



Designation: B523/B523M – 18 (Reapproved 2023)

Standard Specification for Seamless and Welded Zirconium and Zirconium Alloy Tubes¹

This standard is issued under the fixed designation B523/B523M; 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 specification² covers two grades of zirconium and zirconium alloy seamless and welded tubes.

1.2 Unless a single unit is used, for example corrosion mass gain in mg/dm^2 , the values stated in either inch-pound or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 The following precautionary caveat pertains only to the test methods portion 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.*

1.4 *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

[A370 Test Methods and Definitions for Mechanical Testing of Steel Products](#)

[B551/B551M Specification for Zirconium and Zirconium Alloy Strip, Sheet, and Plate](#)

[B614 Practice for Descaling and Cleaning Zirconium and Zirconium Alloy Surfaces](#)

[E8/E8M Test Methods for Tension Testing of Metallic Materials](#)

[E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications](#)

[E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing](#)

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

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *annealed, n*—for purposes of this specification “annealed” denotes material that exhibits a recrystallized grain structure.

3.2 *Lot Definitions:*

3.2.1 *tubes, n*—a lot shall consist of a material of the same size, shape, condition, and finish produced from the same ingot or powder blend by the same reduction schedule and the same heat treatment parameters. Unless otherwise agreed between manufacturer and purchaser, a lot shall be limited to the product of an 8 h period for final continuous anneal, or to a single furnace load for final batch anneal.

4. Classification

4.1 The tubes are furnished in two grades as follows:

4.1.1 *Grade R60702*—Unalloyed zirconium.

4.1.2 *Grade R60704*—Zirconium-tin alloy.

5. Ordering Information

5.1 Orders for material under this specification should include the following information:

5.1.1 Quantity (weight or number of pieces, or both),

5.1.2 Name of material (zirconium seamless or welded tube),

5.1.3 Dimensions (diameter, wall thickness as either average or minimum, lengths),

5.1.4 ASTM designation and year of issue,

5.1.5 Grade number (see 4.1), and

¹ This specification is under the jurisdiction of ASTM Committee B10 and is the direct responsibility of Subcommittee B10.02 on Zirconium and Hafnium.

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² For ASME Boiler and Pressure Vessel Code Applications, see related Specification SB-523 in Section II of that Code.

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.

5.1.6 Additions to the specification, if required. See 6.3.1, 7.3, 10.1, 12.7.3, 14.1, and 15.1 for additional optional requirements for the purchase order.

NOTE 1—A typical ordering description is as follows: 1000 pieces of seamless zirconium tubes, 2 in. [50 mm] in outside diameter by 0.06 in. [1.5 mm] in average wall thickness by 10 ft [3 m] in length, vacuum annealed, ASTM B523/B523M - 01, Grade R60702.

6. Materials and Manufacture

6.1 Seamless tube shall be made by any seamless method that will yield a product meeting the requirements of this specification.

6.2 Welded tube shall be made from sheet or strip meeting the requirements of Specification B551/B551M by an automatic arc-welding process or other method of welding that will yield a product meeting the requirements of this specification. Filler metal shall not be used. Welded tubing shall be supplied as follows:

6.2.1 As welded, or

6.2.2 As welded and further reduced.

6.3 The tube shall be furnished annealed.

6.3.1 Purchaser shall specify one of the following:

(a) annealed in air

(b) annealed in vacuum

7. Chemical Composition

7.1 The material shall conform to the requirements as to chemical composition prescribed in Table 1.

7.2 The manufacturer's ingot analysis shall be considered the chemical analysis for tubing, except for hydrogen and nitrogen, which shall be determined on the finished product.

7.3 When requested by the purchaser and stated in the purchase order, a product analysis for any elements listed in Table 1 shall be made on the finished product.

7.3.1 The manufacturer's analysis shall be considered as verified if the check analysis confirms the manufacturer's reported values within the tolerances prescribed in Table 2.

