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SPECIFICATION FOR SEAMLESS AND WELDED ZIRCONIUM AND ZIRCONIUM ALLOY PIPE



SB-658/SB-658M



(Identical with ASTM Specification B658/B658M-11e1.)

Standard Specification for Seamless and Welded Zirconium and Zirconium Alloy Pipe

1. Scope

1.1 This specification covers three grades of seamless and welded zirconium pipe.

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 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:

B614 Practice for Descaling and Cleaning Zirconium and Zirconium Alloy Surfaces

E8/E8M Test Methods for Tension Testing of Metallic Materials

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

E2626 Guide for Spectrometric Analysis of Reactive and Refractory Metals

2.2 ANSI Standard:

B36.19 Stainless Steel Pipe

2.3 ASME Standard:

ASME Boiler and Pressure Vessel Code, Section VIII

ASME Boiler and Pressure Vessel Code, Section IX

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *annealed, n*—for purposes of this specification “annealed” denotes material that exhibits a recrystallized grain structure.

3.2 Lot Definitions:

3.2.1 *pipe, 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.

4. Classification

4.1 The pipe is 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 materials under this specification should include the following information:

5.1.1 Quantity (weight or total length),

5.1.2 Name of material (zirconium pipe),

5.1.3 Grade number (see 4.1),

5.1.4 Nominal pipe size and schedule (Table X1.1),

5.1.5 Lengths (random or specified cut lengths),

5.1.6 Method of manufacture (Section 6),

5.1.7 Workmanship and quality level requirements (Section 10),

5.1.8 ASTM designation and year of issue, and

TABLE 1 Chemical Requirements^A

| Element | Composition, % | | |
|--------------------------|-----------------------|------------|------------|
| | UNS Grade Designation | | |
| | R60702 | R60704 | 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 |

^A 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 compositions.

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 |

TABLE 3 Tensile Requirements

| | UNS Grade Designations | | |
|---|------------------------|----------|----------|
| | 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, % ^A | 16 | 14 | 16 |

^A When a sub-size specimen is used, the gauge length shall be as specified in Test Methods E8/E8M for that specimen.

5.1.9 Additions to the specification and supplementary requirements, if required. See 7.3, 14.1, 15.1, and 18.1 for additional optional requirements for the purchase order.

NOTE 1—A typical ordering description is as follows: 240-ft [70-mm] zirconium pipe, seamless, descaled 3.0-in. [75-mm] Schedule 40 by 12-ft [3-m] lengths, ASTM B658/B658M - 05, Grade R60702.

6. Materials and Manufacture

6.1 Seamless pipe shall be made from any seamless method that will yield a product meeting this specification.

6.2 Pipe containing welded seams or other joints made by welding shall comply with the following provisions:

6.2.1 Welded by welders, welding operators, and welding procedures qualified under the provisions of Section IX of the ASME Boiler and Pressure Vessel Code.

6.2.2 Filler metal, when used, shall be the same grade as the base metal.

6.2.3 Welds in grade R60705 shall be stress relief annealed within 14 days after welding to prevent delayed hydride cracking. The heat treatment shall be as follows:

6.2.3.1 The stress-relieving treatment shall consist of holding the pipe at a minimum temperature of 1100°F [600°C] for not less than 30 min per inch [25mm] of the maximum thickness in a nonreducing atmosphere. The minimum time at this temperature is 15 min. All stress-relieved parts shall be cleaned subsequently and shall be free of oxide scale contamination (see Practice B614).

6.3 The pipe shall be furnished in the annealed or stress-relieved condition.

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 piping, 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. Tensile Requirements

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

9. Permissible Variations in Dimensions

9.1 *Diametric*—any point (cross section) along the length of the pipe, the variations in outside diameters shall not exceed those prescribed in Table 4.

