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Standard Specification for High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels¹

This standard is issued under the fixed designation A453/A453M; 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.

This standard has been approved for use by agencies of the Department of Defense.

^{e1}Note—A typo in Table 5 was corrected editorially in June 2011.

1. Scope*

1.1 This specification² covers five grades of bolting with twelve classes of yield strength ranging from 50 to 120 ksi [345 to 827 MPa] for use in high-temperature service such as fasteners for pressure vessel and valve flanges. See Specification A962/A962M for the definition of bolting. The material requires special processing and is not intended for general purpose applications.

1.2 The following referenced general requirements are indispensable for application of this specification: Specification A962/A962M.

1.3 Supplementary Requirements are provided for use at the option of the purchaser. The Supplementary Requirements shall only apply when specified individually by the purchaser in the purchase order or contract.

1.4 This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable “M” specification designation (SI units), the inch-pound units shall apply.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. 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.

2. Referenced Documents

2.1 *ASTM Standards*:³

A193/A193M Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

A962/A962M Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range

E139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *heat-treatment charge*—one heat of material heat treated in one batch. If a continuous operation is used, the weight processed as a heat-treatment charge shall not exceed the weights in Table 1.

3.1.2 *lot*—a lot shall consist of the quantities shown in Table 2.

4. Ordering Information

4.1 The inquiry and order shall indicate the following:

4.1.1 Quantity (weight or number of pieces),

¹ This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.22 on Steel Forgings and Wrought Fittings for Piping Applications and Bolting Materials for Piping and Special Purpose Applications.

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² For ASME Boiler and Pressure Vessel Code Applications see related Specification SA-453 in Section II of that Code.

³ 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.

*A Summary of Changes section appears at the end of this standard.

TABLE 1 Continuous Heat-Treatment Charge Sizes

| Diameter, in. [mm] | Weight, lb [kg] |
|-------------------------|-----------------|
| To 1¼ [44] | 3000 [1400] |
| Over 1¼ [44] to 2½ [63] | 6000 [2700] |
| Over 2½ [63] | 12000 [5400] |

TABLE 2 Lot Sizes

| Diameter, in. [mm] | Maximum Lot Size, lb [kg] |
|-------------------------------|---------------------------|
| 1½ [38] and under | 200 [90] |
| Over 1½ [38] to 1¼ [44], incl | 300 [140] |
| Over 1¼ [44] to 2½ [63], incl | 600 [270] |
| Over 2½ [63] | 20 pieces |

- 4.1.2 Description of item (bars, bolts, nuts, etc.),
- 4.1.3 Grade and class (see Table 3),
- 4.1.4 Method of finishing (see 6.1),
- 4.1.5 Type of thread desired (see 6.1.1),
- 4.1.6 Alternative test method option (see 8.2.4.3),
- 4.1.7 Bolt shape option, if any,
- 4.1.8 Thread option, if any,
- 4.1.9 Test method for surface quality, if any,
- 4.1.10 Test location option, if any,
- 4.1.11 Rejection option, if any, and
- 4.1.12 If stress-rupture testing is not required, except for Grade 660 Class D and Grade 668 (see 8.2.1).

5. Common Requirements

5.1 Bolting supplied to this specification shall conform to the requirements of Specification A962/A962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A962/A962M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A962/A962M, this specification shall prevail.

6. Materials and Manufacture

6.1 Finishing Process:

6.1.1 Threads may be formed by machining or rolling. Threads may be formed after precipitation heat treatment or after solution anneal but prior to precipitation heat treatment. Type designations are as follows:

Type M1—threads formed by machining after precipitation heat treatment.

Type M2—threads formed by machining after solution anneal but prior to precipitation heat treatment.

Type R1—threads formed by rolling after precipitation heat treatment.

Type R2—threads formed by rolling after solution anneal but prior to precipitation heat treatment.

When not specified by the purchaser, the type supplied shall be the option of the manufacturer.

6.2 Heat Treatment—Each grade and class shall be heat treated as prescribed in Table 4.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 3.

8. Mechanical Properties

8.1 Tension Test:

8.1.1 Requirements—The material in each heat-treatment charge shall conform to the room-temperature tensile requirements in Table 5.

8.1.2 Number of Specimens:

8.1.2.1 Heat-Treated Bars—When not more than two sizes of bars are heat treated in the same load, one tension test shall be made from each size in each heat of material in the heat-treatment charge (see 3.1.1). When more than two sizes of bars are treated in the same charge, one tension test shall be made from one bar of each of the two largest diameters from each heat of material in the heat-treating charge.

