Designation: B 776 – 01a

Standard Specification for Hafnium and Hafnium Alloy Strip, Sheet, and Plate[1]

This standard is issued under the fixed designation B 776; 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 two grades of hafnium strip, sheet, and plate, one specifically for nuclear applications (Grade R1) and one for commercial applications for alloying (Grade R3).

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 *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:*

E 8 Test Methods for Tension Testing of Metallic Materials[2]

E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[3]

3. Terminology

3.1 *Lot Definitions:*

3.1.1 *castings*—a lot shall consist of all castings produced from the same pour.

3.1.2 *ingot*—no definition required.

3.1.3 *rounds, flats, tubes, and wrought powder metallurgical products (single definition, common to nuclear and non-nuclear standards)*—a lot shall consist of a material of the same size, shape, condition, and finish produced from the ingot or powder blend by the same reduction schedule and the same heat treatment parameters. 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 final batch anneal.

3.1.4 *sponge*—a lot shall consist of a single blend produced at one time.

3.1.5 *weld fittings*—definition is to be mutually agreed upon between manufacturer and the purchaser.

4. Classification

4.1 The strip, sheet, or plate is to be furnished in one of the two grades shown in Table 1.

5. Ordering Information

5.1 Purchase orders for material under this specification shall include the following information as required to adequately describe the desired material:

5.1.1 Quantity (weight or number of pieces),

5.1.2 Number of material,

5.1.3 Form (strip, sheet, plate),

5.1.4 Metallurgical condition (6.2),

5.1.5 Finish (Section 11),

5.1.6 Applicable dimensions (thickness, width, and length),

5.1.7 Grade (Table 1), and

5.1.8 ASTM designation and year of issue.

NOTE 1—A typical ordering description is as follows: twenty-eight pieces hafnium plate, annealed; mechanically descaled and pickled; 0.158 in. by 6.000 in. thick by 18-in. long lengths; Grade R1; ASTM B 776 – ___.

5.2 In addition to the data specified in 5.1, the following options and points of agreement between the manufacturer and the purchaser shall be specified on the purchase order if required:

5.2.1 Mechanical test temperature (see 8.1),

5.2.2 Tolerances (Section 10),

5.2.3 Workmanship standards (Section 11),

5.2.4 Special or alternate tests (Sections 8 and 14),

5.2.5 Inspection (Section 16),

5.2.6 Corrosion testing (Section 9),

5.2.7 Zirconium analysis requirements (Table 1), and

5.2.8 The isotopic hafnium composition and its analysis, if required, shall be mutually agreed upon by the purchaser and producer.

6. Materials and Manufacture

6.1 The sheet, strip, or plate covered by this specification shall be formed with conventional forging and rolling equipment found in primary ferrous and nonferrous metal plants, and

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

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

TABLE 1 Chemical Requirements

Elements	Composition, weight	
	Grade R1	Grade R3
Aluminum	0.010	0.050
Carbon	0.015	0.025
Chromium	0.010	0.050
Copper	0.010	...
Hydrogen	0.0025	0.0050
Iron	0.050	0.0750
Molybdenum	0.0020	...
Nickel	0.0050	...
Niobium	0.010	...
Nitrogen	0.010	0.015
Oxygen	0.040	0.130
Silicon	0.010	0.050
Tantalum	0.020	...
Tin	0.0050	...
Titanium	0.010	0.050
Tungsten	0.0150	0.0150
Uranium	0.0010	...
Vanadium	0.0050	...
Zirconium	[A]	[A]
Hafnium	balance	balance

[A] Zirconium shall be reported. Acceptable levels shall be established by mutual agreement between purchaser and producer.

made from ingots produced by vacuum melting in electron beam or consumable arc furnaces, or both, of a type conventionally used for reactive metals.

6.2 The sheet, strip, and plate shall be supplied in the recrystallized annealed condition unless otherwise specified.

7. Chemical Compositions

7.1 The material shall conform to the chemical composition requirements prescribed in Table 1.

7.2 The manufacturer's ingot analysis shall be considered the chemical analysis for sheet, strip, and plate, except for hydrogen and nitrogen, which shall be determined on the finished product.

7.3 When requested by the purchaser and stated in the purchase order, a product analysis for any elements listed in Table 1 shall be made on the finished product.

7.3.1 The manufacturer's analysis shall be considered as verified if the check analysis confirms the manufacturer's reported values within the tolerances prescribed in Table 2.

8. Mechanical Properties

8.1 Grade R1 shall conform to the requirements prescribed in Table 3 for room temperature mechanical properties. Elevated temperature properties shall be used to determine compliance only when specified in the purchase order.

