



~~Designation: B394-03~~ Designation: B394 - 09

Standard Specification for Niobium and Niobium Alloy Seamless and Welded Tubes¹

This standard is issued under the fixed designation B394; 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 wrought niobium and niobium alloy seamless and welded tubes as follows: ~~Note 1—Committee B10 has adopted “niobium” as the designation for Element No. 41, formerly named “columbium.”~~

1.1.1 *R04200-Type 1*—Reactor grade unalloyed niobium,

1.1.2 *R04210-Type 2*—Commercial grade unalloyed niobium,

1.1.3 *R04251-Type 3*—Reactor grade niobium alloy containing 1 % zirconium, and

1.1.4 *R04261-Type 4*—Commercial grade niobium alloy containing 1 % zirconium.

~~1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.~~

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*²

B391 [Specification for Niobium and Niobium Alloy Ingots](#)

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

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

E2626 [Guide for Spectrometric Analysis of Reactive and Refractory Metals](#)

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 ~~lot, n~~ —a lot shall consist of all material produced from the same ingot at one time, with the same cross section, processed with the same nominal metallurgical parameters and heat treated at the same conditions.

4. Ordering Information

4.1 Orders for materials under this specification shall include the following information as applicable:

4.1.1 Type and grade (Section 1),

4.1.2 ASTM designation and year of issue,

4.1.3 Welding (Section 5),

4.1.4 Quantity in weight, number of pieces, and dimensions,

4.1.5 Chemistry (6.3),

4.1.6 Temper designation (Section 8),

4.1.7 Permissible variations in length and quantity or weight (9.2, 9.4, and Table 1^B),

4.1.8 Quality and finish (10.4),

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 B10.03 on Niobium and Tantalum.

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² 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.

TABLE 1 Permissible Variations in Diameter and Wall Thickness Measured at any Location^A

Nominal Outside Diameter, in. (mm) ^B	Variation in Outside Diameter, Over and Under, in. (mm) ^B	Variation in Inside Diameter, Over and Under, in. (mm) ^C	Variation in Wall Thickness, Over and Under, % ^{C,D}
0.187 to 0.625 (4.7 to 15.9), excl	0.004 (0.010)	0.004 (0.010)	10
0.625 to 1.000 (15.9 to 25.4), excl	0.005 (0.13)	0.005 (0.13)	10
1.000 to 2.000 (25.4 to 50.8), excl	0.0075 (0.19)	0.0075 (0.19)	10
2.000 to 3.000 (50.8 to 76.2), excl	0.010 (0.25)	0.010 (0.25)	10
3.000 to 4.000 (76.2 to 101.6), excl	0.0125 (0.32)	0.0125 (0.32)	10

^A These tolerances are applicable to only two dimensions, such as outside diameter and wall, or inside diameter and wall, or outside diameter and inside diameter.

^B For applicable tolerances for very small tubes, less than 0.187 in. (4.9 mm) in outside diameter, or very thin wall tubes, less than 0.010 in. (0.25 mm), the producer should be consulted.

^C When tubes as ordered require wall thicknesses $\frac{3}{4}$ in. (19.05 mm) or over, or an inside diameter 60 % or less of the outside diameter, a wider variation in wall thickness is required. On such sizes, a variation in wall thickness of 12.5 % over and under will be permitted.

^D Ovality measured at any cross section: For tubes with nominal wall thickness less than 3 % of the nominal outside diameter, the ovality tolerance is double the tolerance shown in the second and third columns.

- 4.1.9 Sampling (11.2),
- 4.1.10 Hydrostatic or pneumatic test (14.2),
- 4.1.11 Inspection (Section 15),
- 4.1.12 Required reports (Section 17), and
- 4.1.13 Additions to the specification and supplementary requirements, as required.

5. Materials and Manufacture

5.1 Material covered by this specification shall be made from ingots that conform to Specification B391 and that are produced by vacuum or plasma arc melting, vacuum electron-beam melting, or a combination of these three methods.

5.2 Seamless tubes may be made by any seamless method that will yield a product meeting the requirements of this specification, such as, but not limited to, extrusion of billets with subsequent cold working by drawing, swaging, or ~~rolling, pilgering,~~ with intermediate anneals, until the final dimensions are reached.

5.3 Welded tubing shall be made from flat-rolled products by an automatic or semiautomatic welding process with no addition of filler metal in the welding operation. Other methods of welding, such as the addition of filler metal or hand welding, may be employed if approved by the purchaser and tested by methods agreed upon between the manufacturer and the purchaser. The manufacturer must use proper precautions to prevent contamination during welding.

6. ~~Chemical and Hardness Requirements~~ Chemical and Hardness Requirements

6.1 The niobium and niobium alloy ingots and billets for conversion to finished products covered by this specification shall conform to the requirements for chemical composition ~~and hardness~~ as prescribed in Table 2 ~~and Table 3~~.