8.1.2.2 Finished Parts—One tension test shall be made if the lot consists of parts of the same nominal diameter. If the lot consists of parts of more than one nominal diameter, one tension test shall be made from each nominal diameter of each heat involved in the lot (see Section 3).

8.2 Stress-Rupture Test:



TABLE 3 Chemical Requirements

| Grade 660 | | Grade 651 | | |
|------------------------|-------------|---|------------|---|
| UNS Number | S66286 | S63198 | | |
| | Content, % | Product Analysis Variation, Over or Under, % | Content, % | Product Analysis Variation, Over or Under, % |
| Carbon | 0.08 max | 0.01 over | 0.28–0.35 | 0.02 |
| Manganese | 2.00 max | 0.04 | 0.75–1.50 | 0.04 |
| Phosphorus | 0.040 max | 0.005 over | 0.040 max | 0.005 over |
| Sulfur | 0.030 max | 0.005 over | 0.030 max | 0.005 over |
| Silicon | 1.00 max | 0.05 | 0.30–0.80 | 0.05 |
| Nickel | 24.0–27.0 | 0.20 | 8.0–11.0 | 0.15 |
| Chromium | 13.5–16.0 | 0.20 | 18.0–21.0 | 0.25 |
| Molybdenum | 1.00–1.50 | 0.05 | 1.00–1.75 | 0.05 |
| Tungsten | ... | ... | 1.00–1.75 | 0.05 |
| Titanium | 1.90–2.35 | 0.05 | 0.10–0.35 | 0.05 over |
| Columbium ⁴ | ... | ... | 0.25–0.60 | 0.05 |
| Aluminum | 0.35 max | 0.05 over | ... | ... |
| Vanadium | 0.10–0.50 | 0.03 | ... | ... |
| Boron | 0.001–0.010 | 0.0004 under to 0.001 over | ... | ... |
| Copper | ... | ... | 0.50 max | 0.03 over |

| Grade 662 | | Grade 665 | | |
|------------|-------------|---|------------|---|
| UNS Number | S66220 | S66545 | | |
| | Content, % | Product Analysis, Variation Over or Under, % | Content, % | Product Analysis Variation, Over or Under, % |
| Carbon | 0.08 max | 0.01 over | 0.08 max | 0.01 over |
| Manganese | 0.40–1.00 | 0.03 | 1.25–2.00 | 0.04 |
| Phosphorus | 0.040 max | 0.005 over | 0.040 max | 0.005 over |
| Sulfur | 0.030 max | 0.005 over | 0.030 max | 0.005 over |
| Silicon | 0.40–1.00 | 0.05 | 0.10–0.80 | 0.05 |
| Nickel | 24.0–28.0 | 0.20 | 24.0–28.0 | 0.20 |
| Chromium | 12.0–15.0 | 0.15 | 12.0–15.0 | 0.15 |
| Molybdenum | 2.0–3.5 | 0.10 | 1.25–2.25 | 0.10 |
| Titanium | 1.80–2.10 | 0.05 | 2.70–3.3 | 0.05 |
| Aluminum | 0.35 max | 0.05 over | 0.25 max | 0.05 over |
| Copper | 0.50 max | 0.03 over | 0.25 max | 0.03 over |
| Boron | 0.001–0.010 | 0.0004 under to 0.001 over | 0.01–0.07 | 0.005 |

| Grade 668 | | Grade 668 | | |
|------------------------|-------------|---|------------|---|
| UNS Number | S66285 | S66285 | | |
| | Content, % | Product Analysis, Variation Over or Under, % | Content, % | Product Analysis Variation, Over or Under, % |
| Carbon | 0.08 max | 0.01 over | 0.08 max | 0.01 over |
| Manganese | 2.00 max | 0.04 | 1.25–2.00 | 0.04 |
| Phosphorus | 0.040 max | 0.005 over | 0.040 max | 0.005 over |
| Sulfur | 0.030 max | 0.005 over | 0.030 max | 0.005 over |
| Silicon | 1.00 max | 0.05 | 0.10–0.80 | 0.05 |
| Nickel | 17.5 – 21.5 | 0.20 | 24.0–28.0 | 0.20 |
| Chromium | 13.5–16.0 | 0.20 | 12.0–15.0 | 0.15 |
| Molybdenum | 1.50 max | 0.05 | 1.25–2.25 | 0.10 |
| Tungsten | ... | ... | 2.70–3.3 | 0.05 |
| Titanium | 2.2–2.8 | 0.05 | 0.25 max | 0.05 over |
| Columbium ⁴ | ... | ... | 0.25 max | 0.03 over |
| Aluminum | 0.50 max | 0.05 over | 0.01–0.07 | 0.005 |
| Vanadium | 0.50 max | 0.03 | | |
| Boron | 0.001–0.010 | 0.0004 under to 0.001 over | | |
| Copper | ... | ... | | |

⁴ Or columbium plus tantalum.