TABLE 2 Permissible Variation in Check Analysis Between Different Laboratories

Element	Permissible Variation in Product Analysis, %
Hydrogen	0.002
Nitrogen	0.01
Carbon	0.01
Zirconium	0.02
Iron and Chromium	0.025
Tin	0.05
Niobium	0.05
Oxygen	0.02

TABLE 3 Mechanical Properties

Grade	Condition	Test Temperature	Tensile Strength, min ksi (MPa)	Yield Strength, min ksi (MPa)	Elongation, (min %) in 2 in. (50 mm)
Longitudinal:					
R1	annealed	RT	58 (400)	22 (151)	20
	annealed	600°F (316°C)	25 (172)	11 (83)	25
Transverse:					
R1	annealed	RT	45 (310)	25 (172)	20
	annealed	600°F (316°C)	23 (158)	14 (96)	30

9. Corrosion Properties

9.1 When required by the purchaser and stated in the purchase order, the following corrosion testing shall be performed:

9.1.1 Two samples chosen at random from each lot shall be corrosion tested in water at 680°F (360°C), 2690 psi for 672 + 8 − 0 h using the manufacturer's standard procedure.

9.1.2 *Grade R1*—Coupons shall exhibit a weight gain of not more than 10 mg/dm^2.

9.1.3 Grade R3 will be tested for information only, if required by purchase order.

10. Permissible Variations in Dimensions

10.1 *Thickness*—The variation in thickness of strip, sheet, and plate are given in the following tables:

10.1.1 Cold-rolled sheet, Table 4.

10.1.2 Hot-rolled strip, Table 5,

10.1.3 Cold-rolled strip, Table 6.

10.2 *Width and Length*—The variation in width and length are given in the following tables:

10.2.1 Hot- and cold-rolled sheet, Table 7 and Table 8.

10.2.2 Hot-rolled strip, Table 9.

10.2.3 Cold-rolled strip, Table 10.

10.3 *Crown Tolerances*—The variations in crown tolerances are given in the following tables:

10.3.1 Hot-rolled strip, Table 11.

10.3.2 Cold-rolled strip, Table 12.

10.4 *Camber Tolerances*—The variations in camber tolerances are given in the following tables:

10.4.1 Hot- and cold-rolled sheet, Table 13.

TABLE 4 Permissible Variation in Thickness of Cold-Rolled Hafnium Sheet[A]

Specified Thickness, in.	Permissible Variations In Thickness, ± in.
0.146 – 0.1875, excl	0.007
0.131 – 0.145	0.006
0.115 – 0.130	0.005
0.099 – 0.114	0.0045
0.084 – 0.098	0.004
0.073 – 0.083	0.0035
0.059 – 0.072	0.003
0.041 – 0.058	0.0025
0.027 – 0.040	0.002
0.017 – 0.026	0.0015
0.008 – 0.016	0.001
0.006 – 0.007	0.0008
0.005	0.0005

[A] Thickness measurements are taken at least ⅜ in. from edge.

TABLE 5 Permissible Variations in Thickness of Hot-Rolled Hafnium Strip

Specified width, in.	Variations from specified thickness for widths, given, over and under, in.[A]
3 – 18, incl	+ 0.01, – 0

[A] Thickness measurements shall be taken ⅜ in. from edge. Tolerances do not include crown.

10.4.2 Hot- and cold-rolled strip, Table 14.

10.4.3 Plate, Table 15.

10.5 Flatness tolerances permissible for plate are given in Table 16.

11. Workmanship, Finish, and Appearance

11.1 Cracks, seams, slivers, blisters, burrs, and other injurious imperfections shall not exceed standards of acceptability agreed upon by the manufacturer and the purchaser.

11.2 Flat-rolled product in the hot-rolled condition shall be furnished with one of the following finishes as designated on the order.

11.2.1 Not descaled,

11.2.2 Mechanically descaled, and

11.2.3 Mechanically descaled and pickled.

11.3 Material in the cold-rolled condition shall be furnished with a bright cold-rolled finish, or finished by mechanical or chemical methods.

11.4 The following types of edges are available:

11.4.1 Mill edge,

11.4.2 Slit edge,

11.4.3 Sheared edge, and

11.4.4 Machined edge.

12. Number of Tests and Retests

12.1 Two tension tests shall be made from each lot, one in the longitudinal and one in the transverse direction at each of the required temperatures.

