



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

This standard is issued under the fixed designation B654/B654M; 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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

## 1. Scope

1.1 This specification covers hafnium alloyed niobium foil, sheet, strip, and plate.

1.2 The material covered by this specification is R04295, niobium-base alloy containing approximately 10 % hafnium and 1 % titanium.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *The following safety hazards caveat pertains only to the test methods portion, Section 14, of this specification: This standard does not purport to address all of the safety problems, 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>

[B652/B652M Specification for Niobium-Hafnium Alloy Ingots](#)

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

[E21 Test Methods for Elevated Temperature Tension Tests 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:*

<sup>1</sup> This specification is under the jurisdiction of Committee B10 on Reactive and Refractory Metals and Alloys and is the direct responsibility of Subcommittee B10.03 on Niobium and Tantalum.

Current edition approved May 1, 2010. Published June 2010. Originally approved in 1979. Last previous edition approved in 2004 as B654–04. DOI: 10.1520/B0654\_B0654M-10.

<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.

3.1.1 *foil, n*—a flat product less than 6 in. [150 mm] wide and less than 0.005 in. [0.13 mm] in thickness.

3.1.2 *lot, n*—a lot is defined as that material produced from one ingot and heat-treated at the same conditions. Unless otherwise agreed between manufacturer and purchaser, a lot shall be limited to the product of an 8 h period for final continuous anneal or to a single furnace load for a final batch anneal.

3.1.3 *plate, n*—a flat product 6 in. [150 mm] or more in width and more than 0.187 in. [4.8 mm] in thickness.

3.1.4 *sheet, n*—a flat product 6 in. [150 mm] or more in width and from 0.005 in. [0.13 mm] to 0.187 in. [4.8 mm] in thickness.

3.1.5 *strip, n*—a flat product, may be supplied in coil, less than 6 in. [150 mm] wide and from 0.005 in. [0.13 mm] to 0.187 in. [4.8 mm] in thickness.

## 4. Ordering Information

4.1 Orders for material under this specification should include the following information as applicable:

4.1.1 General alloy description (see 1.2) and ASTM designation and year of issue,

4.1.2 Quantity in weight or pieces,

4.1.3 Size, diameter or thickness, width, and length, as applicable,

4.1.4 Chemical Composition (Section 6),

4.1.5 Temper (Section 7),

4.1.6 Mechanical test temperature and limits (Sections 8 and 14),

4.1.7 Permissible dimensional tolerances and weight or quantity variations (see 9.3),

4.1.8 Quality and finish (see 10.2),

4.1.9 Sampling (see 13.2),

4.1.10 Inspection Witnessing (see 15.2),

4.1.11 Certification Requirements (Section 18), and

4.1.12 Packaging (Section 20).

## 5. Materials and Manufacture

5.1 Materials covered by this specification shall be made from ingots in accordance with Specification [B652/B652M](#).

**TABLE 1 Chemical Requirements for Ingot**

Niobium-Hafnium Alloy R04295	
Element	Content, Maximum Weight % (Except Where Otherwise Specified)
Carbon	0.015
Oxygen	0.025
Nitrogen	0.010
Hydrogen	0.0015
Hafnium	9–11
Titanium	0.7–1.3
Zirconium	0.700
Tungsten	0.500
Tantalum	0.500
Niobium by difference	...

**TABLE 2 Additional Chemical Requirements for Finished Product**

Niobium-Hafnium Alloy R04295	
Element	Content, Maximum Weight %
Oxygen	0.035
Carbon	0.015
Nitrogen	0.010
Hydrogen	0.0015

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

## 6. Chemical Composition

6.1 The chemical composition of niobium-hafnium alloy ingots and billets for conversion to finished products covered by this specification shall conform to the requirements in [Table 1](#). Analysis for elements, not listed in [Table 1](#) and not normally expected in niobium-hafnium alloy, shall not be required unless specified at time of purchase.

6.2 The manufacturer's ingot analysis shall be considered the chemical analysis for products supplied under this specification.

6.3 When specified in the purchase order, the manufacturer shall test the product for elements specified in [Table 2](#). The results of the tests shall meet the limits shown in [Table 2](#).

## 7. Temper Designations

7.1 Unless otherwise stated, the materials supplied under this specification shall be in the annealed condition, defined as at least 90 % recrystallized.

7.2 Other temper designations, such as cold-worked temper or stress-relieved temper may be specified in the purchase order.

## 8. Mechanical Requirements

8.1 Materials in the annealed condition supplied under this specification shall conform to the requirements for mechanical properties as specified in [Table 3](#). Unless otherwise specified in the purchase order, the materials shall conform to the requirements for room temperature mechanical properties. The purchaser may specify elevated temperature mechanical properties at the time of purchase.