6.2 The manufacturer's ingot analysis shall be considered the chemical analysis for products supplied under this specification, except for interstitials as specified in 6.3. ~~Alternately, an analysis of a representative sample of in process or final product from the same ingot may be substituted.~~

6.3 When requested by the purchaser at the time of purchase, the manufacturer shall furnish a report certifying the values of the interstitial elements (C, O, N, H) ~~on end product as prescribed in Table 4~~ ~~for each lot of material supplied.~~ ~~for each lot of material supplied.~~ End product interstitial samples must be taken after all thermal and chemical processing.

6.4 Guide E2626 is recommended as a guide, where applicable.

7. Mechanical Requirements

7.1 The annealed materials supplied under this specification shall conform to the requirements for mechanical properties as specified in ~~Table 5~~ Table 4.

8. Temper Designations

8.1 Unless otherwise stated, the materials supplied under these specifications shall be in the fully annealed condition, that is, at least 90 % recrystallized.

8.2 Other temper designations, such as cold-worked temper or stress-relieved temper, can be specified as agreed upon between the purchaser and the manufacturer at the time of purchase.

TABLE 2 Chemical Requirements

Element	Type 1 (Reactor Grade Unalloyed Niobium) R04200	Type 2 (Commercial Grade Unalloyed Niobium) R04210	Type 3 (Reactor Grade Niobium—1 % Zirconium) R04251	Type 4 (Commercial Grade Niobium—1 % Zirconium) R04261
Max Weight % (Except Where Otherwise Specified)				
Each ingot:				
Carbon	0.01	0.01	0.01	0.01
Nitrogen	0.01	0.01	0.01	0.01
Oxygen	0.015	0.025	0.015	0.025
Hydrogen	0.0015	0.0015	0.0015	0.0015
Zirconium	0.02	0.02	0.8 to 1.2 (range)	0.8 to 1.2 (range)
Tantalum	0.1	0.3	0.1	0.5
Iron	0.005	0.01	0.005	0.01
Silicon	0.005	0.005	0.005	0.005
Tungsten	0.03	0.05	0.03	0.05
Nickel	0.005	0.005	0.005	0.005
Molybdenum	0.010	0.020	0.010	0.050
Hafnium	0.02	0.02	0.02	0.02
Titanium	0.02	0.03	0.02	0.03
When specified:				
Boron	2 ppm	...	2 ppm	...
Aluminum	0.002	0.005	0.002	0.005
Beryllium	0.005	...	0.005	...
Chromium	0.002	...	0.002	...
Cobalt	0.002	...	0.002	...

9. Permissible Variations in Dimensions and Weight

9.1 *Diameter and Wall Thickness*—The permissible variations in diameter and wall thickness of the tubes shall not exceed those prescribed in Table 1.

9.2 *Length*—When tube is ordered cut to length, the useable length shall not be less than that specified, but a variation of $\pm 1/8$ in. (3.18 mm) will be permitted for lengths up to 6 ft (1.8 m). For lengths over 6 ft, a variation of $\pm 1/4$ in. (6.4 mm) will be permitted, unless otherwise specified at the time of purchase.

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

9.4 *Quantity or Weight*—For orders requiring up to 100 ft (30.5 m) of finished tubing, the manufacturer may overship by 20 %. When the order is for quantities up to 1000 ft (305 m) or 1000 lb (453.6 kg), the manufacturer may overship by 10 %. The permissible overshipment shall be negotiated for orders larger than this quantity.

10. Quality and Finish

10.1 Finished niobium and niobium alloy tubes shall be free of injurious internal and external imperfections of a nature that will interfere with the purpose for which it was intended.

10.2 The finished tubes shall be visibly free of oxide, grease, oil, residual lubricants, and other extraneous materials.

10.3 The finished tubes shall be free of cracks, seams, slivers, burrs, blisters, and other injurious imperfections exceeding 10 % of the nominal wall thickness.

10.4 Methods of testing for these defects and standards of acceptability shall be as agreed upon between the manufacturer and the purchaser.

11. Sampling

11.1 Samples for chemical and mechanical testing shall be taken from the finished material after all metallurgical processing to determine conformity to this specification. The samples may be taken prior to final inspection and minor surface conditioning by abrasion and pickling, and shall be representative of the finished product.

11.2 Care shall be exercised to ensure that the sample selected for testing is representative of the material and that it is not contaminated by the sampling procedure. If there is any question relating to the sampling technique or the analysis thereof, the methods of sampling and analysis shall be as agreed upon between the purchaser and the manufacturer.

12. Number of Tests and Retests

12.1 Two samples from each lot of tubes shall be tested for flare and tensile properties in the longitudinal direction.

12.2 When hydrostatic or pneumatic testing is required, all tubes in the lot shall be tested.

12.3 If end-product chemical tests are required (6.3), one chemical test shall be made from each lot of finished product.