12.2 Two chemistry tests for hydrogen and nitrogen content shall be made from each lot of finished product.

12.3 *Retests* :

12.3.1 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.

12.3.2 If the results of any tests of any lot do not conform to the requirements specified, retests shall be made on additional sheet, strip, or plate of double the original number from the same lot, each of which shall conform to the requirements specified.

13. Significance of Numerical Limits

13.1 For the purpose of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding methods of Practice E 29.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition, and tolerances (when expressed as decimals)	nearest unit in the last righthand place of figures of the specified limit
Tensile strength and yield strength	nearest 1000 psi (10 MPa)
Elongation	nearest 1 %

14. Special Tests

14.1 Additional tests may be specified in the purchase order. The test method and standards shall be agreed upon in advance between manufacturer and purchaser.

15. Test Methods

15.1 *Tension Tests*—Conduct the room temperature tensile test in accordance with Test Methods E 8 and elevated temperature tensile test in accordance with Test Methods E 21. Determine the yield strength by the offset (0.2 %) method. Determine the tensile properties using a strain rate of 0.003 to 0.007 in./in./min (mm/mm/min) through the yield strength. After the yield strength has been exceeded, increase the crosshead speed to approximately 0.05 in./in./min (mm/mm/min) to failure.

15.2 *Chemical Tests*—Conduct the chemical analysis by the standard techniques normally used by the manufacturer.

16. Inspection

16.1 The manufacturer shall inspect the material covered by this specification prior to shipment and, on request, shall furnish the purchaser with certificates of test. If so specified in 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 designated test. If the purchaser's representative does not present himself at the time agreed upon for the testing, the manufacturer shall consider the requirement for purchaser's inspection at the place of manufacture to be waived.

16.2 The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. This inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

17. Rejection

17.1 Rejection for failure of the material to meet the requirements of this specification shall be reported to the manufacturer within 60 calendar days from the receipt of the material by the purchaser. Unless otherwise specified, rejected material may be returned to the manufacturer at the manufacturer's expense, unless the purchaser receives, within three weeks of the notice of rejection, other instructions for disposition.

18. Certification

18.1 When specified in the purchase order or contract, 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

TABLE 6 Permissible Variations in Thickness of Cold-Rolled Hafnium Strip

NOTE 1—For thickness under 0.010 in. in width to 18 in., a tolerance of ± 10 % of the thickness shall apply.
NOTE 2—Thickness measurements shall be taken 3/8 in. in from edge of the strip, except on widths less than 1 in., where the tolerances are applicable for measurements at all locations.

Specified Thickness, in.	Permissible variations in thickness, for widths given, ± in.					
	3/16 incl to 1, excl	1 to 3 in., excl	3 to 6 in., excl	Over 6 to 9 in., incl	Over 9 to 12 in., incl	Over 12 to 18 in., incl
Under 3/16 – 0.161, incl	0.002	0.003	0.004	0.004	0.004	0.005
0.160–0.100, incl	0.002	0.002	0.003	0.004	0.004	0.004
0.099–0.069, incl	0.002	0.002	0.003	0.003	0.003	0.004
0.068–0.050, incl	0.002	0.002	0.003	0.003	0.003	0.003
0.049–0.040, incl	0.002	0.002	0.0025	0.003	0.003	0.003
0.039–0.035, incl	0.002	0.002	0.0025	0.003	0.003	0.003
0.034–0.029 incl	0.0015	0.015	0.002	0.0025	0.0025	0.0025
0.028–0.026, incl	0.001	0.015	0.0015	0.002	0.002	0.002
0.025–0.020, incl	0.001	0.001	0.0015	0.002	0.002	0.002
0.019–0.017, incl	0.001	0.001	0.001	0.0015	0.0015	0.002
0.016–0.013, incl	0.001	0.001	0.001	0.0015	0.0015	0.0015
0.012	0.001	0.001	0.001	0.001	0.0015	0.0015
0.011	0.001	0.001	0.001	0.001	0.001	0.0015
0.010	0.001	0.001	0.001	0.001	0.001	0.001

TABLE 7 Permissible Variations in Width and Length of Hot- and Cold-Rolled Hafnium Sheet

Specified width, in., for thickness under 3/16 in.	Permissible variations in width, in.
3 – 10, excl	+ 1/8, − 0
10 – 18	+ 1/8, − 1/8
Specified length, ft	**Permissible variations in length, in.**
up – 10, incl	+ 1/2, − 0
over 10 – 20, incl	+ 1, − 0

