



Designation: B551/B551M – 12 (Reapproved 2021)

# Standard Specification for Zirconium and Zirconium Alloy Strip, Sheet, and Plate<sup>1</sup>

This standard is issued under the fixed designation B551/B551M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification<sup>2</sup> covers five grades of zirconium strip, sheet, and plate.

1.2 Unless a single unit is used, for example corrosion mass gain in  $\text{mg}/\text{dm}^2$ , 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>3</sup>

**E8/E8M Test Methods for Tension Testing of Metallic Materials**

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

**E290 Test Methods for Bend Testing of Material for Ductility**

<sup>1</sup> 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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<sup>2</sup> For ASME Boiler and Pressure Vessel Code applications, see related Specification SB-551 in Section II of that Code.

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

## 3. Terminology

3.1 *Definitions:*

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

3.2 *Lot Definition:*

3.2.1 *lot, n*—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.

3.3 *Forms:*

3.3.1 *plate, n*—a flat product more than 0.125 in. [3.2 mm] in thickness.

3.3.2 *sheet, n*—a flat product 6 in. [150 mm] or more in width and from 0.005 in. [0.13 mm] to 0.188 in. [4.8 mm] in thickness.

3.3.3 *strip, n*—a flat product, may be supplied in coil, less than 6 in. [150 mm] in width and from 0.005 in. [0.13 mm] to 0.188 in. [4.8 mm] in thickness.

## 4. Classification

4.1 The strip, sheet, or plate is to be furnished in five grades as follows:

4.1.1 *Grade R60700*—Low oxygen zirconium.

4.1.2 *Grade R60702*—Unalloyed zirconium.

4.1.3 *Grade R60704*—Zirconium-tin.

4.1.4 *Grade R60705*—Zirconium-niobium.

4.1.5 *Grade R60706*—Zirconium-niobium.

## 5. Ordering Information

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

5.1.1 Standard designation and year of issue,

5.1.2 Quantity (weight or number of pieces),

5.1.3 Lot definition for continuous anneal, if applicable (3.2.1),

5.1.4 Form (3.3) and dimensions,

5.1.5 Grade (4.1),

5.1.6 Metallurgical condition, if not in the recrystallized annealed condition (6.3),

- 5.1.7 Chemical analysis of elements not listed (7.1.4),
- 5.1.8 Product analysis (7.1.3 and 7.3.1),
- 5.1.9 Tensile test temperature (8.1),
- 5.1.10 Material condition and finish (9.1 – 9.5),
- 5.1.11 Workmanship and appearance (11.1 and 11.3),
- 5.1.12 Purchaser inspection (15.1 and 15.2),
- 5.1.13 Rejection and referee (16.2),
- 5.1.14 Product marking, (18.1 and 18.1.1),
- 5.1.15 Packaging and package marking (19.1),
- 5.1.16 Additions to the specification and supplementary requirements, if required, and
- 5.1.17 Additional requirements for explosion cladding, if applicable (Supplementary Requirements S1).

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 B551/B551M-07, Grade R60705.

## 6. Materials and Manufacture

6.1 Material covered by this specification shall be made from ingots that are produced by vacuum or plasma arc melting, vacuum electron-beam melting, a combination of these three methods or other melting processes conventionally used for reactive metals. All processes to be done in furnaces usually used for reactive metals.

6.2 The various mill products covered by this specification shall be formed with the conventional extrusion, forging, or rolling equipment normally found in primary ferrous and nonferrous plants.

6.3 The strip, sheet, and plate shall be supplied in the recrystallized annealed condition unless otherwise specified in the purchase order.

## 7. Chemical Composition

7.1 The material covered by this specification shall conform to the chemical composition requirements prescribed in Table 1.

7.1.1 The elements listed in Table 1 are intentional alloy additions or elements which are inherent to the manufacture of sponge, ingot or mill product.

7.1.2 Elements intentionally added to the melt must be identified, analyzed, and reported in the chemical analysis.

7.1.3 Elements other than those listed in Table 1 are deemed to be capable of occurring in the grades listed in Table 1 by and only by way of unregulated or unanalyzed scrap additions to the ingot melt. Therefore, product analysis for elements not listed in Table 1 shall not be required unless specified and shall be considered to be in excess of the intent of this specification.

7.1.4 When agreed upon by producer and purchaser and requested by the purchaser in his written purchase order, chemical analysis shall be completed for specific residual elements not listed in this specification.

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.

7.2.1 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 top face. A minimum of three samples per ingot is required.

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

7.2.3 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 7.2.1 to determine the composition, except for hydrogen and nitrogen, which shall be determined on the finished product.

### 7.3 Check Analysis:

7.3.1 Check analysis is an analysis made by the purchaser or the manufacturer of the metal after it has been processed into finished mill forms, and is either for the purpose of verifying the composition of a heat or lot or to determine variations in the composition within a heat or lot. Acceptance or rejection of a lot of material may be made by the purchaser on the basis of this check analysis. When requested by the purchaser and stated in the purchase order, a product check analysis for any elements listed in Table 1 shall be made on the finished product.

