



Standard Specification for Zirconium and Zirconium Alloy Bar and Wire¹

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1. Scope

1.1 This specification² covers three grades of zirconium and zirconium alloy bar and wire.

1.2 Unless a single unit is used, for example corrosion mass gain in mg/dm², 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 methods 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 8 Test Methods for Tension Testing of Metallic Materials³
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications⁴

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

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

3.2 Lot Definitions:

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

3.2.2 *ingot*—no definition required.

3.2.3 *rounds, flats, tubes, and wrought powder metallurgical products (single definition, common to nuclear and non-nuclear standards)*—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*—a lot shall consist of a single blend produced at one time.

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

4. Classification

4.1 The bar or wire is to be furnished in three grades as follows:

- 4.1.1 *Grade R60702*—Unalloyed zirconium.
- 4.1.2 *Grade R60704*—Zirconium-tin.
- 4.1.3 *Grade R60705*—Zirconium-niobium.

5. Ordering Information

5.1 Orders for material under this specification should include the following information:

- 5.1.1 Quantity (weight or number of pieces),
- 5.1.2 Name of material (zirconium bar or wire) (Table 1),
- 5.1.3 Grade number (see 4.1),
- 5.1.4 ASTM designation and year of issue, and
- 5.1.5 Additions to the specification and supplementary requirements, if required.

NOTE 1—A typical ordering description is as follows: 1000 lb (500 kg) zirconium cold drawn bar, 0.35 in. (10 mm) in diameter by 10 ft (3 m) in length, ASTM B 550 - 01, Grade R60702.

6. Materials and Manufacture

6.1 Bar and wire covered by this specification shall be formed with conventional fabrication methods and equipment found in primary ferrous and nonferrous metal plants.

6.2 Bar and wire will be supplied in the conditions prescribed in Table 2.

6.3 The products covered include the sections and sizes shown in Table 1.

7. Chemical Composition

7.1 The material shall conform to the requirements as to chemical composition prescribed in Table 3.

7.2 The manufacturer's ingot analysis shall be considered the chemical analysis for bar and wire, except for hydrogen and

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² For ASME Boiler and Pressure Vessel Code applications, see related Specification SB-550 in Section II of that Code.

³ *Annual Book of ASTM Standards*, Vol 03.01.

⁴ *Annual Book of ASTM Standards*, Vol 14.02.

TABLE 1 Product Sections and Size

Product	Section	Size
Bars:	Hot-finished round, squares, octagons, and hexagons	¼ in. (6.4 mm) and over in diameter or size
	Hot-finished flats	¼ in. (6.4 mm) to 10 in. (250 mm), incl. in width, and ⅛ in. (3.2 mm) and over in thickness
	Cold-finished rounds, squares, octagons, hexagons, and shapes	Over ½ in. (13 mm) in diameter or size ^A
Wire:	Cold-finished flats	⅜ in. (9.5 mm) and over in width, ^B and ⅛ in. (3.2 mm) and over in thickness ^C
	Cold-finished rounds, squares, octagons, hexagons, and shapes	½ in. (13 mm) and under in diameter or size
	Cold-finished flats	⅛ in. (1.6 mm) to under ⅜ in. (9.5 mm) in width, and 0.010 in. (.25 mm) to under ⅜ in. (4.8 mm) in thickness

^ASizes ½ in. (13 mm) and under are wire when in coils, and cut wire when finished in straight lengths.

^BWidths less than ⅜ in. (9.5 mm) and thicknesses less than ⅜ in. (4.8 mm) are generally described as flat wire.

^CThickness ⅛ in. (3.2 mm) to under ⅜ in. (4.8 mm) can be cold-rolled strip as well as bar.

TABLE 2 Condition

Form	Condition
Bars	hot finished
	hot finished and annealed
	cold finished
	cold finished and annealed
Wire	cold finished
	cold finished and annealed

nitrogen, which shall be determined on the finished product.

7.3 When requested by the purchaser and stated in the purchase order, a product analysis for any elements listed in Table 3 shall be made on the finished product.

7.3.1 The manufacturer's analysis shall be considered as verified if the check analysis confirms the manufacturer's reported values within the tolerances prescribed in Table 4.

