



# Standard Specification for Niobium and Niobium Alloy Strip, Sheet, and Plate<sup>1</sup>

This standard is issued under the fixed designation B393; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

<sup>ε1</sup> NOTE—Editorial corrections were made throughout in January 2010.

## 1. Scope

1.1 This specification covers five grades of wrought niobium and niobium alloy strip, sheet, and plate 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.

1.1.5 *R04220-Type 5*—RRR grade pure niobium.

NOTE 1—This grade of niobium is used in superconducting applications that require the ultra high purity. Because of the high purity the product is conducive to very large grains that can adversely affect formability. It is not recommended for other applications.

1.2 Except for dimensional tolerances in [Table 1](#), 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*:<sup>2</sup>

[B391 Specification for Niobium and Niobium Alloy Ingots](#)  
[E8 Test Methods for Tension Testing of Metallic Materials](#)

<sup>1</sup> 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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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[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 *plate, n*—a flat product 6 in. (152.4 mm) or more in width and greater than  $\frac{3}{16}$  in. (4.76 mm) in thickness.

3.1.3 *sheet, n*—a flat product 6 in. (152.4 mm) or more in width and from 0.005 in. (0.13 mm) to  $\frac{3}{16}$  in. (4.76 mm) in thickness.

3.1.4 *strip, n*—a flat product, which may be supplied in coil, less than 6 in. (152.4 mm) in width and from 0.005 in. (0.13 mm) to  $\frac{3}{16}$  in. (4.76 mm) in thickness.

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

4.1.4 Chemistry ([6.3](#)),

4.1.5 Temper designation ([Section 8](#)),

4.1.6 Permissible overshipment ([9.3](#)),

4.1.7 Quality and finish ([10.3](#)),

4.1.8 Sampling ([11.2](#)),

4.1.9 Inspection ([Section 15](#)),

4.1.10 Required reports ([Section 17](#)),

4.1.11 Marking ([Section 18](#)), and

4.1.12 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.

**TABLE 1 Dimensional Tolerances for Niobium Flat-Rolled Products**

Thickness of Material, in. (mm) in lower table	Tolerance on Thickness <sup>A</sup> plus or minus, in. (mm) in lower table		Tolerance on Width (slit) <sup>B</sup> plus or minus, in.(mm) in lower table		Tolerance on Sheared Lengths, in. (mm)			
	Width under 6 in. or 152.4 mm	Width 6 to 24 in. or 152.4 to 609.6 mm	Width under 6 in. or 152.4 mm	Width 6 to 24 in. or 152.4 to 609.6 mm	Length 12 in. or 304.8 mm and under		Length over 12 in. or 304.8 mm	
					Plus	Minus	Plus	Minus
Inches								
0.005 to 0.010 excl	0.0005	0.001	0.012	...	1/16	0	3/32	0
0.010 to 0.015 excl	0.0007	0.001	0.015	0.015	1/16	0	3/32	0
0.015 to 0.020 excl	0.0008	0.0015	0.015	0.015	1/16	0	3/32	0
0.020 to 0.030 excl	0.0015	0.0025	0.020	0.025	1/16	0	3/32	0
0.030 to 0.060 excl	0.0025	0.0035	0.025	0.030	1/16	0	3/32	0
0.060 to 0.090 excl	0.004	0.005	0.025	0.035	1/16	0	3/32	0
0.090 to 0.125 excl	0.006	0.007	...	...	1/16	0	3/32	0
0.125 to 0.187 excl	0.010	0.010	...	...	1/16	0	3/32	0
0.187 to 0.250 excl	0.015	0.015	...	...	1/8	0	5/32	0
0.250 to 0.312 excl	0.020	0.020	...	...	1/8	0	5/32	0
0.312 to 0.375 excl	0.025	0.025	...	...	3/16	0	7/32	0
Millimetres								
0.13 to 0.254 excl	0.013	0.025	0.30	...	1.59	0	2.38	0
0.254 to 0.381 excl	0.018	0.025	0.38	0.38	1.59	0	2.38	0
0.381 to 0.508 excl	0.020	0.038	0.38	0.38	1.59	0	2.38	0
0.508 to 0.762 excl	0.038	0.064	0.51	0.64	1.59	0	2.38	0
0.762 to 1.524 excl	0.064	0.089	0.64	0.76	1.59	0	2.38	0
1.524 to 2.286 excl	0.102	0.127	0.64	0.89	1.59	0	2.38	0
2.286 to 3.175 excl	0.15	0.18	...	...	1.59	0	2.38	0
3.175 to 4.75 excl	0.25	0.25	...	...	1.59	0	2.38	0
4.75 to 6.35 excl	0.38	0.38	...	...	3.18	0	3.97	0
6.35 to 7.925 excl	0.51	0.51	...	...	3.18	0	3.97	0
7.925 to 9.52 excl	0.64	0.64	...	...	4.76	0	5.56	0

