Designation: B352/B352M – 02 (Reapproved 2006)

Standard Specification for Zirconium and Zirconium Alloy Sheet, Strip, and Plate for Nuclear Application[1]

This standard is issued under the fixed designation B352/B352M; 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 hot- and cold-rolled zirconium and zirconium alloy sheet, strip, and plate.

1.2 One unalloyed and three alloys for use in nuclear applications are described.

1.3 The products covered in this specification include the following forms and sizes:

1.3.1 *Sheet*, 24 in. [600 mm] or more in width; under 0.187 in. [4.8 mm) in thickness,

1.3.2 *Strip*, less than 24 in. [600 mm] in width; under 0.187 in. [4.8 mm] in thickness, and

1.3.3 *Plate*, over 10 in. [250 mm] in width; 0.187 in. [4.8 mm] and over in thickness.

NOTE 1—Material over 0.187 in. [4.8 mm] in thickness and less than 10 in. [250 mm] wide is covered as bar in Specification B351/B351M.

1.4 Unless a single unit is used, for example corrosion mass gain in mg/dm^2, the values stated in either inch-pound or SI units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore each system must be used independently of the other. SI values cannot be mixed with inch-pound values.

1.5 The following precautionary caveat pertains only to the test method portions 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]

B350/B350M Specification for Zirconium and Zirconium Alloy Ingots for Nuclear Application

B351/B351M Specification for Hot-Rolled and Cold-Finished Zirconium and Zirconium Alloy Bars, Rod, and Wire for Nuclear Application

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

E114 Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method

E214 Practice for Immersed Ultrasonic Testing by the Reflection Method Using Pulsed Longitudinal Waves[3]

G2/G2M Test Method for Corrosion Testing of Products of Zirconium, Hafnium, and Their Alloys in Water at 680°F [360°C] or in Steam at 750°F [400°C]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *annealed*, *n*—denotes material that exhibits a recrystallized grain structure.

3.2 *Lot Definitions:*

3.2.1 *castings*, *n*—a lot shall consist of all castings produced from the same pour.

3.2.2 *ingot*, *n*—no definition required.

3.2.3 *rounds, flats, tubes, and wrought powder metallurgical products (single definition, common to nuclear and non-nuclear standards)*, *n*—a lot shall consist of a material of the same size, shape, condition, and finish produced from the same 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.

3.2.4 *sponge*, *n*—a lot shall consist of a single blend produced at one time.

[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 B10.02 on Zirconium and Hafnium.

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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.

[3] Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

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

4. Ordering Information

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

4.1.1 Quantity (weight or number of pieces),
4.1.2 Name of material,
4.1.3 Condition (Section 6),
4.1.4 Finish (Section 14),
4.1.5 Form (Sheet, strip, plate,)
4.1.6 Edge (Section 15),
4.1.7 Dimensions (size, thickness, width and length),
4.1.8 Grade designation (Table 1), and
4.1.9 ASTM designation and year of issue.

NOTE 2—A typical ordering description is as follows: _ 5000 lb reactor grade zirconium alloy, cold-rolled, vacuum annealed strip, 4.750 by 0.065 by 72 in., ASTM Specification B352/B352M - 01, Grade R60804.

4.2 In addition to the data specified in 4.1, the following options and points of agreement between the manufacturer and the purchaser should be specified on the purchase order as required:

4.2.1 Temperature and direction of mechanical testing (see 8 and Table 2),
4.2.2 Workmanship standards (Section 13),
4.2.3 Special tests (Section 12),
4.2.4 Inspection (Section 17), and
4.2.5 Corrosion visual standards (Section 9).
4.2.6 Oxygen limits (see footnote A, Table 1).

5. Materials and Manufacture

5.1 Materials covered by this specification shall be produced by multiple vacuum melting in arc furnaces, electron beam melting, or other melting processes conventionally used for reactive metals; all processes to be done in furnaces usually used for reactive metals.

TABLE 1 Chemical Requirements

Element	Composition, Weight %			
	UNS R60001	UNS R60802	UNS R60804	UNS R60901
Tin	. . .	1.20–1.70	1.20–1.70	. . .
Iron	. . .	0.07–0.20	0.18–0.24	. . .
Chromium	. . .	0.05–0.15	0.07–0.13	. . .
Nickel	. . .	0.03–0.08	. . .	. . .
Niobium (columbium)	. . .	. . .	. . .	2.40–2.80
Oxygen	[A]	[A]	[A]	0.09–0.15
Iron + chromium + nickel	. . .	0.18–0.38	. . .	. . .
Iron + chromium	. . .	. . .	0.28–0.37	. . .
	Maximum Impurities, Weight %			
Aluminum	0.0075	0.0075	0.0075	0.0075
Boron	0.00005	0.00005	0.00005	0.00005
Cadmium	0.00005	0.00005	0.00005	0.00005
Calcium	...	0.0030	0.0030	...
Carbon	0.027	0.027	0.027	0.027
Chromium	0.020	. . .	. . .	0.020
Cobalt	0.0020	0.0020	0.0020	0.0020
Copper	0.0050	0.0050	0.0050	0.0050
Hafnium	0.010	0.010	0.010	0.010
Hydrogen	0.0025	0.0025	0.0025	0.0025
Iron	0.150	. . .	. . .	0.150
Magnesium	0.0020	0.0020	0.0020	0.0020
Manganese	0.0050	0.0050	0.0050	0.0050
Molybdenum	0.0050	0.0050	0.0050	0.0050
Nickel	0.0070	. . .	0.0070	0.0070
Niobium	...	0.0100	0.0100	...
Nitrogen	0.0080	0.0080	0.0080	0.0080
Phosphorus	. . .	. . .	. . .	0.0020
Silicon	0.0120	0.0120	0.0120	0.0120
Tin	0.0050	. . .	. . .	0.010
Tungsten	0.010	0.010	0.010	0.010
Titanium	0.0050	0.0050	0.0050	0.0050
Uranium	0.00035	0.00035	0.00035	0.00035

[A] When so specified in the purchase order, oxygen shall be determined and reported. Maximum, minimum, or both, permissible values should be specified in the purchase order.

