



Designation: B 350/B350M – 01

Used in USNRC-RDT standards

Standard Specification for Zirconium and Zirconium Alloy Ingots for Nuclear Application¹

This standard is issued under the fixed designation B 350/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.

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:*

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications²

E 114 Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method³

3. Classification

3.1 Ingots are furnished in five grades as follows:

3.1.1 R60001 Unalloyed Zirconium,

3.1.2 R60802 Zirconium-Tin Alloy,

3.1.3 R60804 Zirconium-Tin Alloy,

3.1.4 R60901 Zirconium-Niobium Alloy, and

3.1.5 R60904 Zirconium-Niobium Alloy.

4. Ordering Information

4.1 Orders for material under this specification should include the following information as required to describe

adequately the desired material:

4.1.1 Quantity in weight or pieces,

4.1.2 Name of material,

4.1.3 Grade (Table 1),

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

4.1.5 ASTM designation and year of issue.

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 – 01.

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 in the purchase order if required:

4.2.1 Inspection (Section 11), and

4.2.2 Oxygen analysis requirements (Table 1).

5. Materials and Manufacture

5.1 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.

6. Condition

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

6.2 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].

7. Chemical Requirements

7.1 The ingot shall conform to the requirements for chemical composition as prescribed in Table 1.

7.2 The ingot shall be sampled in sufficient places along the side wall so that the top sample is within 5 in. [125 mm] of the

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² *Annual Book of ASTM Standards*, Vol 14.02.

³ *Annual Book of ASTM Standards*, Vol 03.03.



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	0.09–0.13	^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
Carbon	0.027	0.027	0.027	0.027	0.027
Chromium	0.020	...	...	0.020	0.010
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	0.005
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
Nitrogen	0.0080	0.0080	0.0080	0.0080	0.0065
Phosphorus	...	...	...	0.0020	0.0020
Silicon	0.0120	0.0120	0.0120	0.0120	0.010
Tin	0.0050	...	...	0.0050	0.0050
Tungsten	0.010	0.010	0.010	0.010	0.005
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.

top face and the distance between samples or between the bottom face and a sample does not exceed one ingot diameter. A minimum of three samples per ingot is required.

7.3 These samples shall be analyzed for the alloying and impurity elements given in Table 1.

7.4 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.

7.5 *Product Check Analysis*—Product check analysis is an analysis made by or for the purchaser for the purpose of verifying the composition of the ingot. The check analysis tolerances reflect the variation between laboratories in the measurement of chemical composition. The permissible variation in the product check analysis from the specified range is as prescribed in Table 2.

8. Retest

8.1 If any sample or specimen exhibits obvious contamination, improper preparation, or flaws disqualifying it as a representative sample, it shall be discarded and a new sample or specimen substituted.

8.2 If the results of any test are not in conformance with the requirements of this specification, the ingot may be retested at the option of the manufacturer. The manufacturer may scalp or crop the ingot to remove nonconforming material then resample remaining ingot position(s). The ingot shall be acceptable

TABLE 2 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

if all results of retests following the initial test(s) conform to this specification.

9. Significance of Numerical Limits

9.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in Table 1 and Table 2, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E 29.

10. Ultrasonic Test

10.1 Ingots shall be inspected ultrasonically by the methods described in 10.1.1 and 10.1.2 unless otherwise agreed upon between the manufacturer and the purchaser.

10.1.1 *Standardization*—The test shall be conducted in