Designation: ~~B350/B350M – 11 (Reapproved 2016)~~ B350/B350M – 11 (Reapproved 2016)$^{\varepsilon 1}$

Standard Specification for Zirconium and Zirconium Alloy Ingots for Nuclear Application[1]

This standard is issued under the fixed designation B350/B350M; 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.

ε^1 NOTE—Note 2 was added editorially in March 2017.

1. Scope

1.1 This specification covers vacuum-melted zirconium and zirconium alloy ingots for nuclear application.

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

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]

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E114 Practice for Ultrasonic Pulse-Echo Straight-Beam Contact Testing

E2626 Guide for Spectrometric Analysis of Reactive and Refractory Metals

3. Terminology

3.1 *Lot Definitions:*

3.1.1 *ingot, n*—a quantity of metal cast into a shape suitable for subsequent processing to various mill products.

4. Classification

4.1 Ingots are furnished in five grades as follows:

4.1.1 R60001 Unalloyed Zirconium,

4.1.2 R60802 Zirconium-Tin Alloy,

4.1.3 R60804 Zirconium-Tin Alloy,

4.1.4 R60901 Zirconium-Niobium Alloy, and

4.1.5 R60904 Zirconium-Niobium Alloy.

5. Ordering Information

5.1 Orders for material under this specification should include the following information as required to describe adequately the desired material:

5.1.1 Quantity in weight or pieces,

5.1.2 Name of material,

5.1.3 Grade (Table 1),

5.1.4 Size (diameter, length, or weight), in the unit system regarded as standard (inch-pound or SI), and

5.1.5 ASTM designation and year of issue.

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[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.

TABLE 1 Chemical Requirements

Element	Composition, Weight %				
	UNS R60001	UNS R60802	UNS R60804	UNS R60901	UNS R60904
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	2.50–2.80
Oxygen	[A]	[A]	[A]	0.09–0.15	[A]
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	0.0075
Boron	0.00005	0.00005	0.00005	0.00005	0.00005
Cadmium	0.00005	0.00005	0.00005	0.00005	0.00005
Calcium	...	0.0030	0.0030	...	...
Carbon	0.027	0.027	0.027	0.027	0.027
Chromium	0.020	...	...	0.020	0.020
Cobalt	0.0020	0.0020	0.0020	0.0020	0.0020
Copper	0.0050	0.0050	0.0050	0.0050	0.0050
Hafnium	0.010	0.010	0.010	0.010	0.010
Hydrogen	0.0025	0.0025	0.0025	0.0025	0.0010
Iron	0.150	...	...	0.150	0.150
Magnesium	0.0020	0.0020	0.0020	0.0020	0.0020
Manganese	0.0050	0.0050	0.0050	0.0050	0.0050
Molybdenum	0.0050	0.0050	0.0050	0.0050	0.0050
Nickel	0.0070	...	0.0070	0.0070	0.0070
Niobium	...	0.0100	0.0100	...	...
Nitrogen	0.0080	0.0080	0.0080	0.0080	0.0080
Phosphorus	...	...	...	0.0020	0.0020
Silicon	0.0120	0.0120	0.0120	0.0120	0.012
Tin	0.0050	...	...	0.010	0.010
Tungsten	0.010	0.010	0.010	0.010	0.010
Titanium	0.0050	0.0050	0.0050	0.0050	0.0050
Uranium (total)	0.00035	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.

NOTE 1—A typical ordering description is as follows: two each zirconium ingots, Grade R60001, 12 in. diameter by 1000 lb each, ASTM Specification: B350/B350M – 01.

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

5.2.1 Inspection (Section 12), and

5.2.2 Oxygen analysis requirements (Table 1).

6. Materials and Manufacture

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

7. Condition

7.1 Unless otherwise specified, ingots shall be conditioned by machining or grinding or both to remove surface and subsurface defects detrimental to subsequent fabrication.

7.2 After conditioning has been completed, no abrupt changes in diameter or local depression that will impair subsequent fabrication shall be permitted. The difference between the maximum and minimum radii of the conditioned ingot shall not exceed 20 % of the maximum radius. Lands, grooves, and local depressions shall be blended to a maximum angle of 30° to the axis of the ingot. Each end of the ingot shall be chamfered or radiused. The minimum chamfer or radius shall be ½ in. [12 mm].

8. Chemical Requirements

8.1 The ingot shall conform to the requirements for chemical composition as prescribed in Table 1. Guide E2626 may be used as a guide for chemical analysis techniques.

NOTE 2—Nuclear grade zirconium ingots produced from electrolytic starting material should be produced using methods such that the final ingot fluorine content is <1ppm to mitigate risk of poor breakaway performance. In order to achieve this target fluorine level, a quad melt process under vacuum is strongly recommended.