8. Mechanical Properties

8.1 The annealed material shall conform to the requirements for mechanical properties, at room temperature, as prescribed in Table 5. Wire supplied for welding applications shall be furnished with a temper suitable for uniform feeding in semiautomatic or automatic welding equipment.

9. Permissible Variations in Dimensions

9.1 Unless otherwise specified, all bar or wire shall conform to the permissible variations in dimensions prescribed in the applicable Tables 6-14, inclusive.

10. Workmanship, Finish and Appearance

10.1 Bars in the hot-finished condition which will conform to the tolerances prescribed in Tables 6 and 7, shall be furnished with one of the following finishes as designated on the purchase order:

- 10.1.1 Not descaled,
- 10.1.2 Mechanically descaled,
- 10.1.3 Mechanically descaled and pickled, and
- 10.1.4 Turned (round bars only).

10.2 Bars and wire in cold-finished condition, that will conform to the tolerances prescribed in Tables 8-12, shall be furnished with one of the following finishes as designated on the purchase order.

- 10.2.1 Cold drawn or cold rolled, or swaged,
- 10.2.2 Turned (round bars only),

10.2.3 Centerless ground (round bars only), and

10.2.4 Polished (round bars only).

10.3 Bars or wire shall be free of cracks, seams, slivers, blisters, burrs, and other injurious imperfections in accordance with standards of acceptability agreed upon between the manufacturer and the purchaser.

11. Significance of Numerical Limits

11.1 For the purpose of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding methods of Practice E 29.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition and tolerances (when expressed as decimals)	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength and yield strength	nearest 1000 psi (10 MPa)
Elongation	nearest 1 %

12. Number of Tests and Retests

12.1 One longitudinal tension test shall be made from each lot of bar and rod, see 13.1.

12.2 One chemistry test for hydrogen and nitrogen content shall be made from each lot of finished product, see 13.2.

12.3 *Retests:*

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

12.3.2 If the results of any tests of any lot do not conform to the requirements specified, retests shall be made on additional samples from the same lot, each of which shall conform to the requirements specified.

13. Test Methods

13.1 *Tension Tests*—Conduct the tension test in accordance with Test Methods E 8. Determine the yield strength by the offset (0.2 %) method. Determine the tensile properties using a strain rate of 0.003 to 0.007 in./in. (mm/mm)/min through the yield strength. After the yield strength has been exceeded, the cross-head speed may be increased to approximately 0.05 in./in. (mm/mm)/min to failure.

13.2 *Chemical Tests*—Conduct the chemical analysis by the standard techniques normally used by the manufacturer.

TABLE 3 Chemical Requirements^A

Element	Composition, %		
	Grades R60702	Grades R60704	Grades R60705
Zirconium + hafnium, min	99.2	97.5	95.5
Hafnium, max	4.5	4.5	4.5
Iron + chromium	0.2 max	0.2 to 0.4	0.2 max
Tin	...	1.0 to 2.0	...
Hydrogen, max	0.005	0.005	0.005
Nitrogen, max	0.025	0.025	0.025
Carbon, max	0.05	0.05	0.05
Niobium	2.0 to 3.0
Oxygen, max	0.16	0.18	0.18

^ABy agreement between the purchaser and the manufacturer, analysis may be required and limits established for elements and compounds not specified in the table of chemical composition.

TABLE 4 Permissible Variation in Check Analysis Between Different Laboratories

Element	Permissible Variation in Product Analysis, %
Hydrogen	0.002
Nitrogen	0.01
Carbon	0.01
Hafnium	0.1
Iron + chromium	0.025
Tin	0.05
Niobium	0.05
Oxygen	0.02

TABLE 5 Tensile Requirements^A

	Grades		
	R60702	R60704	R60705
Tensile Strength, min, ksi (MPa)	55 (380)	60 (415)	80 (550)
Yield Strength, min, ksi (MPa)	30 (205)	35 (240)	55 (380)
Elongation in 2 in. or 50 mm min, % ^B	16	14	16

^AFor bar only.

^BWhen a sub-size specimen is used, the gage length shall be as specified in Test Methods E 8 for the specimen.

