

3.1.7 *land, n*—section of finished tube where the exterior and the interior surfaces have not been enhanced, to provide better support where passing through baffles, or for sections of tube that will subsequently be formed as U-bends; normally neither inside nor outside surfaces are enhanced in the land.

3.2 *Condition (of finished tubes):*

3.2.1 *as-enhanced tube, n*—tube which is supplied with no thermal treatment following enhancement.

3.2.2 *annealed tube, n*—tube where at least the enhanced length has been heat treated such that a recrystalized microstructure results for improved ductility for forming of coils or U-bends. Refer to S2.

3.2.3 *stress relieved tube, n*—U-tube where at least the bent section has been heat treated after bending for dimensional stability of the bends. Refer to 7.2.

3.2.4 *thermally oxidized tube, n*—tube where the entire length has been heat treated specifically for the purpose of enhancing or thickening the surface oxide. Refer to S3.

3.3 *Lot Definition*—A lot shall consist of finished tube from the same base tube heat, enhanced in the same manner and nominal dimensions, and subsequently heat treated using the same resistance heating parameters, in the same furnace charge, or if in a continuous furnace with continuous temperature monitoring and control within a 24 h time period.

4. Ordering Information

4.1 Purchase orders for tubes described in this specification should include the following to describe the tubes adequately.

4.1.1 ASTM Specification B891 designation and year of issue.

4.1.2 ASTM Specification B338 grade number.

4.1.3 If either welded or seamless is required for base tube.

4.1.4 Quantity (number of pieces) and the total tube length to be suppled under the purchase order.

4.1.5 Base tube dimensions; diameter, wall thickness (average or minimum wall thickness must be specified), tube length(s).

4.1.6 Enhancement: configuration of finned surfaces (fins per unit length, fin height, wall thickness under fin, etc. – refer to Fig. 1), configuration of ribbed surfaces (pitch, height, thickness of rib – refer to Fig. 2), length of plain ends, location and length of lands (refer to Figs. 3 and 4).

4.1.7 Dimensions: length of straight tubes (refer to Fig. 3), bend radii and leg lengths to tangent of U-bends (refer to Fig. 4).

4.1.8 Condition: heat treatment, (annealing, stress relieving, or thermal oxidation) requirements other than the standard as-enhanced condition (refer to 3.2, Section 7, and S2 and S3).

4.1.9 Nondestructive test requirements other than standard eddy current test (refer to Section 10).

4.1.10 Pressure test requirements other than standard pneumatic air under water or pressure differential tests (refer to Section 10).

4.1.11 Packaging, if other than manufacturer's standard (refer to Section 16).

4.1.12 Supplementary Requirements made a part of the purchase order.

5. General Requirements

5.1 Tubes described by this specification shall be furnished with plain ends.

5.2 Enhanced sections of the tube shall be supplied in the cold worked condition produced by the enhancing operation unless specified otherwise in the purchase order (refer to Supplementary Requirements S2 and S3.)

5.3 The tubes shall be able to stand properly conducted expansion and bending without showing cracks or other flaws.

6. Materials and Manufacture

6.1 The enhanced tubes shall be manufactured from annealed seamless or stress relieved or annealed welded base tubes that conform to the requirements of Specification B338.