TABLE 4 Permissible Variations in Diameter^A

| Nominal Outside Diameter, (NPS) ^B in. [mm] | Permissible Variations in Outside Diameter, in. [mm] | |
|---|--|-----------|
| | Over | Under |
| 1/8 to 1 1/2 [3.2 to 40], incl | 1/64 [.4] | 1/32 [.8] |
| Over 1 1/2 to 4 [40 to 100], incl | 1/32 [.8] | 1/32 [.8] |
| Over 4 to 8 [100 to 200], incl | 1/16 [1.6] | 1/32 [.8] |
| Over 8 to 12 [200 to 305], incl | 3/32 [2.4] | 1/32 [.8] |

^A For seamless pipe only. Tolerances on welded pipe shall be as agreed upon between the manufacturer and the purchaser.

^B NPS = nominal pipe size.

9.1.1 The tolerances on the outside diameter include ovality except as provided for in 9.1.2.

9.1.2 Thin-wall pipe usually develops significant ovality (out-of-roundness) during final annealing, straightening, or both. Thin-wall pipe is defined as having a wall thickness of 3 % or less of the outside diameter. The diameter tolerances of Table 4 are not sufficient to provide for additional ovality expected in thin-wall pipe and are applicable only to the mean of the extreme (maximum and minimum) outside diameter readings in any one cross section. However, for thin-wall pipe the difference in extreme outside diameter readings (ovality) in any one cross section shall not exceed 1.5 % of the specified outside diameter.

9.2 *Thickness*—The variation in thickness at any point shall not be more than ±12.5 % of the nominal wall thickness specified.

9.3 *Length*:

9.3.1 Pipe shall be furnished in lengths as specified in the purchase order. No pipe shall be under the specified length and not more than ¼ in. [6.4 mm] over that specified.

9.3.2 For pipe ordered to random lengths, the lengths and variations shall be agreed upon between the manufacturer and the purchaser.

NOTE 2—A system of standard pipe sizes approved by the American National Standards Institute as ANSI B36.19, reproduced as Table X1.1, shall apply, pending the development of similar standards for zirconium.

10. Workmanship, Finish, and Appearance

10.1 The finished pipe shall be reasonably straight, shall have smooth ends, free of burrs, and shall be free of cracks, seams, blisters, and other injurious imperfections in accordance with standards of acceptability agreed upon between the manufacturer and the purchaser. Minor defects may be removed provided the dimensional tolerances in accordance with Section 9 are not exceeded. Unless otherwise specified, the pipe shall be furnished free of scale.

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 E29.

| 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, see 13.1.

12.2 One chemistry test for hydrogen and nitrogen content shall be made from each lot of finished product, see 13.3.

12.3 A hydrostatic proof test shall be performed on each length of pipe, see 13.2.

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 pipe 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 E8/E8M. 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 *Hydrostatic Tests*—Prior to dimensional checks, upsetting, swaging, expanding, or other forming operations, test each pipe ⅛ in. [3.2 mm] and larger in outside diameter, and with wall thickness of 0.015 in. [0.4 mm] and over to a hydrostatic pressure sufficient to produce a fiber stress of three fourths of the minimum yield strength of the pipe, provided that the test pressure does not exceed 5000 psi [35 MPa]. Determine the test pressure as follows:

$$P = 2St/D \tag{1}$$

where:

- P* = hydrostatic test pressure, psi [MPa],
- S* = allowable fiber stress of three fourths of the minimum yield strength (Table 2), psi [MPa],
- t* = average wall thickness of the pipe, in. [mm], and
- D* = nominal diameter of the pipe, in. [mm].

13.3 *Chemical Tests*—Conduct the chemical analysis by the standard techniques normally used by the manufacturer. Guide E2626 may be used as a guide for chemical analysis techniques.

13.4 When specified in the purchase order, all butt welds shall be 100 % radiographed or x-rayed per ASME Code Section VIII, paragraph UW-51.

14. Inspection

14.1 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.

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 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. 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 Unless otherwise specified, each length of pipe 3/8 in. [9.5 mm] nominal diameter and larger, manufactured in accordance with this specification, shall be marked legibly, either by stenciling, stamping, or rolling, with the manufacturer’s private identifying mark, the ASTM designation, the grade, and heat number. On smaller than 3/8-in. [9.5-mm] nominal diameter pipe that is bundled, the same information may be stamped legibly on a metal tag securely attached to each bundle.

