



# Standard Specification for Zirconium and Zirconium Alloy Forgings<sup>1</sup>

This standard is issued under the fixed designation B493/B493M; 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 three grades of zirconium and zirconium alloy forgings (see 4.1).

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 The following safety hazards caveat pertains only to the test method portion, Section 12, of this specification: *This standard does not purport to address all of the safety problems, 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*:<sup>3</sup>  
[E8 Test Methods for Tension Testing of Metallic Materials](#)

## 3. Terminology

### 3.1 Lot Definition:

3.1.1 *forgings, n*—parts, including semi-finished products, or complex shapes, produced by hot mechanical work using hammers, presses, or forging machines; 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.

<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-493 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.

## 4. Classification

- 4.1 The forgings are furnished in three grades as follows:
- 4.1.1 *Grade R60702*—Unalloyed zirconium.
  - 4.1.2 *Grade R60704*—Zirconium-tin alloy.
  - 4.1.3 *Grade R60705*—Zirconium-niobium alloy.

## 5. Ordering Information

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

- 5.1.1 Quantity (weight and number of pieces),
- 5.1.2 Name of material (zirconium forgings),
- 5.1.3 Finish (Section 9),
- 5.1.4 Dimension (diameter, thickness, length, width, or as specified in appropriate drawings),
- 5.1.5 ASTM designation and year of issue,
- 5.1.6 Grade number (see 4.1), and
- 5.1.7 Additions to the specification and supplementary requirements, if required, including, but not limited to: product marking (see 17.1), check analysis (see 7.3), inspection (see 13.1), lot definition (see 3.1.1), internal soundness (see S1.1), and surface quality (see S2.1) requirements.

NOTE 1—A typical ordering description is as follows: 8000-lb zirconium forgings, mechanically descaled, 100 mm by 120 mm by 1.2 m. rectangular bar, ASTM B493/ 493M - 08, Grade R60702.

## 6. Materials and Manufacture

6.1 The forgings shall be formed with conventional forging equipment normally found in primary ferrous and nonferrous metal plants.

6.2 Forgings shall be furnished in the annealed conditions.

## 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 forgings, 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 check 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.



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

Element	Composition, %		
	UNS Grade Designation		
	R60702	R60704	R60705
Zirconium + hafnium, min <sup>B</sup>	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	0.16	0.18	0.18

<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.

<sup>B</sup> Zirconium is determined by difference.

**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

**8. Workmanship and Quality Level Requirements**

8.1 The material shall be free of injurious imperfections. Minor surface imperfections may be removed by spot grinding if such grinding does not reduce the dimensions of the finished piece below the minimum permitted by the tolerance for the product.

**9. Finish and Appearance**

9.1 The forgings shall have one of the following surface conditions as specified in the purchase order:

- 9.1.1 As forged,
- 9.1.2 Mechanically descaled, or
- 9.1.3 Mechanically descaled and pickled.

**10. Tensile Requirements**

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

**11. Number of Tests and Retests**

11.1 Two tension tests shall be performed on each lot.

**TABLE 3 Tensile Requirements**

	UNS Grade Designation		
	R60702	R60704	R60705
Tensile strength, min, MPa [ksi]	380 [55]	415 [60]	485 [70]
Yield strength, min, MPa [ksi]	205 [30]	240 [35]	380 [55]
Elongation in 50 mm [2 in.], gauge min, % <sup>A</sup>	16	14	16

<sup>A</sup> When a sub-size specimen is used, the gauge length shall be as specified in Test Methods **E8** for that specimen.

11.2 Two chemistry tests for hydrogen and nitrogen content shall be performed on each lot of finished product.

**11.3 Retests:**

11.3.1 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.

11.3.2 If the results of any tests of any lot do not conform to the requirements specified, retests shall be made on additional forgings of double the original number from the same lot, each of which shall conform to the requirements specified.

**12. Test Methods**

12.1 *Tension Tests*—Tension tests shall be performed in accordance with Test Methods **E8**. Determine the yield strength by the offset (0.2 %) method. Determine the tensile properties using a strain rate of 0.003 to 0.007 mm/mm/min. [in./in./min.] through the yield strength. After the yield strength has been exceeded, increase the cross-head speed to approximately 0.05 mm/mm/min. [in./in./min.] to failure.

12.2 *Chemical Tests*—The chemical analyses shall be performed according to the standard techniques normally used by the manufacturer.

**13. Inspection**

13.1 The manufacturer shall inspect the material covered by this specification prior to shipment. 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 the purchaser’s inspection at the place of manufacture to be waived.

13.2 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 not to interfere unnecessarily with the operation of the works.

**14. Rejection and Rehearing**

14.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

**15. Certification**

15.1 A producer’s or supplier’s certification shall be furnished to the purchaser certifying that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. A report of the test results shall be included as part of the certification.

## 16. Referee

16.1 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.

## 17. Product Marking

17.1 Unless otherwise specified, each forging over 1 kg [2 lb], manufactured in accordance with this specification, shall

be marked legibly, either by stenciling, stamping, or rolling with the manufacturer's private identification mark, the ASTM designation, the grade, and lot number. On smaller than 1 kg [2 lb] forgings, the same information shall be stamped legibly on the container, or on a metal tag securely fastened to each part or package of parts.

## 18. Packaging and Package Marking

18.1 The forgings shall be packaged either in a suitable box or banded on a skid.

## 19. Keywords

19.1 zirconium; zirconium alloy forging

## SUPPLEMENTARY REQUIREMENTS

### S1. Special Internal Soundness

S1.1 Forging shall be produced with specified internal soundness to be verified by electric test or radiography to standards agreed upon between the manufacturer and the purchaser prior to the acceptance of the order.

### S2. Surface Quality

S2.1 The surface quality shall be as agreed upon between the manufacturer and the purchaser.

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