



Designation: B 551/B 551M – 02

Standard Specification for Zirconium and Zirconium Alloy Strip, Sheet, and Plate¹

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1. Scope

1.1 This specification² covers four grades of zirconium strip, sheet, and plate.

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:*

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 strip, sheet, or plate is to be furnished in four grades as follows:

4.1.1 *Grade R60702*—Unalloyed zirconium.

4.1.2 *Grade R60704*—Zirconium-tin.

4.1.3 *Grade R60705*—Zirconium-niobium.

4.1.4 *Grade R60706*—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 strip, sheet, or plate),

5.1.3 Grade number (see 4),

5.1.4 ASTM designation and year of issue,

5.1.5 Finish and appearance (Section 10), and

5.1.6 Additions to the specification and supplementary requirements, if required.

NOTE 1—A typical ordering description is as follows: 9000-lb (5000 kg) zirconium sheet, 0.098 in. (2.5 mm) by 12 in. (300 mm) by 144 in. (3.5 m), ASTM B 551 - 01, Grade R60705.

6. Materials and Manufacture

6.1 The strip, sheet, and plate covered by this specification shall be formed with conventional forging and rolling equipment found in primary ferrous and nonferrous metal plants.

6.2 The strip, sheet, and plate shall be supplied in the recrystallized annealed condition.

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 ASME Boiler and Pressure Vessel Code applications, see related Specification SB-551 in Section II of that Code.

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

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

7. Chemical Composition

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

7.2 The manufacturer’s ingot analysis shall be considered the chemical analysis for strip, sheet, and plate, except for hydrogen and 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 1 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 2.

8. Mechanical Properties

8.1 The material, as represented by the test specimens, shall conform to the tensile properties prescribed in Table 3.

8.2 For strip and sheet, the bend test specimen shall stand being bent at ambient temperature through an angle of 105° without fracture in the outside of the bent portion. The bend shall be made on a radius equal to that shown in Table 3 for the applicable grade.

9. Permissible Variations in Dimensions

9.1 *Thickness*—The variation in thickness of strip, sheet, and plate are given in the following tables:

- 9.1.1 Hot- and cold-rolled sheet, Table 4.
- 9.1.2 Hot-rolled strip, Table 5.
- 9.1.3 Cold-rolled strip, Table 6.
- 9.1.4 Plate, Table 7

9.2 *Width and Length*—The variation in width and length are given in the following tables:

- 9.2.1 Hot- and cold-rolled sheet, Table 8.
- 9.2.2 Hot-rolled strip, Tables 9 and 10.
- 9.2.3 Cold-rolled strip, Tables 11 and 10.
- 9.2.4 Plate, Table 12.

9.3 *Crown Tolerances*—The variations in crown tolerances are given in the following tables:

- 9.3.1 Hot-rolled strip, Table 13.
- 9.3.2 Cold-rolled strip, Table 14.

9.4 *Camber Tolerances*—The variations in camber tolerances are given in the following tables.

- 9.4.1 Hot- and cold-rolled sheet, Table 15.
- 9.4.2 Hot- and cold-rolled strip, Table 16.

TABLE 2 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

9.4.3 Plate, Table 17.

9.5 *Diameter*—The variation in diameter tolerance for circular plates is given in Table 18.

9.6 *Weight*—The permissible variation in weight for zirconium sheet is given in Table 19.

9.7 *Flatness*—The permissible variation from a flat surface for zirconium plate is given in Table 20.

10. Workmanship, Finish and Appearance

10.1 Flat-rolled product in the hot-rolled condition shall be furnished with one of the following finishes as designated on the order.

- 10.1.1 Not descaled,
- 10.1.2 Mechanically descaled, or
- 10.1.3 Mechanically descaled and pickled.

10.2 Material in the cold-rolled condition shall be furnished with a bright cold-rolled finish, or finished by mechanical or chemical methods.