<sup>A</sup> Tolerance on thickness of sheet over 24 in. (610 mm) wide shall be  $\pm 10\%$  of the thickness.

<sup>B</sup> Tolerance on width of sheared sheet shall be  $\pm 1/16$  in. ( $\pm 1.6$  mm) and on sheared plate shall be  $\pm 1/8$  in. ( $\pm 3.2$  mm) up to material thickness of 0.375 in. (9.5 mm).

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 2](#).

6.2 The manufacturer's ingot analysis shall be considered the chemical analysis for products supplied under this specification, except for end product 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 specified.

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 products as prescribed in [Table 3](#) 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 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 Tolerances for thickness, width, and length for flat-rolled products covered by this specification shall be as prescribed in [Table 1](#).

9.2 Flatness tolerance for sheet and plate products supplied under this specification shall be a maximum of 6 % (2 % for RRR grade sheet and strip) as determined by the following equation (see [Fig. 1](#)):

$$\text{Flatness, \%} = (H/L) \times 100 \quad (1)$$

where:

$H$  = maximum vertical distance between a flat reference and the lower surface of the sheet, and

$L$  = minimum horizontal distance between the highest point on a sheet and the point of contact with a flat reference surface. ([Fig. 1](#) is included to illustrate the method for taking measurements for calculation of sheet flatness. However, a value of  $H$  less than  $1/32$  in. (0.070 mm) shall not be cause for rejection.)

**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	Type 5 (RRR Superconducting Grade Pure Niobium) R04220
	Max Weight % (Except Where Otherwise Specified)				
Each ingot:					
Carbon	0.01	0.01	0.01	0.01	0.0030
Nitrogen	0.01	0.01	0.01	0.01	0.0030
Oxygen	0.015	0.025	0.015	0.025	0.0040
Hydrogen	0.0015	0.0015	0.0015	0.0015	0.0005
Zirconium	0.02	0.02	0.8 to 1.2 (range)	0.8 to 1.2 (range)	0.010
Tantalum	0.1	0.3	0.1	0.5	0.1
Iron	0.005	0.01	0.005	0.01	0.005
Silicon	0.005	0.005	0.005	0.005	0.005
Tungsten	0.03	0.05	0.03	0.05	0.007
Nickel	0.005	0.005	0.005	0.005	0.003
Molybdenum	0.010	0.020	0.010	0.050	<sup>A</sup>
Hafnium	0.02	0.02	0.02	0.02	<sup>A</sup>
Titanium	0.02	0.03	0.02	0.03	0.005
When specified:					
Boron	2 ppm	...	2 ppm	...	
Aluminum	0.002	0.005	0.002	0.005	0.005
Beryllium	0.005	...	0.005	...	
Chromium	0.002	...	0.002	...	<sup>B</sup>
Cobalt	0.002	...	0.002	...	<sup>B</sup>

<sup>A</sup> The limits shown below are for information only when the RRR ratio is greater than 260.

<sup>B</sup> Total of these metals is 0.005 %.

**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	Type 5 (RRR Superconducting Grade Pure Niobium) R04220
	Max Weight %				
Oxygen	0.0250	0.0400	0.0250	0.0400	0.0040
Carbon	0.0100	0.0150	0.0100	0.0150	0.0030
Nitrogen	0.0100	0.0100	0.0100	0.0100	0.0030
Hydrogen	0.0015	0.0015	0.0015	0.0015	0.0005

**TABLE 4 Mechanical Properties<sup>A</sup> 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. (25.4- mm) gage length, min, %	
			0.010 in. or Greater	Less Than 0.010 in.
Types 1 and 2	18 000 (125)	10 500 (73)	20	15
Types 3 and 4	28 000 (195)	18 000 (125)	20	15
Type 5 (RRR grade) <sup>B</sup>	14 000 (95)	7 200 (50)	30	30

<sup>A</sup> Refer to Section 14 for conditions of mechanical tests.

