Designation: A 453/A 453M – 04

Standard Specification for High-Temperature Bolting Materials, with Expansion Coefficients Comparable to Austenitic Stainless Steels[1]

This standard is issued under the fixed designation A 453/A 453M; 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.

1. Scope*

1.1 This specification[2] covers four grades of bolting materials with ten 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. The material requires special processing and is not intended for general purpose applications. The term "bolting material," as used in this specification, covers rolled, forged, or hot-extruded bars; bolts, nuts, screws, washers, studs, and stud bolts. Headed bolts and rolled threads may be supplied.

NOTE 1—Other bolting materials are covered by Specification A 193/A 193M and Specification A 437/A 437M.

1.2 Supplementary Requirement S 1 of an optional nature is provided. This shall apply only when specified by the purchaser in the order.

1.3 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:* [3]

A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service

A 437/A 437M Specification for Alloy-Steel Turbine-Type Bolting Material Specially Heat Treated for High-Temperature Service

A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range

E 139 Test Method for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bolting material*—this covers rolled, forged, or hot-extruded bars; bolts, nuts, screws, washers, studs, and stud bolts; and also includes those manufactured by upset heading or roll threading techniques.

3.1.2 *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.

3.1.3 *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),

4.1.2 Description of material (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 7.2.4.3),

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

[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.**

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TABLE 1 Continuous Heat-Treatment Charge Sizes

Diameter, in. [mm]	Weight, lb [kg]
To 1¾ [44]	3000 [1400]
Over 1¾ [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 1¾ [44], incl	300 [140]
Over 1¾ [44] to 2½ [63], incl	600 [270]
Over 2½ [63]	20 pieces

4.1.12 If stress-rupture testing is not required, except for Grade 660 Class D (see 7.2.1).

5. Common Requirements

5.1 Material and fasteners supplied to this specification shall conform to the requirements of Specification A 962/A 962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A 962/A 962M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 962/A 962M, this specification shall prevail.

6. Materials and Manufacture

6.1 *Finishing Process*:

6.1.1 Threads may be performed by machining or rolling. For Type 1 bolting, threading shall be performed after precipitation heat treatment. Types M1 and M2 bolting shall have machine cut threads. For Types 2 R1 and R2, bolting shall have rolled threads. Types R1 and M1 bolting, threading shall be performed after precipitation heat treatment. Types R2 and M2 bolting shall be threaded after solution heat treatment 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. Mechanical Properties

7.1 *Tension Test*:

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

7.1.2 *Number of Specimens*:

7.1.2.1 *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 3.1.2). 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.

7.1.2.2 *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).

7.1.2.3 The diameter range shall be in increments of ½ in. [12.5 mm].

7.2 *Stress-Rupture Test*:

7.2.1 *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 does not require stress-rupture and shall be stamped NR.

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

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

7.2.4 *Test Method*:

7.2.4.1 The rupture test shall be performed in accordance with Practice E 139.

7.2.4.2 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 rupture shall occur in the smooth section of the bar.

7.2.4.3 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.

7.2.4.4 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, 7.2.4.2, and 7.2.4.3.

7.3 *Hardness Test*:

7.3.1 *Requirements*—The material shall conform to the room temperature hardness requirements prescribed in Table 5. For Grade 660 Class D, in the case of conflict, tensile test results shall prevail over minimum hardness.

7.3.2 *Number of Tests*:

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

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

7.3.2.3 *Fasteners*—One test each on two fasteners or on a sample per Guide F 1470, Table 3, sample size B for each heat lot, whichever is the larger sample.

7.3.3 *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.

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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[A]	...	...	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

[A] Or columbium plus tantalum.

TABLE 4 Heat Treatment Requirements[A]

Grade	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 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

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

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TABLE 5 Mechanical Property Requirements

Grade	Class	Tensile Strength, min		Yield Strength (0.2 % Offset), min		Elongation in 4× Diam, min, %	Reduction of Area, min, %	Brinell Hardness Number	Approximate Rockwell Hardness, B and C	
		ksi	MPa	ksi	MPa				min	max
660	A, B, and C	130	895	85	585	15	18	248–341	24 HRC	37 HRC
	D	130	895	105	725	15	18	248–321	24 HRC	35 HRC
651	A	100	690	70[A]	485	18	35	217–277	95 HRB	29 HRC
				60[B]	415					
	B	95	655	60[A]	415	18	35	212–269	93 HRB	28 HRC[C]
				50[B]	345					
662	A	130	895	85	585	15	18	248–321	24 HRC	35 HRC[C]
	B	125	860	80	550	15	18	248–321	24 HRC	35 HRC
665	A	170	1170	120	830	12	15	311–388	32 HRC	41 HRC
	B	155	1070	120	830	12	15	311–388	32 HRC	41 HRC

[A] Material sizes 3 in. [76 mm] and under in diameter.
[B] Material sizes over 3 in. [76 mm] in diameter.
[C] Conversion numbers taken from Specification A 193/A 193M, Table number 2 (austenitic steels); others by interpolation.

TABLE 6 Stress Rupture Requirements

Grade	Class	Test Temperature, °F [°C]	Stress, min		Time to Rupture, min, h[A]	Elongation, min, %
			ksi	MPa		
660	A, B, and C	1200 [650]	56	385	100	5
651	A and B	1200 [650]	40	275	100	5
662	A and B	1200 [650]	55	380	100	5
665	A	1200 [650]	75	515	100	3
	B	1200 [650]	70	485	100	5

[A] The combination bar specimen shown in Fig.number 1 shall be tested continuously at the temperature and at the minimum stress specified or at a greater stress and shall rupture in a time not less than that specified.