8. Tensile Requirements

8.1 The material, as represented by the test specimens, shall conform to the tensile properties prescribed in Table 3.

TABLE 1 Chemical Requirements^A

Element	Composition, %	
	UNS Grade Designation	
	R60702	R60704
Zirconium + hafnium, min ^B	99.2	97.5
Hafnium, max	4.5	4.5
Iron + chromium	0.2 max	0.2 to 0.4
Tin	...	1.0 to 2.0
Hydrogen, max	0.005	0.005
Nitrogen, max	0.025	0.025
Carbon, max	0.05	0.05
Niobium
Oxygen, max	0.16	0.18

^A By agreement between the purchaser and the manufacturer, analysis may be required and limits established for elements and compounds not specified in the table of chemical composition.

^B The value for zirconium + hafnium, min, is a warranted but not a measured value.

TABLE 2 Permissible Variation in Product Analysis Between Different Laboratories

Element	Permissible Variation in Product Analysis, %
Hydrogen	0.002
Nitrogen	0.01
Carbon	0.01
Hafnium	0.1
Iron + chromium	0.025
Tin	0.05
Niobium	0.05
Oxygen	0.02

TABLE 3 Tensile Requirements

	UNS Grade Designation	
	R60702	R60704
Tensile strength, min, ksi [MPa]	55 [380]	60 [415]
Yield strength, min, ksi [MPa]	30 [205]	35 [240]
Elongation in 2 in. or 50 mm, min, %	16	14

9. Permissible Variation in Dimensions

9.1 *Diameter*—At any point (cross section) along the length of the tube, the variation in outside diameter shall not exceed those prescribed in Table 4.

9.2 *Length*—When tubes are ordered cut to length, the length shall be not less than that specified, but a variation of 1/8 in. [3.2 mm] will be permitted on tube up to 10 ft [3 m], inclusive. For lengths over 10 ft, an additional over-tolerance of 1/8 in. [3.2 mm] for each 10 ft [3 m] or fraction thereof shall be permissible up to 1/2 in. [13 mm], maximum.

9.3 *Straightness*—The tube shall be free of bends or kinks and the maximum uniform bow shall not exceed the values shown in Table 5.

9.4 *Squareness of Cut*—The angle of cut of the end of any tube up to 1 1/2 in. [40 mm] in outside diameter may depart from square not more than 0.016 in./in. [mm/mm].

10. Workmanship and Quality Level Requirements

10.1 The finished tube shall be clean and free of foreign material, shall have smooth ends, free of burrs, and shall be free of injurious external and internal imperfections in accordance with standards of acceptability agreed upon between the manufacturer and the purchaser. Minor defects may be removed provided the dimensional tolerances of Table 4 are not exceeded.

11. Significance of Numerical Limits

11.1 For the purpose of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding methods of Practice E29.

TABLE 4 Permissible Variations in Outside Dimensions Based on Individual Measurements

Outside Diameter, in. [mm]	Diameter Tolerance, in. [mm] ^{A,B}	Permissible Variations ^C in Wall Thickness, <i>t</i> , %
Under 1 [25], excl	±0.004 [±0.100]	10
Over 1 to 1½ [25 to 40], incl	±0.005 [±0.125]	10
Over 1½ to 2 [40 to 50], incl	±0.006 [±0.150]	10
Over 2 to 2½ [50 to 65], incl	±0.007 [±0.180]	10
Over 2½ to 3½ [65 to 90], incl	±0.010 [±0.250]	10

^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.

^B Ovality is the maximum and minimum outside diameter of a tube measured at any one cross section. If the measurement is made with a ring gage, the following formula shall apply: Ovality = specified OD tube + diameter tolerance +0.002 in. [.05 mm] (length of ring gage, 1 in. [25 mm]) × specified tube OD.

^C When minimum wall tubes are ordered, tolerances are all plus and shall be double the values shown.