10.3 The following types of edges are available:

- 10.3.1 Mill edge,
- 10.3.2 Slit edge,
- 10.3.3 Sheared edge, and
- 10.3.4 Machined edge.

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.

TABLE 1 Chemical Requirements^A

Element	Composition, %			
	Grades			
	R60702	R60704	R60705	R60706
Zirconium + hafnium, min	99.2	97.5	95.5	95.5
Hafnium, max	4.5	4.5	4.5	4.5
Iron + chromium	0.2 max	0.2 to 0.4	0.2 max	0.2 max
Tin	...	1.0 to 2.0
Hydrogen, max	0.005	0.005	0.005	0.005
Nitrogen, max	0.025	0.025	0.025	0.025
Carbon, max	0.05	0.05	0.05	0.05
Niobium	2.0 to 3.0	2.0 to 3.0
Oxygen, max	0.16	0.18	0.18	0.16

^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 3 Tensile Requirements

	Grades			
	R60702	R60704	R60705	R60706
Tensile strength, min, ksi (MPa)	55 (380)	60 (415)	80 (550)	74 (510)
Yield strength, min, ksi (MPa)	30 (205)	35 (240)	55 (380)	50 (345)
Elongation in 2 in. or 50 mm, min, % ^A	16	14	16	14
Bend test radius ^B	5T	5T	3T	2.5T

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

^BT equals the thickness of the bend test specimen. Bend tests are not applicable to material over 0.187 in. (4.8 mm) in thickness.

TABLE 4 Permissible Variations in Thickness of Hot- and Cold-Rolled Zirconium Sheet^A

Specified Thickness, in. (mm)	Permissible Variations in Thickness, plus and minus, in. (mm)
0.146–0.1875, excl (3.7–4.8)	0.014 (0.35)
0.131–0.145 (3.31–3.69)	0.012 (0.30)
0.115–0.130 (2.91–3.30)	0.010 (0.25)
0.099–0.114 (2.51–2.90)	0.009 (0.23)
0.084–0.098 (2.12–2.50)	0.008 (0.20)
0.073–0.083 (1.84–2.11)	0.007 (0.18)
0.059–0.072 (1.49–1.83)	0.006 (0.15)
0.041–0.058 (1.04–1.48)	0.005 (0.13)
0.027–0.040 (0.67–1.03)	0.004 (0.10)
0.017–0.026 (0.42–0.66)	0.003 (0.08)
0.008–0.016 (0.19–0.41)	0.002 (0.05)
0.006–0.007 (0.15–0.18)	0.0015 (0.04)
0.005 (0.13)	0.001 (0.025)

^AThickness measurements are taken at least 3/8 in. (9.5 mm) in from edge.

TABLE 5 Permissible Variations in Thickness of Hot-Rolled Zirconium Strip

Specified Width, in. (mm)	Variation from Specified Thickness for Widths Given, Over and Under, in ^A (mm)	
	0.187–0.118, incl	0.119–0.083, incl
To 3½ incl	0.006 (0.15)	0.005 (0.13)
Over 3½–12, incl	0.007 (0.18)	0.006 (0.15)
Over 12–18, incl	0.008 (0.20)	0.008 (0.20)
Over 18–24, incl	0.010 (0.25)	0.010 (0.25)

^AThickness measurements shall be taken 3/8 in. (9.5 mm) from edge. Tolerances do not include crown.

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 shall be made from each lot (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 Two bend tests, one in the longitudinal and one in the transverse direction, shall be made from each lot (see 8.2).

12.4 Retests:

12.4.1 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.

12.4.2 If the results of any tests of any lot do not conform to the requirements specified, retests shall be made on additional

sheet, strip, or plate of double the original number from the same lot, each of which shall conform to the requirements specified.

12.4.3 Retesting after failure of initial retests may be done only with the approval of the purchaser.

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.

