



Standard Specification for Hot-Rolled and Cold-Finished Zirconium and Zirconium Alloy Bars, Rod, and Wire for Nuclear Application¹

This standard is issued under the fixed designation B 351; 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-finished zirconium and zirconium alloy bars, rod, and wire, other than those required for reforging, including rounds, squares, and shapes.

1.2 One unalloyed grade and three alloy grades for use in nuclear applications are described.

1.3 The products covered include the following sections and sizes:

Bars:
Rounds, squares and hexagons $\frac{3}{8}$ in. (9.5 mm) and over in diameter or size
Flats $\frac{1}{4}$ to 10 in. (6.4 to 250 mm) incl in width and $\frac{1}{8}$ in. (3.2 mm) and over in thickness^A

Rod:
Rounds in coils for subsequent reworking $\frac{1}{4}$ to $\frac{3}{4}$ in. (6.4 to 19 mm) in diameter

Wire
Thickness $\frac{1}{8}$ in. (3.2 mm) to under $\frac{3}{16}$ in. (4.8 mm) can be cold-rolled strip as well as bar.
less than $\frac{3}{8}$ in. (9.5 mm) in diameter or size

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:

B 350 Specification for Zirconium and Zirconium Alloy Ingots for Nuclear Application²

E 8 Test Methods of Tension Testing of Metallic Materials³

E 21 Practice for Elevated Temperature Tension Tests of Metallic Materials³

¹ This specification is under the jurisdiction of ASTM Committee B-10 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 Annual Book of ASTM Standards, Vol 02.04.

³ Annual Book of ASTM Standards, Vol 03.01.

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications⁴

E 114 Practice for Ultrasonic Pulse-Echo Straight—Beam Examination by the Contact Method⁵

E 214 Practice for Immersed Ultrasonic Examination by the Reflection Method Using Pulsed Longitudinal Waves⁵

G 2 Test Method for Corrosion Testing of Products of Zirconium, Hafnium, and Their Alloys in Water at 680°F or in Steam at 750°F⁶

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

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

3.1.2 *lot*—shall consist of all material of the same size, shape, condition, and finish produced from the same ingot by the same reduction schedule and heat treatment with the final heat treatment in the same furnace charge.

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), B351-97

4.1.2 Name of material,

4.1.3 Condition (Section 6),

4.1.4 Finish (Section 14),

4.1.5 Cross section (round, square, etc.),

4.1.6 Form (bar, rod, wire),

4.1.7 Dimensions (size, thickness, width and length),

4.1.8 Grade (Table 1), and

4.1.9 ASTM designation and year of issue.

NOTE 1—A typical ordering description is as follows: 250 lb (100 kgs) zirconium alloy bar; hot rolled, annealed; mechanically descaled and pickled; $\frac{3}{4}$ in. (19 mm) by 4 in. (100 mm) by 144 in. (3.6 m), ASTM Specification B 351, dated __, Grade R60802.

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 Annual Book of ASTM Standards, Vol 14.02.

⁵ Annual Book of ASTM Standards, Vol 03.03.

⁶ Annual Book of ASTM Standards, Vol 03.02.

TABLE 1 Chemical Requirements

Element	Composition, Weight %			
	Grade R60001	Grade R60802	Grade R60804	Grade 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	...	...	...	2.40–2.80
Oxygen	A	0.09–0.16	0.09–0.16	0.09–0.13
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
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
Nitrogen	0.0080	0.0080	0.0080	0.0080
Phosphorus	...	...	...	0.0020
Silicon	0.0120	0.012	0.0120	0.0120
Tin	0.0050	...	...	0.0050
Titanium	0.0050	0.0050	0.0050	0.0050
Tungsten	0.010	0.010	0.010	0.010
Uranium (total)	0.00035	0.00035	0.00035	0.00035

^AWhen 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.

- 4.2.1 Mechanical test temperature (see 8.1),
- 4.2.2 Tolerances (Section 10),
- 4.2.3 Workmanship standards (Section 13),
- 4.2.4 Special tests (Section 12),
- 4.2.5 Inspection (Section 16), and
- 4.2.6 Corrosion visual standards (Section 9).
- 4.2.7 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.

6. Condition

6.1 Grades R60001, R60802, and R60804 furnished under this specification shall be in the annealed condition unless otherwise specified.

6.2 Grade R60901 in sizes under 1 in. (25 mm) in minimum dimension furnished under this specification shall be in the cold-worked condition unless otherwise specified. Sizes 1 in. (25 mm) and over in minimum dimension shall be furnished in the annealed condition unless otherwise specified.

7. Chemical Composition

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

7.2 The manufacturer's ingot analysis made in accordance with Specification B 350 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 B 350, 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 in the product analysis from the specified range is as prescribed in Table 2.

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 3 for room temperature mechanical properties. Elevated temperature properties shall be used to determine compliance only when specified in the purchase order.