TABLE 8 Permissible Variations in Length of Hot- and Cold-Rolled Hafnium Sheet

Specified length, ft	Permissible variations in length, in.
to 5, incl	+ 3/8, − 0
over 5– 10, incl	+ 1/2, − 0
over 10 – 15, incl	+ 3/8, − 0

TABLE 9 Permissible Variations in Width of Hot-Rolled Hafnium Strip

	Permissible variations in width, in.					
	Mill edge		Slit edge		Sheared edge	
	+	−	+	−	+	−
to 3½, incl	1/8	0	1/32	1/32	1/16	1/16
over 3½ – 12, incl	1/2	1/8	1/32	1/32		0
over 12 – 18, incl	3/8	1/8	3/64	3/64	1/8	0

been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

19. Referee

19.1 In the event of disagreement between the manufacturer and the purchaser on 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.

TABLE 10 Permissible Variations in Width of Cold-Rolled Hafnium Strip (Slit Edge)

Specified Thickness, in.	Permissible variations in width, for widths given, ±, in.				
	Under 1/2 to 3/16 in., incl	1/2 to 6 in., incl	over 6 to 9 in., incl	over 9 to 12 in., incl	over 12 to 18 in., incl
Under 3/16 – 0.161, incl	...	0.016	0.020	0.020	0.031
0.160 – 0.100, incl	...	0.010	0.016	0.016	0.020
0.099 – 0.069, incl	0.008	0.008	0.010	0.010	0.016
0.068 and under	0.005	0.005	0.005	0.010	0.016

TABLE 11 Crown Tolerances for Hot-Rolled Hafnium Strip

Specified width, in.	Permissible variation in thickness from edge to center of strip, for width given, in.
to 3½, incl	0.003
over 3½ – 12, incl	0.004
over 12 – 18, incl	0.006

TABLE 12 Crown Tolerances for Cold-Rolled Hafnium Strip

Specified Thickness, in.	Tolerances by which the thickness at middle of strip may be greater than at edges, for widths given, in.		
	to 5, incl	over 5 to 12, incl	over 12 to 18, incl
0.005 – 0.101, incl	0.00075	0.001	...
Over 0.010 – 0.025, incl	0.001	0.0015	0.002
Over 0.025 – 0.065, incl	0.0015	0.002	0.0025
Over 0.065 – 3/16, excl	0.002	0.0025	0.003

20. Marking and Packaging

20.1 Each shipment shall be legibly and conspicuously marked or tagged with the following information:

20.1.1 Purchase order or contract number,

20.1.2 Name of material,

20.1.3 Grade,

TABLE 13 Camber Tolerance for Hot- and Cold-Rolled Hafnium Sheet[A]

Specified width, in.	Tolerance per unit length of any 8 ft, in.
3 – 18, incl	⅛

[A]Camber is the greatest deviation of a side edge from a straight line, the measurement being taken on the concave side with a straightedge.

TABLE 14 Camber Tolerances for Hot- and Cold-Rolled Hafnium Strip[A]

Specified width, in.	Tolerance, per unit length of any 8 ft, in.
to 1½, incl	⅛
over 1½ – 18	⅛

[A]Camber is the deviation of a side edge from a straight line. The measurement is taken by placing an 8-ft, straightedge on the concave side and measuring the greatest distance between the strip edge and the straightedge.

TABLE 15 Camber Tolerance for Hafnium Plate[A]

Tolerance:	⅛ in. × (number of feet of length/5)

[A]Camber is the greatest deviation of a side edge from a straight line. The measurement is taken by placing a straightedge on the concave side and measuring the greatest distance between the plate edge and the straightedge.

TABLE 16 Permissible Variations from A Flat Surface for Annealed Hafnium Plate

NOTE 1—Variations in flatness apply to plates up to 15 ft in length, or to any 15 ft of longer plates.

NOTE 2—If the longer dimension is under 36 in., the variation is not greater than ¼ in.

NOTE 3—The shorter dimension specified is considered the width and the variation in flatness across the width does not exceed the tabular amount for that dimension.

NOTE 4—The maximum deviation from a flat surface does not customarily exceed the tabular tolerance for the longer dimension specified.

Specified thickness, in.	18 or under
3/16 – ¼, excl	¼
¼ – ¾, excl	¼
⅜ – ½, excl	¼
½ – ¾, excl	¼
¾ –1, excl	¼

20.1.4 Size,

20.1.5 Lot, heat or ingot number,

20.1.6 Condition,

20.1.7 Gross, net, and tare weights, and

20.1.8 ASTM specification designation.

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

21. Keywords

21.1 hafnium; hafnium alloy; strip; sheet; plate