7.3.2 Check analysis limits shall be as specified in Table 2. These limits are the amounts an individual result for a given element may vary under or over the specified limits shown in Table 1.

TABLE 1 Chemical Requirements<sup>A</sup>

Element	Composition, %				
	Grades				
	R60700	R60702	R60704	R60705	R60706
Zirconium + hafnium, min	99.2	99.2	97.5	95.5	95.5
Hafnium, max	4.5	4.5	4.5	4.5	4.5
Iron + chromium	0.2 max	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	0.005
Nitrogen, max	0.025	0.025	0.025	0.025	0.025
Carbon, max	0.05	0.05	0.05	0.05	0.05
Niobium	...	...	...	2.0 to 3.0	2.0 to 3.0
Oxygen, max	0.10	0.16	0.18	0.18	0.16

<sup>A</sup> By 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 (see 7.1.1).

**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

7.3.3 Check analysis tolerances do not broaden the specified heat analysis requirements but cover variations between laboratories in the measurement of chemical content.

7.3.4 The manufacturer shall not ship material that is outside the limits specified in [Table 1](#) for the applicable grade.

## 8. Mechanical Properties

8.1 The material, as represented by the test specimens, shall conform to the tensile properties prescribed in [Table 3](#) for room temperature mechanical properties.

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 around a mandrel having a radius equal to that shown in [Table 3](#) for the applicable grade. Bend testing shall be performed in accordance with Test Methods [E290](#).

## 9. Condition and Finish

9.1 Sheet, strip, or plate shall be furnished in one of the following conditions as designated on the purchase order:

Form	Condition
Strip	hot-rolled
	hot-rolled, annealed
	cold-rolled
	cold-rolled, annealed cold-rolled, annealed, followed by a final light cold-rolled pass, generally on polished rolls
Sheet	hot-rolled
	hot-rolled, annealed
	cold-rolled, annealed
	cold-rolled, annealed, followed by a final light cold-rolled pass, generally on polished rolls
Plate	hot-rolled hot-rolled, annealed

9.2 Hot-rolled sheet, strip, or plate shall be furnished with one of the following finishes as designated in the purchase order:

- 9.2.1 Not descaled,
- 9.2.2 Mechanically descaled,
- 9.2.3 Mechanically descaled and pickled,
- 9.2.4 As-ground.

9.3 Cold-rolled sheet or strip shall be furnished with one of the following finishes as designated in the purchase order:

- 9.3.1 Bright cold-rolled,
- 9.3.2 Ground 32 μin. [0.8 μm] rms or better, or
- 9.3.3 Pickled.

9.4 *Hot-Rolled Strip*—The following types of edges can be furnished on hot-rolled strip when specified in the purchase order:

- 9.4.1 Mill edge,
- 9.4.2 Split edge, or
- 9.4.3 Sheared edge.

9.5 *Cold-Rolled Strip*—A slit edge is normally furnished on cold-rolled strip. A machined edge is available for weld preparation when specified in the purchase order.

9.6 *Sheet and Plate*—Both hot- and cold-rolled sheet and plate are furnished with a sheared edge.

## 10. Permissible Variations in Dimensions and Weights

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

- 10.1.1 Hot-rolled strip, [Table 4](#).
- 10.1.2 Cold-rolled strip, [Table 5](#).
- 10.1.3 Hot- and cold-rolled sheet, [Table 6](#).
- 10.1.4 Plate, [Table 7](#).

10.2 *Width*—The variations in width are given in the following tables:

- 10.2.1 Hot-rolled strip, [Table 8](#).
- 10.2.2 Cold-rolled strip, [Table 9](#).
- 10.2.3 Hot- and cold-rolled sheet, [Table 10](#).
- 10.2.4 Plate, [Table 11](#).

10.3 *Length*—The variations in length are given in the following tables:

- 10.3.1 Hot- and cold-rolled strip, [Table 12](#).
- 10.3.2 Hot- and cold-rolled sheet, [Table 13](#).
- 10.3.3 Plate, [Table 11](#).

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

- 10.4.1 Hot-rolled strip, [Table 14](#).

**TABLE 3 Tensile Requirements**

	Grades				
	R60700	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]
Tensile strength, max, ksi [MPa]	55 [380]	...	...	...	...
Yield strength, max, ksi [MPa]	44 [305]	...	...	...	...
Elongation in 2 in. or 50 mm, min, % <sup>A</sup>	20	16	14	16	14
Bend test radius <sup>B</sup>	5T	5T	5T	3T	2.5T

<sup>A</sup> When a sub-size specimen is used, the gage length shall be as specified in Test Methods [E8/E8M](#) for that specimen.

<sup>B</sup> T equals the thickness of the bend test specimen. Bend tests are not applicable to material over 0.187 in. [4.8 mm] in thickness.