Designation: A 193/A 193M – 04c

Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service[1]

This standard is issued under the fixed designation A 193/A 193M; 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 alloy and stainless steel bolting material for pressure vessels, valves, flanges, and fittings for high-temperature service. The term *bolting material* as used in this specification covers bars, bolts, screws, studs, stud bolts, and wire. Bars and wire shall be hot-wrought. The material may be further processed by centerless grinding or by cold drawing. Austenitic stainless steel may be carbide solution treated or carbide solution treated and strain-hardened. When strain hardened austenitic steel is ordered, the purchaser should take special care to ensure that Appendix X1 is thoroughly understood.

1.2 Several grades are covered, including ferritic steels and austenitic stainless steels designated B5, B8, and so forth. Selection will depend upon design, service conditions, mechanical properties, and high-temperature characteristics.

NOTE 1—The committee formulating this specification has included fifteen steel types that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent.

NOTE 2—For grades of alloy-steel bolting material suitable for use at the lower range of high-temperature applications, reference should be made to Specification A 354.

NOTE 3—For grades of alloy-steel bolting material suitable for use in low-temperature applications, reference should be made to Specification A 320/A 320M.

1.3 Nuts for use with this bolting material are covered in Section 13.

1.4 Supplementary Requirements S1 through S10 are provided for use when additional tests or inspection are desired. These shall apply only when specified in the purchase order.

1.5 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.

1.6 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 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both

A 320/A 320M Specification for Alloy/Steel Bolting Materials for Low-Temperature Service

A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

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 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials

E 112 Test Methods for Determining Average Grain Size

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

E 150 Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of

[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.

Current edition approved Oct. 1, 2004. Published October 2004. Originally approved in 1936. Last previous edition approved in 2004 as A 193/A 193M-04b.

[2] For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-193 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.**

Rapid Heating and Short Times[4]
E 151 Practice for Tension Tests of Metallic Materials at Elevated Temperatures with Rapid Heating and Conventional or Rapid Strain Rates[4]
E 292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials
E 328 Test Methods for Stress-Relaxation Tests for Materials and Structures
E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
E 709 Guide for Magnetic Particle Examination
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
2.2 *ANSI Standards:*[5]
B1.1 Screw Threads
B18.2.1 Square and Hex Bolts and Screws
B18.2.3.1M Metric Hex Cap Screws
B18.3 Hexagon Socket and Spline Socket Screws
B18.3.1M Metric Socket Head Cap Screws
2.3 *AIAG Standard:*[6]
AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A 962/A 962M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, etc.

3.2 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include, but are not limited to, the ordering information in Specification A 962/A 962M and the following:

3.2.1 Heat-treated condition (that is, normalized and tempered, or quenched and tempered, for the ferritic materials, and carbide solution treated (Class 1), carbide solution treated after finishing (Class 1A), and carbide solution treated and strain-hardened (Classes 2, 2B and 2C), for the austenitic stainless steels; Classes 1B and 1C apply to the carbide solution-treated nitrogen-bearing stainless steels; Class 1D applies to material carbide solution treated by cooling rapidly from the rolling temperature),

3.2.2 Description of items required (that is, bars, bolts, screws, or studs),

3.2.3 Nuts, if required by purchaser, in accordance with 13.1,

3.2.4 Supplementary requirements, if any, and

3.2.5 Special requirements, in accordance with 6.3, 6.5.1, 10.2, 14.1, and 15.1.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 962/A 962M the requirements of this specification shall prevail.

4. Manufacture (Process)

4.1 The steel shall be produced by any of the following processes: open-hearth, basic-oxygen, electric-furnace, or vacuum-induction melting (VIM). The molten steel may be vacuum-treated prior to or during pouring of the ingot or strand casting.

4.2 *Quality*—See Specification A 962/A 962M for requirements.