## 9. Permissible Variations

9.1 *Dimensional tolerances*—Tolerances on niobium-hafnium alloy products covered by this specification shall be as prescribed in [Table 4](#).

9.2 Flatness tolerance for sheet and plate products supplied under this specification shall be 6 % maximum, 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 surface and the lower surface of the sheet, and

$L$  = minimum horizontal distance between the highest point on the sheet and the point of contact with a flat reference surface. (The method for taking measurements for calculation of sheet flatness is shown in [Fig. 1](#). However, a value of  $H$  less than  $\frac{1}{32}$  in. [0.8 mm] shall not be cause for rejection.)

9.3 *Quantity or Weight*—For orders up to 100 ft [30 m], the manufacturer may overship by 20 %. For orders up to 1000 lb [450 kg] or 1000 ft [300 m], the manufacturer may overship by 10 %. The permissible overshipment for orders larger than this quantity shall be negotiated at the time of purchase.

## 10. Quality and Finish

10.1 Niobium-hafnium alloy product shall be free of injurious external and internal imperfections of a nature that will

**TABLE 3 Mechanical Properties for Material, Annealed Condition<sup>A</sup> (90 % Minimum Recrystallized)**

	Ultimate Tensile Strength, min, psi [MPa]	Yield Strength (0.2 % offset), min, psi [MPa]	Elongation in 1 in. [25 mm] gage length, min, %
Material 0.05 in. [1.3 mm] and thinner:			
Room temperature	56 000 [385]	40 000 [275]	20
2000 ± 25°F [1100 ± 15°C]	21 000 [145]	16 000 [110]	20
Material greater than 0.05 in. [1.3 mm] in thickness:			
Room temperature	54 000 [370]	38 000 [260]	20
2000 ± 25°F [1100 ± 15°C]	21 000 [145]	16 000 [110]	20

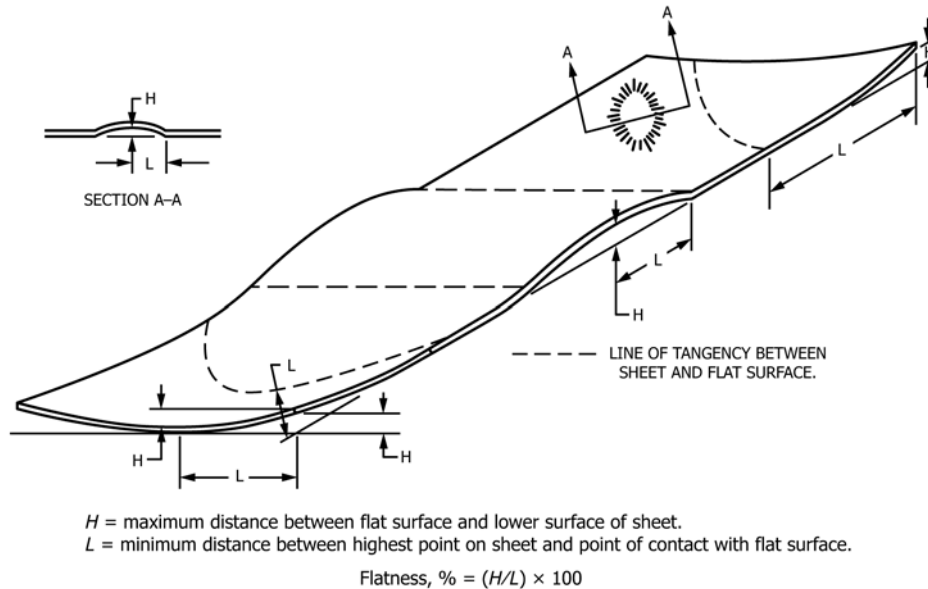
<sup>A</sup> Refer to Section 14 for conditions of mechanical property tests.

**TABLE 4 Dimensional Tolerances for Niobium-Hafnium Alloy 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 in lower table]			
	Width under 6 in. or 150 mm	Width 6 to 24 in. or 150 to 610 mm	Width under 6 in. or 150 mm	Width 6 to 24 in. or 150 to 610 mm	Length 12 in. or 305 mm and under		Length over 12 in. or 305 mm	
					Plus	Minus	Plus	Minus
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
Millimeters								
0.13 to .25 excl	0.013	0.025	0.30	...	1.6	0	2.4	0
0.25 to 0.40 excl	0.018	0.025	0.4	0.4	1.6	0	2.4	0
0.40 to 0.50 excl	0.020	0.04	0.4	0.4	1.6	0	2.4	0
0.50 to 0.8 excl	0.04	0.06	0.5	0.6	1.6	0	2.4	0
0.8 to 1.5 excl	0.06	0.09	0.6	0.8	1.6	0	2.4	0
1.5 to 2.3 excl	0.10	0.13	0.6	0.9	1.6	0	2.4	0
2.3 to 3.2 excl	0.15	0.18	...	...	1.6	0	2.4	0
3.2 to 4.8 excl	0.25	0.25	...	...	1.6	0	2.4	0
4.8 to 6.4 excl	0.4	0.4	...	...	3.2	0	4.0	0
6.4 to 8.0excl	0.5	0.5	...	...	3.2	0	4.0	0
8.0 to 9.5 excl	0.6	0.6	...	...	4.8	0	5.6	0

<sup>A</sup> Tolerance on thickness of sheet over 24 in. [600 mm] wide shall be ±10 % of the thickness.