8.2.1 *Requirements*—The material shall conform to the stress-rupture requirements prescribed in Table 6 for design temperatures above 800 °F [427 °C]. Material not stress-rupture tested shall be permanently stamped NR. Grade 660 Class D and Grade 668 do not require stress-rupture and shall be stamped NR.

8.2.2 The number of specimens shall be the same as the required number of tension test specimens.

8.2.3 The test location and orientation shall be the same as that required for the tension test specimens.

8.2.4 *Test Method:*

8.2.4.1 The rupture test shall be performed in accordance with Practice E139.

8.2.4.2 A combination smooth and notched test specimen, machined to the dimensions prescribed in Fig. 1 and Table 7, shall be tested in accordance with the stress-rupture requirements prescribed in Table 6. The test shall be continued to rupture. The

TABLE 4 Heat Treatment Requirements^A

| Grade Symbol | Class | Solution Treatment | Hardening Treatment |
|--------------|-------|---|--|
| 660 | A | 1650 ± 25 °F [900 ± 14 °C], hold 2 h, min, and liquid quench | 1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool |
| | B | 1800 ± 25 °F [980 ± 14 °C], hold 1 h, min, and liquid quench | 1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool |
| | C | 1800 ± 25 °F [980 ± 14 °C], hold 1 h min, and oil quench | 1425 ± 25 °F [775 ± 14 °C] hold 16 h, air cool, followed by 1200 ± 25 °F [650 ± 14 °C] hold 16 h, air cool |
| | D | 1650 ± 25 °F [900 ± 14 °C], hold 2 h min, and liquid quench or 1800 ± 25 °F [980 ± 14 °C], hold 1 h min, and liquid quench | 1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool If necessary to achieve properties, second age: 1200 ± 25 °F [650 ± 14 °C] hold 16 h, air cool |
| 651 | A | | hot-cold worked at 1200 °F [650 °C] min with 15 % min reduction in cross-sectional area, stress-relief anneal at 1200 °F [650 °C] min or 4 h, min |
| | B | | hot-cold worked at 1200 °F [650 °C] min with 15 % min reduction of cross-sectional area, stress-relief anneal at 1350 °F [730 °C] min for 4 h, min |
| 662 | A | 1800 ± 25 °F [980 ± 14 °C], hold 2 h, liquid quench | 1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool |
| | B | 1950 ± 25 °F [1065 ± 14 °C], hold 2 h, liquid quench | 1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool |
| 665 | A | 1800 ± 25 °F [980 ± 14 °C], hold 3 h, liquid quench | 1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool |
| | B | 2000 ± 25 °F [1095 ± 14 °C], hold 3 h, liquid quench | 1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool |
| 668 | A | 1650 ± 25 °F [900 ± 14 °C], hold 2 h, min and liquid quench | 1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool |
| | B | 1800 ± 25 °F [980 ± 14 °C], hold 1 h, min and liquid quench | 1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool |

^A Times refer to the minimum time material is required to be at temperature.

rupture shall occur in the smooth section of the bar.

8.2.4.3 As an alternative procedure and, when specifically approved by the purchaser, separate smooth and notched test specimens, machined from adjacent sections of the same piece, with gage sections conforming to the respective dimensions of Table 7, may be tested under the above conditions. The notched specimen need not be tested to rupture but shall not rupture in less time than the companion smooth specimen.

8.2.4.4 When the minimum specified time to rupture in Table 6 has been achieved, incremental loading may be used to accelerate the time to rupture. At intervals of 8 to 16 h, preferably 8 to 10 h, the stress shall be increased in increments of 5000 psi [34.5 MPa]. Rupture location, and elongation requirements shall be as prescribed in Table 6, 8.2.4.2, and 8.2.4.3.

8.3 Hardness Test:

8.3.1 *Requirements*—The material shall conform to the room temperature hardness requirements prescribed in Table 5.

8.3.2 Number of Tests:

8.3.2.1 *Bars 2 in. [50 mm] and Over*—One test on each mill-treated length.

8.3.2.2 *Bars under 2 in. [50 mm]*—One test on at least 10 % of the mill treated lengths.

8.3.2.3 *Fasteners*—One test each on two fasteners or on a sample per Guide F1470, Table 3, sample size B for each heat lot, whichever is the larger sample.

8.3.3 *Test Locations*—The hardness test shall be made at the center of the cross section for bars up to 1 in. [25 mm] in diameter, and at the midradius on bars 1 in. [25 mm] and larger in diameter.