5. Discard

5.1 A sufficient discard shall be made to secure freedom from injurious piping and undue segregation.

6. Heat Treatment

6.1 Ferritic steels shall be properly heat treated as best suits the high-temperature characteristics of each grade. Immediately after rolling or forging, the bolting material shall be allowed to cool to a temperature below the cooling transformation range. The materials which are to be furnished in the liquid-quenched condition shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a *quenching charge*) and quenched in a liquid medium under substantially uniform conditions for each quenching charge. Use of water quenching is prohibited for any ferritic grade when heat treatment is part of the fastener manufacturing process. This prohibition does not apply to heat treated bar or to fasteners machined therefrom. The materials that are to be furnished in the normalized or air-quenched condition shall be reheated to the proper temperature to refine the grain and cooled uniformly in air to a temperature below the transformation temperature range. The material, whether liquid-quenched or normalized, shall then be uniformly reheated for tempering. The minimum tempering temperature shall be as specified in Table 2 and Table 3.

[4] Withdrawn.
[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.
[6] Available from Automotive Industry Action Group, 26200 Lahser, Suite 200, Southfield, MI 48034.

TABLE 1 Chemical Requirements (Composition, percent)[A]

Type	Ferritic Steels			
Grade	B5		B6 and B6X	
UNS Designation	5% Chromium		12 % Chromium	
			S 41000 (410)	
	Range	Product Variation, Over or Under[B]	Range	Product Variation Over or Under[B]
Carbon	0.10 min	0.01 under	0.08–0.15	0.01 over
Manganese, max	1.00	0.03 over	1.00	0.03 over
Phosphorus, max	0.040	0.005 over	0.040	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00 max	0.05 over	1.00 max	0.05 over
Chromium	4.0–6.0	0.10	11.5–13.5	0.15
Molybdenum	0.40–0.65	0.05	. . .	. . .

Type	Ferritic Steels			
Grade	B7, B7M		B16	
Description	Chromium-Molybdenum[C]		Chromium-Molybdenum-Vanadium	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon	0.37–0.49[D]	0.02	0.36–0.47	0.02
Manganese	0.65–1.10	0.04	0.45–0.70	0.03
Phosphorus, max	0.035	0.005 over	0.035	0.005 over
Sulfur, max	0.040	0.005 over	0.040	0.005 over
Silicon	0.15–0.35	0.02	0.15–0.35	0.02
Chromium	0.75–1.20	0.05	0.80–1.15	0.05
Molybdenum	0.15–0.25	0.02	0.50–0.65	0.03
Vanadium	. . .	. . .	0.25–0.35	0.03
Aluminum, max %[E]	. . .	. . .	0.015	. . .

Type	Austenitic Steels,[F] Classes 1, 1A, 1D, and 2							
Grade	B8, B8A		B8C, B8CA		B8M, B8MA, B8M2, B8M3		B8P, B8PA	
UNS Designation	S 30400 (304)		S 34700 (347)		S 31600 (316)		S 30500	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.08	0.01 over	0.12	0.01 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over	0.030	0.005 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	17.0–19.0	0.20	16.0–18.0	0.20	17.0–19.0	0.20
Nickel	8.0–11.0	0.15	9.0–12.0	0.15	10.0–14.0	0.15	11.0–13.0	0.15
Molybdenum	. . .	. . .	. . .	. . .	2.00–3.00	0.10	. . .	. . .
Columbium + tantalum	. . .	. . .	10 x carbon content, min; 1.10 max	0.05 under	. . .	. . .	. . .	. . .

TABLE 1 *Continued*

Type	Austenitic Steels,[F] Classes 1A, 1B, 1D, and 2				
Grade	B8N, B8NA		B8MN, B8MNA		B8MLCuN, B8MLCuNA
UNS Designation	S 30451 (304N)		S 31651 (316N)		S 31254
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]	Range
Carbon, max	0.08	0.01 over	0.08	0.01 over	0.020
Manganese, max	2.00	0.04 over	2.00	0.04 over	1.00
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.030
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.010
Silicon, max	1.00	0.05 over	1.00	0.05 over	0.80
Chromium	18.0–20.0	0.20	16.0–18.0	0.20	19.5–20.5
Nickel	8.0–11.0	0.15	10.0–13.0	0.15	17.5–18.5
Molybdenum	. . .	. . .	2.00–3.00	0.10	6.0–6.5
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01	0.18–0.22
Copper	. . .	. . .	. . .	. . .	0.50–1.00