<sup>B</sup> Tolerance on width of sheared sheet shall be + 1/16, -0 in. [+ 1.6, -0 mm].



**FIG. 1 Plate and Sheet Flatness Tolerances**

interfere with the purpose for which it was intended. Material may be finished as forged, rolled, extruded, swaged, drawn; in a cleaned, machined, or ground condition. The manufacturer shall be permitted to remove minor surface imperfections provided such removal does not reduce the dimensions below the minimum permitted by the tolerances in accordance with Section 9.

10.2 Test methods for these defects and standards of acceptability shall be as agreed upon between the purchaser and the manufacturer at the time of purchase.

## 11. Retests

11.1 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.

11.2 In case of failure, two additional specimens shall be retested. If both retest specimens conform to this specification, the original values shall be discarded and the material accepted.

11.3 If the results of the tests 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.

## 12. Significance of Numerical Limits

12.1 The following applies to all specified limits in this standard for purposes of determining conformance with this specification. The observed value or a calculated value shall be rounded off “to the nearest unit” in the last right-hand digit used in expressing the specification limit, in accordance with the rounding-off method of Practice E29.

## 13. Sampling

13.1 Samples shall be taken from the material to determine conformity to this specification. The samples shall be taken so as to be representative of the finished products.

13.2 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 techniques or analysis thereof, the methods of sampling and analysis shall be as agreed upon between the manufacturer and the purchaser.

## 14. Test Methods

14.1 The tensile limits shall apply to samples taken in either the longitudinal or transverse direction of processing.

14.2 *Room Temperature Tension Test*—Conduct room temperature tension tests in accordance with Test Methods E8. Determine the yield strength by the 0.2 % offset method. Small size (1-in. [25-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 0.05 in./in./min [mm/mm/min] to failure.

14.3 *Elevated Temperature Tension Tests*—Conduct elevated temperature tension tests in accordance with Test Methods E21 at the temperature shown in Table 3. One inch [25 mm] gage lengths can be used. Strain rates shall be agreed upon by purchaser and manufacturer.

14.4 *Chemical Tests*—Conduct the chemical analyses by the standard techniques normally used by the manufacturer. Guide E2626 may be used as a guide for chemical analysis techniques.

## 15. Inspection

15.1 The manufacturer shall inspect the material covered by this specification prior to shipment.

15.2 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 agreed upon, the manufacturer shall consider the requirement for the purchaser’s inspection at the place of manufacture to be waived. When the inspector representing the purchaser does appear at the designated time and place, the manufacturer shall afford him, without charge, 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.

## 17. Referee

17.1 In the event of disagreement between the manufacturer and the purchaser of the conformance of the material to the requirements of this specification, or any special tests 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.

## 18. Certification

18.1 A producer’s or supplier’s certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. A report of the test results shall be furnished.

## 19. Product Marking

19.1 Each coil of foil, sheet, strip, or plate shall be marked or tagged legibly and conspicuously with the number of this specification; temper; heat number; manufacturer’s identification; nominal size; and the gross, net, and tare weights.

19.2 The manufacturer shall have the option of affixing tags to each item in such a manner as to not damage or mar the material. The tags shall show the same information specified in 19.1.

19.3 The product shall be marked with characters not less than  $\frac{3}{8}$  in. [9.5 mm] in height, and shall be applied using a suitable marking fluid capable of being removed with conventional 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.

19.4 Plate, flat sheet, and cut strip shall be marked in lengthwise rows of characters recurring at intervals not greater than 2 ft. [0.6 m], the rows being spaced not more than 3 in. [75 mm] apart and alternately staggered.

19.5 Coiled sheet and strip shall be marked or tagged at the outside end of the coil.



## **20. Packaging and Package Marking**

20.1 Unless otherwise specified, material purchased under this specification must be packed by box or other suitable protective containers, and should be so marked as to indicate the nature of the best handling.

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## **21. Keywords**

21.1 niobium-hafnium alloy foil; niobium-hafnium alloy plate; niobium-hafnium alloy sheet; niobium-hafnium alloy strip