TABLE 6 Dimensional Tolerances for Hot-Finished Rounds, Squares, Octagons, and Hexagons

Specified Size, in. (mm)	Variation in Size, in. (mm)	Out of Round, Out of Square, in. (mm)	
Up–0.500 (13)	+0.030 –0 (+0.75)	0.025 (0.64)	
Over 0.500–1.000 (13–25)	+0.050 –0 (+1.3)	0.040 (1)	
Over 1.000–2.000 (25–50)	+0.070 –0 (+1.8)	0.060 (1.5)	
Over 2.000–4.000 (50–100)	+0.150 –0 (+3.8)	0.080 (2)	
Over 4.000–6.000 (100–150)	+0.250 –0 (+6.4)	0.100 (2.5)	

14. Inspection

14.1 The manufacturer shall inspect the material covered by this specification prior to shipment and, on request, shall furnish the purchaser with certificates of test. If so specified in the purchase order, the purchaser or his representative may witness the testing and inspection of the material at the place of manufacture. In such cases the purchaser shall state in his purchase order which tests he desires to witness. The manufacturer shall give ample notice to the purchaser as to the time and place of the designated tests. If the purchaser's representative does not present himself at the time agreed upon for the testing, the manufacturer shall consider the requirement for purchaser's inspection at the place of manufacture to be waived.

14.2 The manufacturer shall afford the inspector represent-

TABLE 7 Dimensional Tolerances in Hot-Rolled Flat Bars

Thickness, in. (mm)	Variation in Thickness, in. (mm)		Variation in Width, ^A in. (mm)
Up–0.150 (3.8)	+0.020 –0 (+0.5)		1/8 –0 (3.2)
Over 0.150–0.250 (3.8–6.3)	+0.030 –0 (+0.75)		5/32 –0 (4.0)
Over 0.250–0.350 (6.3–8.9)	+0.040 –0 (+1.0)		3/16 –0 (4.8)
Over 0.350–0.450 (8.9–11.4)	+0.050 –0 (+1.3)		7/32 –0 (5.6)
Over 0.450–0.550 (11.4–14)	+0.070 –0 (+1.8)		^B
Over 0.550–1.500 (14–38)	+0.080 –0 (+2.0)		^B
Over 1.500 (38)			^B

^AFor bars sheared from plate, width tolerances shall be as follows:

^BDepends on size and quantity ordered.

Specified Thickness, in. (mm)	Width Tolerances, in. (mm)	
	Over	Under
Over 0.100–0.150	1/16 (1.6)	1/16 (1.6)
Over 0.150–0.250	5/64 (2.0)	5/64 (2.0)
Over 0.250–0.350	3/32 (2.4)	3/32 (2.4)
Over 0.350–0.450	7/64 (2.8)	7/64 (2.8)
Over 0.450–0.550	1/8 (3.2)	1/8 (3.2)
Over 0.550–0.650	5/32 (4.0)	5/32 (4.0)

TABLE 8 Permissible Variations in Sectional Dimensions for Cold-Finished Bars in Rounds, Hexagons, Octagons, and Squares

Specified Size, in. (mm)	Permissible Variation, in. ^A (mm)			
	Over		Under	
	Rounds			
Over 1/2–1, incl (13–25)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)
1–1 1/2, excl (25–38)	0.0025 (0.06)	0.0025 (0.06)	0.0025 (0.06)	0.0025 (0.06)
1 1/2–4, incl ^B (38–100)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)	0.003 (0.08)
Hexagons, Octagons, and Squares				
Over 1/2–1, incl (13–25)	0	0	0.004 (0.10)	0.004 (0.10)
Over 1–2, excl (25–50)	0	0	0.006 (0.15)	0.006 (0.15)
Over 2–3, incl (50–75)	0	0	0.008 (0.20)	0.008 (0.20)
Over 3 (75)	0	0	0.010 (0.25)	0.010 (0.25)

^AWhen it is necessary to heat treat or heat treat and pickle after cold finishing, because of special hardness or mechanical property requirements, tolerances are double those shown in the table.