Type	Austenitic Steels[F], Classes 1, 1A, and 2	
Grade	B8T, B8TA	
UNS Designation	S 32100 (321)	
	Range	Product Variation, Over or Under[B]
Carbon, max	0.08	0.01 over
Manganese, max	2.00	0.04 over
Phosphorus, max	0.045	0.010 over
Sulfur, max	0.030	0.005 over
Silicon, max	1.00	0.05 over
Nickel	9.0–12.0	0.15
Chromium	17.0–19.0	0.20
Titanium	5 x (C + N) min, 0.70 max	0.05 under

Type	Austenitic Steels[F], Classes 1C and 1D			
Grade	B8R, B8RA		B8S, B8SA	
UNS Designation	S 20910		S 21800	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.06	0.01 over	0.10	0.01 over
Manganese	4.0–6.0	0.05	7.0–9.0	0.06
Phosphorus, max	0.045	0.005 over	0.060	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00 max	0.05 over	3.5–4.5	0.15
Chromium	20.5–23.5	0.25	16.0–18.0	0.20
Nickel	11.5–13.5	0.15	8.0–9.0	0.10
Molybdenum	1.50–3.00	0.10	. . .	. . .
Nitrogen	0.20–0.40	0.02	0.08–0.18	0.01
Columbium + tantalum	0.10–0.30	0.05	. . .	. . .
Vanadium	0.10–0.30	0.02	. . .	. . .

Type	Austenitic Steels[F], Classes 1, 1A and 1D			
Grade	B8LN, B8LNA		B8MLN, B8MLNA	
UNS Designation	S 30453		S 31653	
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Carbon, max	0.030	0.005 over	0.030	0.005 over
Manganese	2.00	0.04 over	2.00	0.04 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over
Silicon	1.00	0.05 over	1.00	0.05 over
Chromium	18.0–20.0	0.20	16.0–18.0	0.20
Nickel	8.0–11.0	0.15	10.0–13.0	0.15
Molybdenum	. . .	. . .	2.00–3.00	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01

[A] The intentional addition of Bi, Se, Te, and Pb is not permitted.

[B] Product analysis—Individual determinations sometimes vary from the specified limits on ranges as shown in the tables. The several determinations of any individual element in a heat may not vary both above and below the specified range.

[C] Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.

[D] For bar sizes over 3½ in. [90 mm], inclusive, the carbon content may be 0.50 %, max. For the B7M grade, a minimum carbon content of 0.28 % is permitted, provided that the required tensile properties are met in the section sizes involved; the use of AISI 4130 or 4130H is allowed.

[E] Total of soluble and insoluble.

[F] Classes 1 and 1D are solution treated. Classes 1, 1B, and some 1C (B8R and B8S) products are made from solution treated material. Class 1A (B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, and B8MNA) and some Class 1C (B9RA and B8SA) products are solution treated in the finished condition. Class 2 products are solution treated and strain hardened.

TABLE 2 Mechanical Requirements — Inch Products

Grade	Diameter, in.	Minimum Tempering Temperature, °F	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
			Ferritic Steels				
B5							
4 to 6 % chromium	up to 4, incl	1100	100	80	16	50	. . .
B6							
13 % chromium	up to 4, incl	1100	110	85	15	50	. . .
B6X							
13 % chromium	up to 4, incl	1100	90	70	16	50	26 HRC
B7							
Chromium-molybdenum	2½ and under	1100	125	105	16	50	321 HB or 35 HRC
	over 2½ to 4	1100	115	95	16	50	321 HB or 35 HRC
	over 4 to 7	1100	100	75	18	50	321 HB or 35 HRC
B7M[A] Chromium-molybdenum	4 and under	1150	100	80	18	50	235 HB or 99 HRB
	over 4 to 7	1150	100	75	18	50	235 BHN or 99 HRB
B16							
Chromium-molybdenum-vanadium	2½ and under	1200	125	105	18	50	321 HB or 35 HRC
	over 2½ to 4	1200	110	95	17	45	321 HB or 35 HRC
	over 4 to 8	1200	100	85	16	45	321 HB or 35 HRC

