



Designation: B811 – 13 (Reapproved 2022)^{ε1}

Standard Specification for Wrought Zirconium Alloy Seamless Tubes for Nuclear Reactor Fuel Cladding¹

This standard is issued under the fixed designation B811; 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.

^{ε1} NOTE—Editorial changes were made to Table 3 in April 2022.

1. Scope

1.1 This specification covers seamless wrought zirconium-alloy tubes for nuclear fuel cladding application, in the outside diameter (OD) size range of 0.200 in. (5.1 mm) to 0.650 in. (16.5 mm) and wall thickness range of 0.010 in. (0.25 mm) to 0.035 in. (0.89 mm).

1.2 Two grades of reactor grade zirconium alloys are described.

1.2.1 The present UNS numbers designated for the two grades are given in **Table 1**.

1.3 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.

1.4 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.*

1.5 *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.*

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. Referenced Documents

2.1 ASTM Standards:²

B350/B350M Specification for Zirconium and Zirconium Alloy Ingots for Nuclear Application

B353 Specification for Wrought Zirconium and Zirconium Alloy Seamless and Welded Tubes for Nuclear Service (Except Nuclear Fuel Cladding)

E8 Test Methods for Tension Testing of Metallic Materials [Metric] E0008_E0008M

E8M Test Methods for Tension Testing of Metallic Materials [Metric] (Withdrawn 2008)³

E21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials

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

E112 Test Methods for Determining Average Grain Size

G2/G2M Test Method for Corrosion Testing of Products of Zirconium, Hafnium, and Their Alloys in Water at 680°F (360°C) or in Steam at 750°F (400°C)

2.2 Other Document:

ANSI B46.1 Surface Texture (Surface Roughness)⁴

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *dimensions, n*—tube dimensions are outside diameter, inside diameter, and wall thickness. Only two of these parameters may be specified in addition to length, except minimum wall may be specified with outside and inside diameter. In each case, ovality and wall thickness variation (WTV) may be specified as additional requirements.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ The last approved version of this historical standard is referenced on www.astm.org.

⁴ Available from American Iron and Steel Institute (AISI), 1140 Connecticut Ave., NW, Suite 705, Washington, DC 20036, <http://www.steel.org>.

TABLE 1 ASTM and UNS Number Designation for Reactor Grade Zirconium Alloys

Grade	UNS Number
Zirconium-tin alloy	R60802
Zirconium-tin alloy	R60804

3.1.2 *hydride orientation fraction, F_n , n* —the ratio of hydride platelets oriented in the radial direction to the total hydride platelets in the field examined.

3.1.3 *lot size, n* —a lot shall consist of all tubes of the same size, shape, condition, and finish produced from the same ingot by the same reduction schedule and heat treatment. The final heat treatment shall be in a single furnace charge.

3.1.4 *mill finish tubes, n* —tubes that have received all finishing operations subsequent to final anneal, which potentially affects tube mechanical, dimensional, or surface condition. These operations include, but are not limited to, pickling, cleaning, outer and inner surface abrasive conditioning, and straightening.

3.1.5 *ovality, n* —the difference between the maximum and minimum diameter, either outer or inner, as determined at any one transverse cross-section of the tube.

3.1.6 *wall thickness variation (WTV), n* —the difference between maximum and minimum wall thickness measured at any one transverse cross-section of the tube.

NOTE 1—Measurement of ovality and WTV made by a helical scan with a pitch not exceeding 0.25 in. (6.5 mm) shall be considered as equivalent to “at any one cross-section of the tube.”

3.2 Lot Definitions:

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

3.2.2 *ingot, n* —no definition required.

3.2.3 *rounds, flats, tubes, and wrought powder metallurgical products (single definition, common to nuclear and non-nuclear standards), 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.

3.2.4 *sponge, n* —a lot shall consist of a single blend produced at one time.

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

4. Ordering Information

4.1 Purchase orders for tubes covered in this specification shall include the following information to describe adequately the desired material:

- 4.1.1 Quantity,
- 4.1.2 Grade (see Table 1),
- 4.1.3 Condition (recrystallization annealed or stress relief annealed),
- 4.1.4 Tube dimensions and tolerance,
- 4.1.5 ASTM designation and year of issue,

4.1.6 Surface texture on (roughness) the inside and outside surfaces (R_a (micro-inches or micrometers)),

4.1.7 Surface condition on the inside diameter (ID) and outside diameter (OD) surfaces (as pickled, blasted, abraded, etc.),

4.1.8 Sample test conditions (if other than mill finish condition) and standards for corrosion test (see Section 8.2),

4.1.9 General test requirements and test plan for lots (see Section 10),

4.1.10 Number of tests and resampling plan and requirements (see Section 11), and

4.1.11 Certification of test (see Section 16).

NOTE 2—A typical order description may read as follows: 1500 pieces of seamless zirconium-alloy fuel clad tubes OD abraded and ID pickled, Grade R60804, recrystallization annealed 0.650 in. nominal OD by 0.580 in. nominal ID by 0.032 in. minimum wall by 10 ft long with a maximum OD ovality of 0.004 in. and maximum WTV of 0.005 in. in accordance with B811 – XX. Maximum surface finish to be 50 μ in. R_a OD and 50 μ in. R_a ID.

4.2 In addition to the information in 4.1, the following points of agreement between the manufacturer and purchaser should be specified in the purchase order as required:

4.2.1 Method of determining yield strength if other than 0.2 % offset method (see Section 7),

4.2.2 Initial gauge length of mechanical test samples for determining elongation after rupture if other than 2 in. (50 mm),

4.2.3 Mechanical property requirements for tube other than fully recrystallization annealed (see Section 7),

4.2.4 Location of the inside diameter plugs in elevated temperature short-time tension test, when specified (see Section 7.1.3),

4.2.5 Specimen temperature(s) during mechanical testing if other than room temperature and properties and test requirements (see Section 7), and

4.2.6 Grain size requirements and specimen heat treatment method for stress relief annealed tubes (see Section 8.1),

4.2.7 Hydride orientation specimen heat treatment, if required, evaluation method, and magnification of photomicrograph (see Annex A2),

4.2.8 For hydride orientation, angle theta (θ) for determining radial platelets (see Section 8.3 and Annex A2).

4.2.9 Burst property acceptance requirements, when specified (see Section 8.4),

4.2.10 Use of mandrel and post burst test measurement technique (see Annex A1).

4.2.11 Contractile strain ratio acceptance criteria, when specified (see Section 7.3 and Annex A4).

5. Materials and Manufacture

5.1 Materials covered by this specification shall be produced in accordance with Specification B350/B350M; all processes to be done in furnaces usually used for reactive metals.

5.2 Tubes shall be made by a process approved by the purchaser.