TABLE 2 Mechanical Properties[A]

Grade	Condition	Direction of Test	Test Temperature[B]	Tensile Strength, min, ksi [MPa]	Yield Strength (0.2 % Offset), min, ksi [MPa]	Elongation in 2 in. or 50 mm, min, %
R60001 †	annealed	longitudinal	RT	42 [290]	20 [140]	18
		transverse	RT	42 [290]	30 [205]	18
R60802		longitudinal	RT	58 [400]	35 [240]	25
or	annealed	transverse	RT	56 [385]	44 [300]	25
R60804						
R60802		longitudinal	550°F [290°C]	27 [185]	15 [100]	30
or	annealed	transverse	550°F [290°C]	26 [180]	17.5 [120]	30
R60804						
R60901	cold worked	longitudinal	RT	74 [510]	50 [345]	15
		transverse	RT	74 [510]	56 [385]	15
R60901	annealed	longitudinal	RT	65 [450]	45 [310]	20
		transverse	RT	65 [450]	50 [345]	20

[A] When a sub-size specimen is used, the gauge length shall be as specified in Test Methods E8 for that specimen.

[B] "RT" represents room temperature; Note 4 in Test Methods E8 and E8M indicates that RT shall be considered to be 50 to 100°F [10 to 38°C] unless otherwise specified. Paragraph 9.4.4 in Test Methods E21 states that for the duration of the test, the difference between the indicated temperature and the nominal test temperature is not to exceed ±5°F [3°C] for tests at 1800°F [1000°C] and lower, and ±10°F [6°C] for tests at higher temperatures.

† Editorially corrected.

6. Condition

6.1 Sheet, strip, or plate shall be furnished in one of the following conditions as designated on the purchase order:

Form	Condition
Sheet	hot-rolled
	hot-rolled, annealed
	cold-rolled, annealed
	cold-rolled, annealed, followed by a final light cold-rolled pass, generally on polished rolls.
Strip	hot-rolled
	hot-rolled, annealed
	cold-rolled
	cold-rolled, annealed
	cold-rolled, annealed, followed by a final light cold-rolled pass, generally on polished rolls.
Plate	hot-rolled
	hot-rolled, annealed

7. Chemical Composition

7.1 The material shall conform to the requirement for chemical composition as prescribed in Table 1.

7.2 The manufacturer's ingot analysis made in accordance with Specification B350/B350M shall be considered the chemical analysis for material produced to this specification except for hydrogen, oxygen, and nitrogen content, which shall be determined on the finished product. Alternatively, the manufacturer may sample an intermediate or final size during processing with the same frequency and in the same positions relative to the ingot as specified in Specification B350/B350M to determine the composition, except for hydrogen, oxygen, and nitrogen, which shall be determined on the finished product.

7.3 Analysis shall be made using the manufacturer's standard methods. In the event of disagreement as to the chemical composition of the metal, methods of chemical analysis for reference purposes shall be determined by a mutually acceptable laboratory.

7.4 *Product Analysis*—Product analysis is an analysis made by the purchaser or the manufacturer for the purpose of verifying the composition of the lot. The product analysis tolerances reflect the variation between laboratories in the measurement of chemical composition. The permissible variation of the product analysis from the specified range is as prescribed in Table 3.

7.5 *Number of Tests*—Two random samples for each 4000 lb [1800 kg] or fraction thereof shall be analyzed for hydrogen, nitrogen, and oxygen.

8. Mechanical Properties

8.1 The material shall conform to the requirements prescribed in Table 2 for longitudinal room-temperature mechanical properties. Transverse and elevated temperature properties shall be used to determine compliance only when specified in the purchase order. When material is ordered in a condition other than those given in Table 2, the specimens shall be heat treated as referenced in Table 2 prior to test.

8.2 The yield strength shall be determined by the offset (0.2 %) method as prescribed in Test Methods E8.

8.3 The tensile properties shall be determined using a strain rate of 0.003 to 0.007 in./in. [mm/mm]/min through the yield strength. After the yield strength has be exceeded, the cross head speed should be increased to approximately 0.05 in./in. [mm/mm]/min to failure.

8.4 The tensile properties enumerated in this specification shall be determined in accordance with Test Methods E8 or E21.

8.5 *Number of Tests*—For each lot, two random samples for each 4000 lb [1800 kg] or fraction thereof shall be tested for mechanical properties.

TABLE 3 Permissible Variations in Product Analysis

Alloying Elements	Permissible Variation from the Specified Range (Table 1), %
Tin	0.050
Iron	0.020
Chromium	0.010
Nickel	0.010
Iron + chromium	0.020
Iron + chromium + nickel	0.020
Niobium	0.050
Oxygen	0.020
Each Impurity Element	20 ppm or 20 % of the specified limit, whichever is smaller