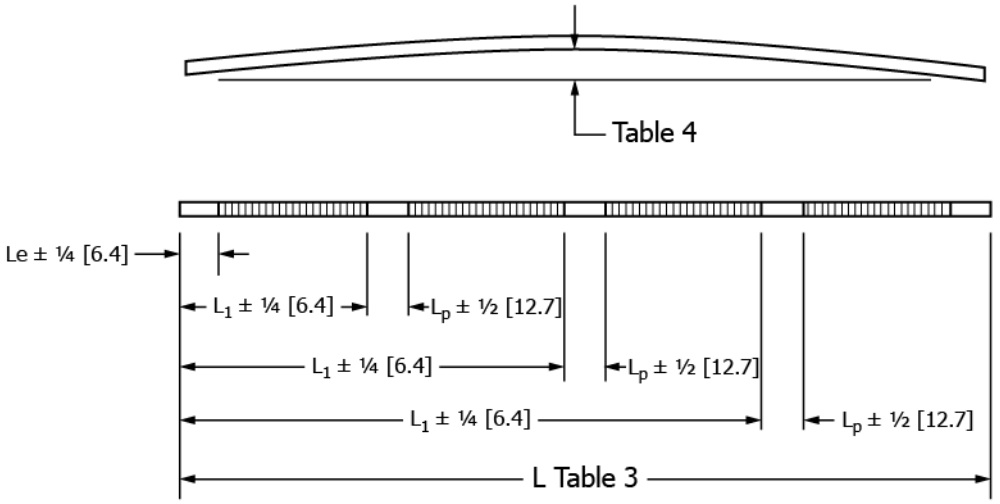

FIG. 3 Straight Tube Dimensional Tolerances

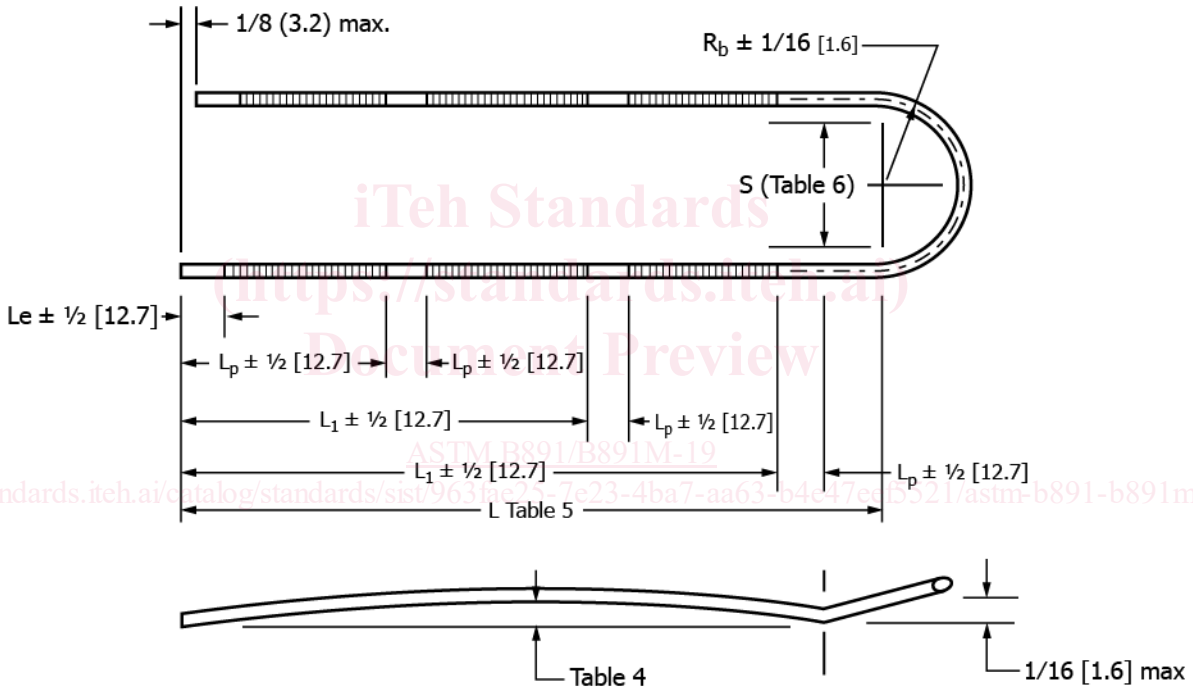

FIG. 4 U-Tube Dimensional Tolerances

6.2 Enhanced sections shall be produced by cold forming.

6.3 Plain ends and lands shall not be cold worked during the enhancing operations.

6.4 The following titanium grades are considered suitable for enhancing: Grade 1 (11, 17, 27), 2, (7, 16, 26), 2H (7H, 16H, 26H), and 3.

6.4.1 Enhancing of other grades may be considered by negotiation with the manufacturer.

7. Condition and/or Heat Treatment

7.1 Straight tubes and the straight sections of U-tubes shall be supplied in the as-enhanced condition as described in 3.2.1, unless specified otherwise by the purchaser (see Supplementary Requirements S2 and S3).

7.2 U-bends shall be stress relieved in the bent length and at least 1 in. [25.4 mm] of material beyond the tangent of each leg using parameters sufficient to maintain dimensional stability of the bend.

7.2.1 U-bends shall include a minimum of 2 in. [50.8 mm] land or unfinned length located on each straight leg beyond the tangent of the bend to allow for clamping surface when electric resistance method is used for heat treatment.

7.2.2 Stress relieving shall be conducted in air or in a protective inert gas atmosphere such that the operation does not result in excessive surface oxidation. Surface oxidation indicated by an iridescent straw to dark blue surface color is normal following stress in relieving in air. Matte gray, or loose white or yellow scale is unacceptable.

8. Chemical Composition

8.1 The composition of the titanium or titanium alloy shall conform to the chemical requirements for the grade specified as listed in Specification B338.

9. Tensile Requirements

9.1 The base tube prior to the enhancing operation shall conform to the tensile properties and other applicable requirements of Specification B338 for the grade specified.