^BFor permissible variations on sizes over 4 in. (100 mm) the manufacturer should be consulted.

ing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. This inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

15. Rejection

15.1 Rejection for failure of the material to meet the requirements of this specification shall be reported to the manufacturer within 60 calendar days from the receipt of the

TABLE 9 Permissible Variations in Width and Thickness for Cold-Finished Bars in Flats

Width, in. (mm)	Permissible Variations in Width for Thicknesses Given, Over and Under, in. ^A (mm)	
	¼ (6.4) and under	Over ¼ (6.4)
	Width	
¾–1, incl	0.004 (0.10)	0.002 (0.05)
Over 1–2, incl	0.006 (0.15)	0.003 (0.08)
Over 2–3, incl	0.008 (0.20)	0.004 (0.10)
Over 3–4½, incl ^B	0.010 (0.25)	0.005 (0.13)
Thickness, in. (mm)	Permissible Variations in Thickness Over and Under, in. ^A (mm)	
	Thickness, in. (mm)	Permissible Variations in Thickness Over and Under, in. ^A (mm)
	Thickness	
¼–1, incl	(3.2–25)	0.002 (0.05)
Over 1–2, incl	(25–50)	0.003 (0.08)
Over 2–3, incl	(50–75)	0.004 (0.10)
Over 3–4½, incl ^B	(75–115)	0.005 (0.13)

^AWhen it is necessary to heat treat and pickle after cold finishing, because of hardness or mechanical property requirements, tolerances are double those shown in the table.

^BFor permissible variations on widths and thicknesses over 4½in. (115 mm) the manufacturer should be consulted.

material by the purchaser. Unless otherwise specified, rejected material may be returned to the manufacturer at the manufacturer's expense, unless the purchaser receives, within three weeks of the notice of rejection, other instructions for disposition.

16. Certification

16.1 A producer or supplier shall furnish the purchaser with a certificate that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. The certificate shall include a report of the test results.

17. Referee

17.1 In the event of disagreement between the manufacturer and the purchaser on the conformance of the material to the requirements of this specification or any special test specified by the purchaser, a mutually acceptable referee shall perform the tests in question. The results of the referee's testing shall be used in determining conformance of the material to this specification.

18. Product Marking

18.1 Each bundle, box, or coil shall be marked or tagged

TABLE 10 Permissible Variations in Sectional Dimensions for Wire^A

Specified Size, in. (mm)	Permissible Variation, in. (mm)	
	Over	Under
Drawn, Centerless Ground, Centerless Ground and Polished Round Wire, and Square Wire ^B		
½ (13)	0.002 (0.05)	0.002 (0.05)
Under ½–5/16, incl (13–18)	0.0015 (0.04)	0.0015 (0.04)
Under 5/16–0.044, incl (8–1.1)	0.001 (0.025)	0.001 (0.025)
Under 0.044–0.033, incl (1.1–0.8)	0.0008 (0.020)	0.0008 (0.020)
Under 0.033–0.024, incl (0.8–0.6)	0.0005 (0.013)	0.0005 (0.013)
Under 0.024–0.012, incl (0.6–0.3)	0.0004 (0.010)	0.0004 (0.010)
Under 0.012–0.008, incl (0.3–0.2)	0.0003 (0.008)	0.0003 (0.008)
Under 0.008–0.007, incl (0.2–1.8)	0.0002 (0.005)	0.0002 (0.005)
Under 0.007–0.00476, incl (0.18–0.12)	0.0002 (0.005)	0.0002 (0.005)
Under 0.00476–0.003, incl (0.12–0.08)	0.0001 (0.003)	0.0001 (0.003)
Drawn Wire in Hexagons and Octagons ^C		
½	0	0.004 (0.10)
Under ½–5/16, incl	0	0.003 (0.08)
Under 5/16–1/8, incl	0	0.002 (0.05)
Wire for Which the Final Operation is a Surface Treatment to Remove Scale or Drawing Lubricant		
½	0.004 (0.10)	0.004 (0.10)
Under ½–5/16, incl	0.003 (0.08)	0.003 (0.08)
Under 5/16–0.044, incl	0.002 (0.05)	0.002 (0.05)
Under 0.044–0.033, incl	0.0013 (0.03)	0.0013 (0.03)
Under 0.033–0.024, incl	0.0008 (0.02)	0.0008 (0.02)

^AManufacturers should be consulted for all tolerances for half-round, oval, and half-oval wires.

^BThe maximum out-of-round tolerance for round wire is one half of the total size tolerance shown in the above table.

