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Standard Specification for Niobium and Niobium Alloy Bar, Rod, and Wire[1]

This standard is issued under the fixed designation B392; 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.

ε^1 NOTE—Editorial corrections were made throughout in January 2010.

1. Scope

1.1 This specification covers four grades of wrought niobium and niobium alloy bar, rod, and wire as follows:

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 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

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.

3.1.2 *bar, n*—material less than 6 in. (152.4 mm) in width and 0.187 in. (4.75 mm) or greater in thickness, with a rectangular cross section, supplied in straight lengths.

3.1.3 *rod, n*—material 0.125 to 2.50 in. (3.18 to 63.50 mm) in diameter, in round, hexagonal, or octagonal cross section supplied in straight lengths.

3.1.4 *wire, n*—material 0.020 to 0.124 in. (0.51 to 3.15 mm) in diameter, furnished in coils or on spools or reels. Material less than 0.020 in. (0.51 mm) in diameter is not covered by this specification.

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 (6.3),

4.1.7 Mechanical properties (Section 7),

4.1.8 Condition (8.2),

4.1.9 Permissible Variations (9.2),

4.1.10 Permissible overshipments (9.4),

4.1.11 Quality and finish (Section 10),

4.1.12 Sampling (Section 11),

4.1.13 Inspection (Section 15),

4.1.14 Required reports (Section 17), and

4.1.15 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

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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.

produced by vacuum or plasma arc melting, vacuum electron-beam melting, or a combination of these three methods.

5.2 The various niobium mill products covered by this specification are formed with the conventional extrusion, forging, swaging, rolling, and drawing equipment normally available in metal working plants.

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 as prescribed in Table 1.

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 2 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 3.

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 Additional Chemical Requirements for Finished Product (When Specified by the 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
	Maximum 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 3 Mechanical Properties, Annealed Condition (90 % Minimum Recrystallized)

Grade	Ultimate Tensile Strength, Min, psi (MPa)	Yield Strength, psi (MPa)	Elongation min %, mm[A]
Rod, 0.125 in. (3.18 mm) to 2.5 in. (63.5 mm) diameter			
Types 1 and 2	18 000 (125)	10 500 (73)	25
Types 3 and 4	28 000 (195)	18 000 (125)	20
Wire, 0.020 in. (0.51 mm) to 0.124 in. (3.15 mm)			
Types 1 and 2	18 000 (125)	...	20
Types 3 and 4	28 000 (195)	...	15

[A] 10 in. (254 mm) gage length to 0.050 in. (1.27 mm) diameter, and 1 in. (25.4 mm) or 2 in. (50.8 mm) gage length equal to or over 0.050 in. (1.27 mm).

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 *Tolerances on Rounds*—Tolerances on niobium and niobium alloy round products covered by this specification shall be as prescribed in Table 4.

9.2 *Tolerances for Square, Rectangular, or Other Shapes*—Tolerances for forged or rolled square, rectangular, or other shapes shall be as agreed upon between the purchaser and the manufacturer at the time of purchase.

TABLE 4 Permissible Variations in Dimensions for Rolled, Swaged, or Drawn Rod and Wire

Diameter, in. (mm)	Tolerances, plus or minus, in. (mm)
0.020–0.030 excl (0.51–0.76)	0.00075 (0.019)
0.030–0.060 excl (0.76–1.52)	0.001 (0.025)
0.060–0.090 excl (1.52–2.29)	0.0015 (0.038)
0.090–0.125 excl (2.29–3.18)	0.002 (0.051)
0.125–0.187 excl (3.18–4.75)	0.003 (0.076)
0.187–0.375 excl (4.75–9.53)	0.004 (0.102)
0.375–0.500 excl (9.53–12.7)	0.005 (0.127)
0.500–0.625 excl (12.7–15.9)	0.007 (0.178)
0.625–0.750 excl (15.9–19.1)	0.008 (0.203)
0.750–1.000 excl (19.1–25.4)	0.010 (0.254)
1.000–1.500 excl (25.4–38.1)	0.015 (0.381)
1.500–2.000 excl (38.1–50.8)	0.020 (0.508)
2.000–2.500 incl (50.8–63.5)	0.030 (0.762)