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 manufacturer. 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 representing 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 to not 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 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,

TABLE 6 Permissible Variations in Thickness of Cold-Rolled Zirconium Strip

NOTE 1—For thickness under 0.010 in. (0.25 mm) in widths to 16 in. (400 mm) a tolerance of $\pm 10\%$ of the thickness shall apply; in widths over 16 (400 mm) to 24 in. (600 mm) incl, a tolerance of $\pm 15\%$ of the thickness shall apply.

NOTE 2—Thickness measurements shall be taken $\frac{3}{8}$ in. (9.5 mm) in from edge of the strip, except on widths less than 1 in. (2.5 mm) where the tolerances are applicable for measurements at all locations.

NOTE 3—The tolerances given in this table do not include crown tolerances.

Specified Thickness, in. (mm)	Permissible Variations in Thickness, for Widths Given, Plus and Minus, in. (mm)							
	$\frac{3}{16}$ (4.8 mm) incl, -1 (25 mm), in. excl	1 (25 mm)-3 (75 mm) in., excl	3 (75 mm)-6 (150 mm) in., incl	Over 6 (150 mm)-9 (230 mm) in., incl	Over 9 (230 mm)-12 (300 mm) in., incl	Over 12 (300 mm)-16 (400 mm) in., incl	Over 16 (400 mm)-20 (500 mm) in., incl	Over 20 (500 mm)-24 (600 mm) in., incl
Under $\frac{3}{16}$ -0.161, incl (4.8-4.1)	0.002 (0.05)	0.003 (.08)	0.004 (.10)	0.004 (.10)	0.004 (.10)	0.005 (.13)	0.006 (.16)	0.006 (.16)
0.160-0.100, incl (4.0-2.52)	0.002 (0.05)	0.002 (.05)	0.003 (.08)	0.004 (.10)	0.004 (.10)	0.004 (.10)	0.005 (.13)	0.005 (.13)
0.099-0.069, incl (2.51-1.75)	0.002 (0.05)	0.002 (.05)	0.003 (.08)	0.003 (.08)	0.003 (.08)	0.004 (.10)	0.004 (.10)	0.004 (.10)
0.068-0.050, incl (1.74-1.3)	0.002 (0.05)	0.002 (.05)	0.003 (.08)	0.003 (.08)	0.003 (.08)	0.003 (.08)	0.004 (.10)	0.004 (.10)
0.049-0.040, incl (1.29-1.00)	0.002 (0.05)	0.002 (.05)	0.0025 (.06)	0.003 (.08)	0.003 (.08)	0.003 (.08)	0.004 (.10)	0.004 (.10)
0.039-0.035, incl (0.99-0.90)	0.002 (0.05)	0.002 (.05)	0.0025 (.06)	0.003 (.08)	0.003 (.08)	0.003 (.08)	0.003 (.08)	0.003 (.08)
0.034-0.029, incl (0.89-0.73)	0.0015 (.04)	0.0015 (.04)	0.002 (.05)	0.0025 (.06)	0.0025 (.06)	0.0025 (.06)	0.003 (.08)	0.003 (.08)
0.028-0.026, incl (0.72-0.66)	0.001 (.025)	0.0015 (.04)	0.0015 (.04)	0.002 (.05)	0.002 (.05)	0.002 (.05)	0.0025 (.06)	0.003 (.08)
0.025-0.020, incl (0.65-0.51)	0.001 (.025)	0.001 (.025)	0.0015 (.04)	0.002 (.05)	0.002 (.05)	0.002 (.05)	0.0025 (.06)	0.0025 (.06)
0.019-0.017, incl (0.50-0.43)	0.001 (.025)	0.001 (.025)	0.001 (.025)	0.0015 (.04)	0.0015 (.04)	0.002 (.05)	0.002 (.05)	0.002 (.05)
0.016-0.013, incl (0.42-0.32)	0.001 (.025)	0.001 (.025)	0.001 (.025)	0.0015 (.04)	0.0015 (.04)	0.0015 (.04)	0.002 (.05)	0.002 (.05)
0.012 (.30)	0.001 (.025)	0.001 (.025)	0.001 (.025)	0.001 (.025)	0.0015 (.04)	0.0015 (.04)	0.0015 (.04)	0.0015 (.04)
0.011 (.28)	0.001 (.025)	0.001 (.025)	0.001 (.025)	0.001 (.025)	0.001 (.025)	0.0015 (.04)	0.0015 (.04)	0.0015 (.04)
0.010 (.25)	0.001 (.025)	0.001 (.025)	0.001 (.025)	0.001 (.025)	0.001 (.025)	0.001 (.025)	0.0015 (.04)	0.0015 (.04)