10. Nondestructive, Pressure, and Other Tests

10.1 Nondestructive, pressure, and other tests other than those made mandatory in 10.2 or 10.3 shall be specified in the purchase order.

10.2 *Eddy Current Test*—Each tube in the finished condition, except for bending if that is required, shall be subjected to an eddy current test in accordance with Practice E426 by passing it through an encircling coil designed to test the entire cross section of the tube.

10.2.1 The reference standard tube used to calibrate the eddy current test equipment shall be sound and of the same grade, condition, nominal dimensions, and enhanced configuration as the lot of tubes to be tested on a production basis. Drill four holes not larger than 0.031 in. [0.787 mm] in diameter radially through the enhanced wall in each of four successive planes at 0, 90, 180 and 270°. Use EDM or a suitable drill and jig to guide the drill, taking care to avoid distortion of the adjacent fins. Locate one hole in the weld for welded material. Artificial discontinuities shall be spaced at least 16 in. [406 mm] apart to provide signal resolution adequate for interpretation. Discard the reference standard and replace when erroneous signals are produced from mechanical, metallurgical or other damage to the reference tube.

10.2.2 Adjust the eddy current test unit to obtain an optimum signal-to-noise ratio with the minimum sensitivity required to detect all four artificial defects in the reference standard on a repeatable basis. Equipment adjustments and tube speed maintained during calibration shall be the same for production tubes.

10.2.3 Set aside tubes showing an eddy current indication in excess of any signal obtained from artificial defects in the reference standard and subject them to retest or rejection.

10.2.4 Tubes causing irrelevant signals because of moisture, debris and like effects shall be considered to conform, should they not cause output signals beyond acceptable limits when retested. Tubes causing irrelevant signals because of visible and identifiable handling marks shall be considered to conform, provided the wall thickness in the enhanced and unenhanced areas is not less than the minimum specified.

10.2.5 Tubes causing relevant signals because of injurious defects that reduce the wall thickness below the minimum specified shall be rejected. If, after retest and examination, no source for the reject signal can be discerned, the tube shall be rejected.

10.3 *Pneumatic Pressure Test*—Each tube in the finished condition, except for bending if that is required, shall be subjected to a pneumatic pressure test. Each tube shall withstand a minimum internal pressure of 250 psi [1.72 MPa] for a minimum of 5 s without showing evidence of leakage. The test method used shall permit easy detection of any leakage by placing the tube underwater or by using the pressure differential method as defined in Test Method A1047/A1047M. Any evidence of leakage shall be cause for rejection of that tube.

10.4 *Hydrostatic Pressure Test:*

10.4.1 Hydrostatic test of straight tube is not required unless Supplementary Requirement S1 is made part of the purchase order.

10.4.2 Hydrostatic test of U-bend tube is required. Testing shall be completed for each U-tube. Testing shall be conducted in accordance with Supplementary Requirement S1.

10.4.3 Hydrostatic testing shall be conducted after all required enhancing, bending, and heat treatment is completed.

11. Permissible Variations in Dimensions

11.1 *Diameter:*

11.1.1 The outside diameter of plain ends and lands shall not vary by more than the amount in Table 2, as measured by "go" and "no go" ring gauges. The dimensions of the ring gauges shall be as described in 11.1.3 and 11.1.4.

11.1.2 The diameter over the enhanced sections shall not exceed the diameter of the plain sections involved, as determined by a "go" ring gauge unless otherwise specified.

11.1.3 The inside diameter dimension of the "go" ring gauge shall be equal to the nominal tube diameter, plus the plus tolerance from Table 2, plus 0.002 in. [0.051 mm]. The length of the "go" ring gauge shall be 1 in. [25.4 mm] minimum.

11.1.4 The inside diameter dimension of the "no go" ring or snap-on gauge shall be equal to the nominal tube diameter minus the minus tolerance from Table 2. The length of the "no go" ring gauge shall be 1 in. [25.4 mm] minimum.

11.1.5 Permissible variations from the specified outside diameter in the bent portion of the U-tube for bend radius $R = 2 \times D$ or greater, neither the major nor minor diameter of the tube shall deviate from the nominal diameter prior to bending by more than 10 %.

TABLE 2 Permissible Variations in Outside Dimensions and Wall Thickness Based on Individual Measurements

Outside Diameter, in. [mm]	Diameter Tolerance in. [mm][A]	Permissible Variations[A] in Wall Thickness, t, %	Permissible Variations[A] in Minimimum Wall Thickness, t, %
Under 1 [25.4], excl	±0.004 [±0.102]	±10	±20, –0
1 [25.4]	±0.005 [±0.127]	±10	±20, –0

[A] These permissible variations in outside diameter apply only to tubes as finished at the mill before subsequent swaging, expanding, bending, polishing or other fabricating operations.