9.3 *Other Tolerances and Limitations:*

9.3.1 The permissible variations in cut lengths shall not exceed a total of 0.25 in. (6.35 mm).

9.3.2 The permissible variation in straightness of rounds shall not exceed 0.050 in./ft (4.2 mm/m) in any length.

9.4 *Quantity or Weight*—For orders requiring up to 100 ft (30.5 m) of finished product, 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 bar, rod, and wire shall be free of injurious internal and external imperfections of a nature that will interfere with the purpose for which it was intended. Material may be finished as-rolled, as-cleaned, as-ground, or as-machined. If shipped as hot-worked, cold-worked, cleaned, or ground, the manufacturer shall be permitted to remove minor surface imperfections, if such removal does not reduce the dimensions below the minimum permitted by the tolerances specified in Table 4.

10.2 The finished bars, rods, or wire shall be visibly free of oxide, grease, oil, residual lubricants, and other extraneous materials.

10.3 The finished bars, rods, or wire shall be visibly free of cracks, seams, slivers, burrs, blisters, and other injurious imperfections.

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 A minimum of one sample from each lot of bars, rods, or wire shall be tested for tensile properties in the longitudinal direction.

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

12.3 *Retests*—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.

12.3.1 In case of a failure, retest two additional specimens. If both retest specimens conform to this specification, discard the original values and consider the material acceptable; otherwise, the lot shall be rejected or reworked and tested.

12.4 If the results of the final product inspections are not in conformance with the requirements of this specification, the lot may be reworked at the option of the manufacturer. The lot shall be acceptable if results of all tests, after reworking, conform to this specification.

13. Significance of Numerical Limits

13.1 For the purposes of determining compliance with the specified limits for requirements of the properties listed in this specification, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E29.

14. Test Methods

14.1 *Tension Test*—Conduct tension tests in accordance with Test Methods E8. Determine the yield strength by the 0.2 % offset method. Small size, 1-in. (25.4-mm) gage length specimens proportional to the standard specimen can be used. Determine tensile properties using a strain rate of 0.003 to 0.007 in./in./min (.076 to .178 mm/mm/min) through the yield point. After the yield strength has been exceeded, increase the cross-head speed to approximately 0.02 to 0.05 in./in./min (.500 to 1.27 mm/mm/min) to failure.

15. Inspection

15.1 If so specified on the purchase order, the purchaser or his representative may witness the testing and inspection of the material at the place of manufacture. In such cases, the purchaser shall state in his purchase order which tests he desires to witness. The manufacturer shall give ample notice to the purchaser as to the time and place of the designated test. If the purchaser's representative does not present himself at the agreed-upon time for the testing, and if no new date is set, the manufacturer shall consider the requirement for purchaser's inspection at the place of manufacture to be waived. When the inspector representing the purchaser does appear at the appointed place and time, the manufacturer shall afford him all reasonable facilities to see that the material is being furnished in accordance with this specification. This inspection shall be conducted so as not to interfere unnecessarily with production operations.

16. Rejection and Rehearing

16.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

16.2 In the event of disagreement between the manufacturer and the purchaser about the conformance of the material to the requirements of this specification or any special test specified by the purchaser, a mutually acceptable referee shall perform

the tests in question. The results of the referee's testing shall be used in determining conformance of the material to this specification.

17. Certification

17.1 A producer's or supplier's certification that the material was manufactured, sampled, tested, and inspected in accordance with this specification, and found to meet the requirements shall be furnished to the purchaser. When specified in the purchase order or contract, a report of the test results shall be furnished.

18. Product Marking

18.1 Each bar, rod, bundle, box, coil, or spool shall be marked or tagged legibly and conspicuously, at a minimum, with the heat number, alloy or type, manufacturer's identification, nominal size, and the gross, net, and tare weights. If marking fluids are used, they shall be of such a nature as to be easily removed with cleaning solutions. The markings or their removal shall have no deleterious effect on the material or its performance. The characters shall be sufficiently stable to withstand ordinary handling.

19. Packaging and Package Marking

19.1 All material shall be packed in such a manner as to ensure safe delivery to its destination when properly transported by any common carrier.

20. Keywords

20.1 niobium; niobium alloy; niobium bar; niobium rod; niobium wire