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Used in USDOE-NE standards

Standard Specification for Hot-Rolled and Cold-Finished Zirconium and Zirconium Alloy Bars, Rod, and Wire for Nuclear Application[1]

This standard is issued under the fixed designation B 351/B 351M; 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 four grades of wrought zirconium and zirconium alloy bars, rod, and wire as follows:

1.1.1 *R60001*—Unalloyed grade,

1.1.2 *R60802*—Zirconium-Tin alloy (Zircaloy 2),

1.1.3 *R60804*—Zirconium-Tin alloy (Zircaloy 4), and

1.1.4 *R60901*—Zirconium-Niobium alloy.

1.2 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.

1.3 *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]

B 350/B 350M Specification for Zirconium and Zirconium Alloy Ingots for Nuclear Application

E 8 Test Methods for Tension Testing of Metallic Materials

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

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

E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method

E 214 Practice for Immersed Ultrasonic Testing by the Reflection Method Using Pulsed Longitudinal Waves[3]

G 2/G 2M 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 Definition:*

3.2.1 *lot*, *n*—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 a 12 h period for final continuous anneal, or to a single furnace load for final batch anneal.

3.3 *Forms Definitions:*

3.3.1 *bar*, *n:*

3.3.1.1 *rounds, squares and hexagons, n*—⅜ in. (9.5 mm) and over in diameter or size.

3.3.1.2 *flats, n*—¼ to 10 in. (6.4 to 250 mm) inclusive in width and ⅛ in. (3.2 mm) and over in thickness. Thickness ⅛ in. (3.2 mm) to under 3⁄16 in. (4.8 m) can be cold-rolled strip as well as bar.

3.3.2 *rod*, *n*—rounds in coils for subsequent reworking ¼ to ¾ in. (6.4 to 19 mm) in diameter.

3.3.3 *wire*, *n*—material less than ⅜ in. (9.5 mm) in diameter or size, in round, hexagonal, or octagonal cross section, furnished in coils or on spools or reels.

4. Ordering Information

4.1 Orders for materials under this specification shall include the following information as applicable:

4.1.1 Grade (see Section 1),

4.1.2 Dimensions and form (see 3.3),

4.1.3 Chemical analysis of elements not listed (see 6.1.3),

4.1.4 Product analysis (see 6.1.1.1 and 6.2),

[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.

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4.1.5 Tensile test temperatures (7.1),
4.1.6 Metallurgical condition (see 9.1 and 9.2),
4.1.7 Ultrasonic test standard hole size (see 10.2.2),
4.1.8 Additional ultrasonic tests (see 10.2.4),
4.1.9 Material condition and finish (Section 13),
4.1.10 Workmanship standards and methods of inspection (Section 14),
4.1.11 Product marking (Section 20), and
4.1.12 Packaging and package marking (Section 21).

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 Tolerances (Section 10),
4.2.2 Workmanship standards (Section 13),
4.2.3 Special tests (Section 12),
4.2.4 Inspection (Section 17),
4.2.5 Corrosion visual standards (Section 9), and
4.2.6 Oxygen limits (see footnote A, Table 1).

5. Materials and Manufacture

5.1 Material covered by this specification shall be made from ingots that conform to Specification B 350/B 350M and that are produced by vacuum or plasma arc melting, vacuum electron-beam melting, a combination of these three methods or other melting processes conventionally used for reactive metals. All processes to be done in furnaces usually used for reactive metals.

5.2 The various mill products covered by this specification shall be formed with the conventional extrusion, forging, or rolling equipment normally found in primary ferrous and nonferrous plants.

6. Chemical Composition

6.1 The grades of zirconium and zirconium alloy metal covered by this specification shall conform to the chemical composition requirements prescribed in Table 1.

6.1.1 The elements listed in Table 1 are intentional alloy additions or elements that are inherent to the manufacture of sponge, ingot or mill product.

6.1.1.1 Elements other than those listed in Table 1 are deemed to be capable of occurring in the grades listed in Table 1 by and only by way of unregulated or unanalyzed scrap additions to the ingot melt. Therefore, product analysis for elements not listed in Table 1 shall not be required unless specified in the purchase order and shall be considered to be in excess of the intent of this specification.

6.1.2 Elements intentionally added to the melt must be identified, analyzed, and reported in the chemical analysis.

6.1.3 When agreed upon by producer and purchaser and requested by the purchaser in his written purchase order, chemical analysis shall be completed for specific residual elements not listed in this specification.

6.2 The manufacturer's ingot analysis shall be considered the chemical analysis, except for hydrogen, oxygen, and nitrogen content, which shall be determined on the finished

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 (total)	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.

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