<sup>B</sup> For RRR grade the difference between longitudinal and transverse samples shall not exceed 20 % of the average of the two.

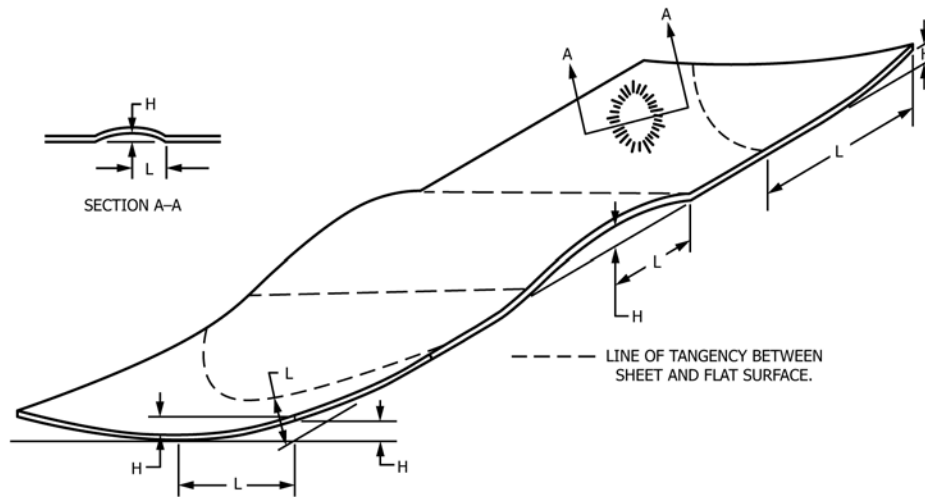
9.3 *Quantity or Weight*—For orders requiring up to 100 lb (45.4 kg) of finished product, the manufacturer may overship by 20 %. When the order is for quantities up to 1000 lb (453.6

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 strip, sheet, and plate 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, or as ground. 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 1.

10.2 The finished strip, sheet, or plate shall be visibly free of oxide, grease, oil, residual lubricants, and other extraneous materials.



$H$  = maximum distance between flat surface and lower surface of sheet.  
 $L$  = minimum distance between highest point on sheet and point of contact with flat surface.  
 Flatness, percent =  $(H/L) \times 100$

FIG. 1 Plate and Sheet Flatness Tolerances

10.3 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 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 strip, sheet, or plate shall be tested for tensile properties. For RRR grade, two samples from each lot, one longitudinal and one transverse, shall be tested for tensile properties.

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 *Rework*—If the results of the final sheet, strip, or plate 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 the 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 (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 (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 strip, sheet, plate, box or carton shall be marked or tagged, 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 or adhesive labels 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.

18.2 When specified in the purchase or contract, cut strip, flat sheet, and plate shall be marked in lengthwise rows of characters recurring at intervals not greater than 2 ft (0.6 m), the rows being spaced more than 3 in. (76.2 mm) apart and alternately staggered. Characters shall be at least  $\frac{3}{8}$  in. (9.5 mm) in height.

18.3 When specified in the purchase or contract, coiled sheet and strip shall be marked at the outside of the coil. Characters shall be at least  $\frac{3}{8}$  in. (9.5 mm) in height.

#### **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 plate; niobium alloy sheet; niobium alloy strip

### **ANNEX**

#### **(Mandatory Information)**

#### **A1. FOR TYPE 5 — RRR GRADE MATERIALS**

A1.1 In addition to specific requirements in the rest of this standard, the following apply:

A1.1.1 Product hardness shall not exceed 60 HV10.

A1.1.2 The residual resistance ratio (RRR) shall be 260 minimum, defined as ratio of electrical resistance at  $273 \pm 5^\circ\text{K}$  divided by resistance at liquid helium temperature (4.2K).

A1.1.3 Average grain size shall not exceed ASTM number 5, with local areas no larger than ASTM number 4.

A1.1.4 Surface roughness for sheet and strip only shall not exceed 1.6 micrometres  $R_a$ .

A1.1.5 Surface scratches for sheet and strip only shall not exceed 50 micrometres in depth.

A1.1.6 The vacuum during heat treatments when the material is at the annealing temperature shall be less than  $5 \times 10^{-5}$  Torr.

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