Designation: B 394 – 99

Standard Specification for Niobium and Niobium Alloy Seamless and Welded Tubes[1]

This standard is issued under the fixed designation B 394; 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 B-10 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.

1.3 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:*

B 391 Specification for Niobium and Niobium Alloy Ingots[2]

E 8 Test Methods for Tension Testing of Metallic Materials[3]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[4]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *lot*—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 Method of manufacture (Section 5),

4.1.4 Temper designation (Section 8),

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

4.1.6 Chemistry (Section 6),

4.1.7 Mechanical properties (Section 7),

4.1.8 Quality and finish (Section1011),

4.1.9 Sampling (Section 11),

4.1.10 Marking (Section 18),

4.1.11 Packaging (Section 19),

4.1.12 Required reports (Section 17),

4.1.13 Disposition of rejected material (Section 16), and

4.1.14 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 B 391 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 rocking, 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 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

[1] This specification is under the jurisdiction of ASTM Committee B-10 on Reactive and Refractory Metals and Alloysand is the direct responsibility of Subcommittee B10.03on Niobium and Tantalum.

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[2] *Annual Book of ASTM Standards*, Vol 02.04.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

and hardness as prescribed in Table 1 and Table 2.

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.

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) as prescribed in Table 3 for each lot of material supplied.

7. Mechanical Requirements

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

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 5.

9.2 *Length*—When tube is ordered cut to length, the useable length shall not be less than that specified, but a variation of + ⅛in. (3.18 mm) will be permitted for lengths up to 6 ft (1.8 m). For lengths over 6 ft, a variation of + ¼in. (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 6.

TABLE 1 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	...

TABLE 2 Brinell Hardness

	Type 1	Type 2	Type 3	Type 4
Maximum average	90	125	125	135
Maximum individual impression	105	150	140	150

TABLE 3 Additional Chemical Requirements for Finished Product (When Specified by Purchaser)

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 %			
Oxygen	0.0250	0.0400	0.0250	0.0400
Carbon	0.0100	0.0150	0.0100	0.0150
Nitrogen	0.0100	0.0100	0.0100	0.0100
Hydrogen	0.0015	0.0015	0.0015	0.0015

TABLE 4 Mechanical Properties[A] for Material, Annealed Condition (90 % Minimum Recrystallized)

Grade	Ultimate Tensile Strength, min, psi (MPa)	Yield Strength (0.2 % offset), min, psi (MPa)	Elongation in 1-in. (25-mm) gage length, min, %
Type 1	18 000 (125)	10 500 (73)	25
Type 2	18 000 (125)	10 500 (73)	25
Type 3	28 000 (195)	18 000 (125)	20
Type 4	28 000 (195)	18 000 (125)	20

[A] Refer to Section 13 for conditions of mechanical property tests.

TABLE 5 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 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.

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