^CDimensions are across flats.

legibly and conspicuously with the purchase order or contract number, manufacturer's private identification mark, the ASTM designation, the grade, size, ingot number, and gross, net, and tare weights.

19. Packaging and Package Marking

19.1 All material shall be boxed, crated, banded on skids, or bundled in such a manner as to assure safe delivery to its destination when properly transported by common carrier.

20. Keywords

20.1 bar; wire; zirconium; zirconium alloy



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TABLE 11 Permissible Variations in Thickness and Width for Cold-Finished Flat Wire

Specified Width, in.	Permissible Variation in Thickness for Given Thickness, Over or Under, in. (mm)			Permissible Variation in Width, in. (mm)	
				Over	Under
	Under 0.029 (0.74)	0.029 (0.75)–0.035 (0.89), excl	0.035 (0.89)– $\frac{3}{16}$ (4.80), incl		
Under $\frac{3}{8}$ (9.5) to $\frac{1}{16}$ (1.6), incl	0.001 (0.025)	0.0015 (0.04)	0.002 (0.05)	0.005 (0.125)	0.005 (0.125)

TABLE 12 Permissible Variations in Length for Hot-Finished or Cold-Finished Bars

Specified Sizes of Rounds, Squares, Hexagons, Octagons, and Widths of Flats, in.	Permissible Variation in Length, in. (mm)			
	To 12 ft (3.5 m), incl		Over 12 ft (3.5 m) to 25 ft (7.6), incl	
	Over	Under	Over	Under
To 2, incl (50)	$\frac{1}{2}$ (13)	0	$\frac{3}{4}$ (20)	0
Over 2–4, incl (50–100)	$\frac{3}{4}$ (20)	0	1 (25)	0
Over 4–6, incl (100–150)	1 (25)	0	1 $\frac{1}{4}$ (32)	0
Over 6–9, incl (150–225)	1 $\frac{1}{4}$ (32)	0	1 $\frac{1}{2}$ (38)	0
Over 9–12, incl (225–300)	1 $\frac{1}{2}$ (38)	0	2 (50)	0
Machine-Cut After Machine Straightening				
To 3, incl	$\frac{1}{8}$ (3.2)	0	$\frac{3}{16}$ (4.8)	0
Over 3–6, incl	$\frac{3}{16}$ (4.8)	0	$\frac{1}{4}$ (6.4)	0
Over 6–9, incl	$\frac{1}{4}$ (6.4)	0	$\frac{5}{16}$ (8.0)	0
Over 9–12, incl	$\frac{1}{2}$ (13.0)	0	$\frac{1}{2}$ (13.0)	0

TABLE 13 Permissible Variations in Length for Round and Shape, Straightened and Cut Wire, and Exact Length Resheared Wire

Diameter, in. (mm)	Length, ft (m)	Permissible Variation, in.	
		Over	Under
		0.125 (3.2) and under	Up to 12 (3.5), incl
0.125 (3.2) and under	Over 12 (3.5)	$\frac{1}{8}$ (3.2)	0
Over 0.125 (3.2) to 0.500 (13.0), incl	Under 3 (1.0)	$\frac{1}{32}$ (0.8)	0
Over 0.125 (3.2) to 0.500 (13.0), incl	3 to 12, incl (1.0–3.5)	$\frac{1}{16}$ (1.6)	0
Over 0.125 (3.2) to 0.500 (13.0), incl	Over 12 (3.5)	$\frac{1}{8}$ (3.2)	0

TABLE 14 Permissible Variations in Straightness for Hot- or Cold-Finished Bars^A

Bars	Permissible Variation
Hot finished	$\frac{1}{8}$ in. (3.2) in any 5 ft (1.5 m); but may not exceed $\frac{1}{8}$ (0.4) × (number of feet (meters) in length/5)
Cold finished	$\frac{1}{16}$ in. (1.6) in any 5 ft (1.5 m); but may not exceed $\frac{1}{16}$ (0.2) × (number of feet (meters) in length/5)

^AThe measurement is taken on the concave side of the bar with a straight edge. Unless otherwise specified, hot-finished or cold-finished bars for machining purposes are furnished machine-straightened to the tolerances specified in the Table.

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