19. Packaging and Package Marking

19.1 Pipe shall be packaged suitably in such a manner as to assure safe delivery to its destination when properly transported by common carrier.

20. Keywords

20.1 pipe; zirconium; zirconium alloy

APPENDIX

(Nonmandatory Information)

X1. PIPE DIMENSIONS

X1.1 Table X1.1 is from Table 1 of ANSI B36.19, with the SI units added in this standard.

TABLE X1.1 Dimensions of Welded and Seamless Zirconium Pipe

NOTE 1—The decimal thickness listed for the respective pipe sizes represents their nominal or average wall dimensions.

| Nominal Pipe Size, in. [mm] | Outside Diameter, in. [mm] | Nominal Wall Thickness, in. [mm] | | | |
|--------------------------------|-------------------------------|----------------------------------|--------------|--------------|---------------|
| | | Schedule 5S | Schedule 10S | Schedule 40S | Schedule 80S |
| 1/8 [3.2] | 0.405 [10.3] | ... | 0.049 [1.24] | 0.068 [1.73] | 0.095 [2.41] |
| 1/4 [6.4] | 0.540 [13.7] | ... | 0.065 [1.65] | 0.088 [2.24] | 0.119 [3.02] |
| 3/8 [9.5] | 0.675 [17.1] | ... | 0.065 [1.65] | 0.091 [2.31] | 0.126 [3.20] |
| 1/2 [13] | 0.840 [21.3] | 0.065 [1.65] | 0.083 [2.11] | 0.109 [2.77] | 0.147 [3.73] |
| 3/4 [20] | 1.050 [26.7] | 0.065 [1.65] | 0.083 [2.11] | 0.113 [2.87] | 0.154 [3.91] |
| 1 [25] | 1.315 [33.4] | 0.065 [1.65] | 0.109 [2.77] | 0.133 [3.38] | 0.179 [4.55] |
| 1 1/4 [32] | 1.660 [42.2] | 0.065 [1.65] | 0.109 [2.77] | 0.140 [3.56] | 0.191 [4.85] |
| 1 1/2 [38] | 1.900 [48.3] | 0.065 [1.65] | 0.109 [2.77] | 0.145 [3.68] | 0.200 [5.08] |
| 2 [50] | 2.375 [60.3] | 0.065 [1.65] | 0.109 [2.77] | 0.154 [3.91] | 0.218 [5.54] |
| 2 1/2 [64] | 2.875 [73.0] | 0.083 [2.11] | 0.120 [3.05] | 0.203 [5.16] | 0.276 [7.01] |
| 3 [76] | 3.500 [88.9] | 0.083 [2.11] | 0.120 [3.05] | 0.216 [5.49] | 0.300 [7.62] |
| 3 1/2 [90] | 4.000 [101.6] | 0.083 [2.11] | 0.120 [3.05] | 0.226 [5.74] | 0.318 [8.08] |
| 4 [100] | 4.500 [114.3] | 0.083 [2.11] | 0.120 [3.05] | 0.237 [6.02] | 0.337 [8.56] |
| 5 [125] | 5.583 [141.3] | 0.109 [2.77] | 0.134 [3.40] | 0.258 [6.55] | 0.375 [9.52] |
| 6 [150] | 6.625 [168.3] | 0.109 [2.77] | 0.134 [3.40] | 0.280 [7.11] | 0.432 [10.97] |
| 8 [200] | 8.625 [219.1] | 0.109 [2.77] | 0.148 [3.76] | 0.322 [8.18] | 0.500 [12.7] |
| 10 [250] | 10.750 [273.0] | 0.134 [3.40] | 0.165 [4.19] | 0.365 [9.27] | 0.500 [12.7] |
| 12 [300] | 12.750 [323.8] | 0.156 [3.96] | 0.180 [4.57] | 0.375 [9.52] | 0.500 [12.7] |