TABLE 7 Permissible Variations in Thickness of Zirconium Plate^A

Specified Thickness, in. (mm)	Permissible Variations in Thickness for Widths Given, in. (mm)			
	To 84 in. (2.1 m), incl		Over 84-120 in. (2.1-3.05 m), incl	
	Plus	Minus	Plus	Minus
$\frac{1}{8}$ (3.2)- $\frac{3}{8}$ (9.5), excl	0.046 (1.17)	0.01 (.25)	0.050 (1.3)	0.01 (.25)
$\frac{3}{8}$ (9.5)- $\frac{3}{4}$ (20), excl	0.054 (1.37)	0.01 (.25)	0.058 (1.47)	0.01 (.25)
$\frac{3}{4}$ (20)-1 (25), excl	0.060 (1.52)	0.01 (.25)	0.064 (1.62)	0.01 (.25)
1 (25)-2 (50) ^B , incl	0.070 (1.78)	0.01 (.25)	0.074 (1.88)	0.01 (.25)

^AFor circles, the plus tolerances for the specified thicknesses apply to the diameter of the circle corresponding to the width ranges shown. For plates of irregular shape, the plus thickness tolerances apply to the greatest width corresponding to the width ranges shown.

^BFor permissible variations on plates over 2 in. (50 mm) thick, the producer should be consulted.

TABLE 8 Permissible Variations in Width and Length of Hot- and Cold-Rolled Zirconium Sheet

Specified Width, in. (m) for Thickness Under $\frac{3}{16}$ in. (4.8 mm)	Permissible Variations in Width, in. (mm)
24-48, excl (7-14)	$+\frac{1}{8}$, -0 (+3.2, -0)
48 and over (14)	$+\frac{3}{16}$, -0 (+4.8, -0)
Specified Length, ft (m)	Permissible Variations in Length, in. (mm)
Up-10, incl (3)	$+\frac{1}{2}$, -0 (+13, -0)
Over 10-20, incl (3-6)	+1, -0 (+25, -0)

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 *Identification*—Unless otherwise specified, each plate, sheet, and strip shall be marked in the respective location indicated below, with the number of this specification, heat number, manufacturer's identification, and the nominal thickness. The characters shall be not less than $\frac{3}{8}$ in. (9.52 mm) in height, shall be applied using a suitable marking fluid, and shall be capable of being removed with a hot alkaline cleaning solution without rubbing. The marking shall have no deleterious effect on the material or its performance. The characters shall be sufficiently stable to withstand ordinary handling

18.1.1 Plate, flat sheet, and flat strip over 6 in. (150 mm) in width shall be marked in lengthwise rows of characters recurring at intervals not greater than 3 in. (75 mm), the rows being spaced not more than 1 in. (40 mm) apart and alternatively staggered. Heat numbers shall occur at least three times across the width of the material and at intervals not greater than 2 ft (0.6 m) along the length. As an option, when permitted by the purchaser, each plate, sheet, or cut length strip may be marked in at least one corner with the number of this specification, heat number, manufacturer's identification, and the nominal thickness in inches or millimetres as required.

18.1.2 Flat strip 6 in. (150 mm) and under in width shall be marked near one end.

18.1.3 Coiled sheet and strip shall be marked near the outside end of the coil.