TABLE 5 Straightness

Length, ft [m]	Maximum Curvature Depth of Arc
Over 3 to 6 [0.9 to 1.85], incl	1/8 in. [3.2 mm]
Over 6 to 8 [1.8 to 2.5], incl	3/16 in. [5 mm]
Over 8 to 10 [2.5 to 3.0], incl	1/4 in. [6.4 mm]
Over 10 [3.0]	1/4 in./any 10 ft [2.1 mm/m]

tubes of double the original number from the same lot, each of which shall conform to the requirements specified.

12.7.3 Retesting after failure of initial retests may be done only with the approval of the purchaser.

13. Test Methods

13.1 *Tension Tests*—Conduct the tension test in accordance with Test Methods E8/E8M. Determine the yield strength by the offset (0.2 %) method. Determine the tensile properties using a strain rate of 0.003 to 0.007 in./in. [mm/mm]/min through the yield strength. After the yield strength has been exceeded, the cross-head speed may be increased to approximately 0.05 in./in. [mm/mm]/min to failure.

13.2 Eddy Current Testing:

13.2.1 Perform the nondestructive test in accordance with Practice E426, or a purchaser-approved procedure.

13.2.1.1 *Drilled Hole*—The calibration tube shall contain three or more holes, equally spaced circumferentially around the tube and longitudinally separated by a sufficient distance to allow distinct identification of the signal from each hole. The holes shall be drilled radially and completely through the tube wall, with care being taken to avoid distortion of the tube while drilling. The holes shall not be larger than 0.031 in. [0.8 mm] in diameter. As an alternative, the producer may choose to drill one hole and run the calibration standard through the test coil three times, rotating the tube approximately 120° each time. More passes with smaller angular increments may be used, provided testing of the full 360° of the coil is obtained. For welded tubing, if the weld is visible, one of the multiple holes or the single hole shall be drilled in the weld.

13.3 Ultrasonic Testing:

13.3.1 For ultrasonic testing, the longitudinal calibration reference notches shall be at the option of the manufacturer, and be any one of the three common notch shapes in accordance with Practice E213. The depth of the notch shall not exceed 10 % of the specified wall thickness of the material or 0.004 in. [0.10 mm], whichever is greater.

13.3.2 Set aside any tubes showing an indication in excess of that obtained from the calibration standard and subject them to rework, retest, or rejection. A tube, therefore, set aside may be further examined for confirmation of the presence of a defect and may be resubmitted for inspection by the same technique if no defect is found. Any tube may also be resubmitted for inspection if reworked so as to remove the

12. Number of Tests and Retests

12.1 One longitudinal tension test, see 13.1, shall be made from each lot.

12.2 One chemistry test, see 7.2 and 13.8, for hydrogen and nitrogen shall be made from each lot of finished product.

12.3 One flare test, see 13.6, shall be made from each lot.

12.4 One reverse flattening test, see 13.7, shall be made from each lot of welded tubing.

12.5 Welded Tubes:

12.5.1 Welded tubes shall be nondestructively tested using the following procedures:

12.5.1.1 Eddy Current Test, see 13.2.

12.5.1.2 Ultrasonic Test, see 13.3.

12.5.1.3 Hydrostatic Test, see 13.4, or pneumatic test, see 13.5.

12.6 Seamless Tubes:

12.6.1 Seamless tubes shall be nondestructively tested using the following procedures:

12.6.1.1 Ultrasonic Test, see 13.3.

12.6.1.2 Eddy Current Test, see 13.2, or hydrostatic test, see 13.4, or pneumatic test, see 13.5.

12.7 Retests:

12.7.1 If any sample or specimen exhibits obvious surface contamination or improper preparation disqualifying it as a truly representative sample, it shall be discarded and a new sample or specimen substituted.

12.7.2 If the results of any tests of any lot do not conform to the requirements specified, retests shall be made on additional