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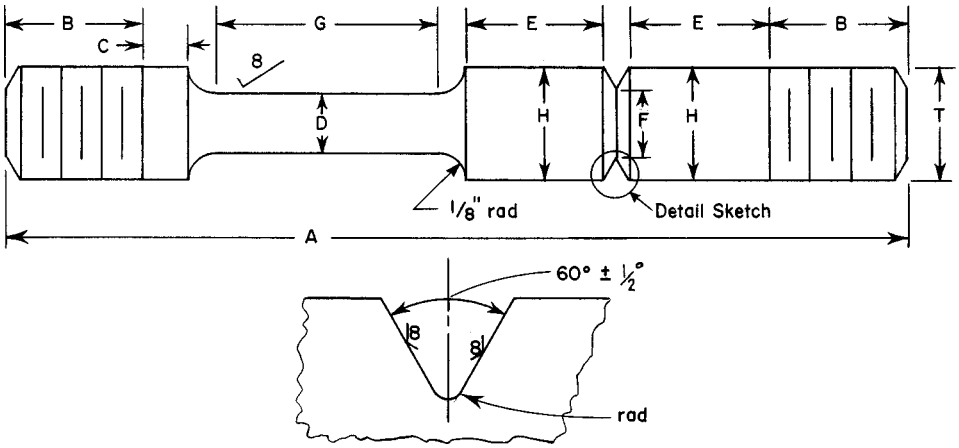

FIG. 1 Combination Smooth-Notch Stress-Rupture Test Specimen

(See Table 6)

8. Product Marking

8.1 *Bolts, Nuts, Screws, Studs, and Steel Bolts*—In addition to the grade and class shown in Table 4, the type designation (see 6.1.1) shall also appear on all bolting material so processed. Grade 660 Class D shall be stamped NR in addition to other required markings.

9. Keywords

9.1 bolts–steel; fasteners–steel; marking; nuts–steel; precipitation hardening steels; pressure vessel service; revision letter; steel bars–alloy; steel bolting material; steel flanges; steel values; temperature service applications–high; year date

TABLE 8 Permissible Variations in Size of Cold-Finished Bars

Specified Size, in. [mm]	Permissible Variations from Specified Size, in. [mm][A]	
	Over	Under
Over ½ to 1 [13 to 25], excl	0.002 [0.05]	0.002 [0.05]
1 to 1½ [25 to 38], excl	0.0025 [0.06]	0.0025 [0.06]
1½ to 4 [38 to 100], incl[B]	0.003 [0.08]	0.003 [0.08]

[A] When it is necessary to heat treat or heat treat and pickle after cold finishing, because of special hardness or mechanical property requirements, the permissible variations are generally double those shown in the table.

[B] For size tolerances of sizes over 4 in. [100 mm], the manufacturer should be consulted.

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TABLE 7 Test Specimen Dimensions

NOTE 1— Surfaces marked[8], finish to 8 µin. [0.2 µm] rms or better.

NOTE 2—The difference between dimensions *F* and *D* shall not exceed 0.0005 in. [0.01 mm] for specimens 1 or 2. The difference shall not exceed 0.001 in. [0.02 mm] for specimens 3, 4, 5, or 6.

NOTE 3—Taper the gage length *G* to the center so that the diameter *D* at the ends of the gage length exceeds the diameter at the center of the gage length by not less than 0.0005 in. [0.01 mm] nor more than 0.0015 in. [0.04 mm].

NOTE 4—All sections shall be concentric about the specimen axis within 0.001 in. [0.02 mm].

NOTE 5—Thread size *T* shall be equal to or greater than diameter *H*.

NOTE 6—Dimensions *A* and *B* are not specified.

NOTE 7—Length of shoulder *C*—⅛ + 1 / 32 −0 in. [3.2 + 0.8 mm].

NOTE 8—Length of shoulder *E*—⅜ + 1/32 −0 in. [10.0 + 0.8 mm].

Specimen Type	Mid-length Gage Dia *D* and Notch-Root Dia *F*	Gage Length, *G*	Shoulder Diameter, *H*	Notch-Root Radius
	Inches			
1	0.125	0.5	0.177	0.005
2	0.160	0.65	0.226	0.005
3	0.178	0.75	0.250	0.005
4	0.252	1.0	0.375	0.007
5	0.357	1.5	0.500	0.010
6	0.505	2.0	0.750	0.015
Tolerance	±0.001	±0.05	±0.003	±0.0005
	Millimetres			
7	3.17	12.0	4.5	0.13
8	4.06	17.0	5.5	0.13
9	4.52	20.0	6.5	0.13
10	6.40	25.0	9.5	0.18
11	9.07	40.0	12.0	0.25
12	12.8	50.0	19.0	0.38
Tolerance	±0.025	±1.3	±0.1	±0.01

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A 453/A 453M – 03, that may impact the use of this specification. (Approved October 1, 2004)

(*1*) Added paragraph 7.3.2.3.

Committee A01 has identified the location of selected changes to this specification since the last issue, A 453/A 453M – 02, that may impact the use of this specification. (Approved October 1, 2003)

(*1*) Revised 4.1.12, 7.2.1, 7.3.1, and 8.1 to include Grade 660 Class D.

(*2*) Corrected Hardness to Tensile conversions in Table 5.

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