Designation: B394 – 03

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

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.

1.3 *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 [3]

E8 Test Methods for Tension Testing of Metallic Materials [4]

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

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 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),

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 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.

[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] *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.

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 ¾ 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.

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.

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 4 for each lot of material supplied.

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	...

TABLE 3 Brinell Hardness

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

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.

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 4 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