Grade, Diameter, in.	Heat Treatment[B]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, all diameters	carbide solution treated	75	30	30	50	223 HB[C] or 96 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated	75	30	30	50	223 HB[C] or 96HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA B8MLCuNA, all diameters	carbide solution treated in the finished condition	75	30	30	50	192 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, and B8MLCuN, all diameters	carbide solution treated	80	35	30	40	223 HB[C] or 96 HRB
Classes 1C and 1D: B8R, all diameters	carbide solution treated	100	55	35	55	271 HB or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	100	55	35	55	271 HB or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	95	50	35	55	271 HB or 28 HRC
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	95	50	35	55	271 HB or 28 HRC
Class 2: B8, B8C, B8P, B8T, and B8N,[D]	carbide solution treated and strain hardened	125	100	12	35	321 HB or 35 HRC
¾ and under						
over ¾ to 1, incl		115	80	15	35	321 HB or 35 HRC
over 1 to 1¼ , incl		105	65	20	35	321 HB or 35 HRC
over 1¼ to 1½ , incl		100	50	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN[D]	carbide solution treated and strain hardened	110	95	15	45	321 HB or 35 HRC
¾ and under						
over ¾ to 1 incl		100	80	20	45	321 HB or 35 HRC

TABLE 2 *Continued*

Grade, Diameter, in.	Heat Treatment[B]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
		Austenitic Steels				
Over 1 to 1¼ , incl		95	65	25	45	321 HB or 35 HRC
over 1¼ to 1½ , incl		90	50	30	45	321 HB or 35 HRC
Class 2B: B8, B8M2[D]	carbide solution treated and strain hardened	95	75	25	40	321 HB or 35 HRC
2 and under						
over 2 to 2½ incl		90	65	30	40	321 HB or 35 HRC
over 2½ to 3 incl		80	55	30	40	321 HB or 35 HRC
Class 2C: B8M3[D]	carbide solution treated and strain hardened	85	65	30	60	321 HB or 35 HRC
2 and under						
over 2		85	60	30	60	321 HB or 35 HRC

[A] To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).
[B] Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over ¾ in. in diameter.
[C] For sizes ¾ in. in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.
[D] For diameters 1½ and over, center (core) properties may be lower than indicated by test reports which are based on values determined at ½ radius.

TABLE 3 Mechanical Requirements —Metric Products

Class	Diameter, [mm]	Minimum Tempering Temperature, °C	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
		Ferritic Steels					
B5							
4 to 6 % chromium	up to M100, incl	593	690	550	16	50	. . .
B6							
13 % chromium	up to M100, incl	593	760	585	15	50	. . .
B6X							
13 % chromium	up to M100, incl	593	620	485	16	50	26 HRC
B7							
Chromium-molybdenum	M64 and under	593	860	720	16	50	321 HB or 35 HRC
	over M64 to M100	593	795	655	16	50	321 HB or 35 HRC
	over M100 to M180	593	690	515	18	50	321 HB or 35 HRC
B7M[A]Chromium-molybdenum	M100 and under	620	690	550	18	50	235 HB or 99 HRB
	over M100 to M180	620	690	515	18	50	235 BHN or 99 HRB
B16							
Chromium-molybdenum-vanadium	M64 and under	650	860	725	18	50	321 HB or 35 HRC
	over M64 to M100	650	760	655	17	45	321 HB or 35 HRC
	over M100 to M180	650	690	586	16	45	321 HB or 35 HRC

Class Diameter, mm	Heat Treatment[B]	Tensile Strength, min, MPa	Yield Strength, min, 0.2 % offset, MPa	Elongation in 4 D, min %	Reduction of Area, min %	Hardness, max
	Austenitic Steels					
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, all diameters	carbide solution treated	515	205	30	50	223 HB[C] or 96 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated	515	205	30	50	223 HB[C] or 96HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA B8MLCuNA, all diameters	carbide solution treated in the finished condition	515	205	30	50	192 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, and B8MLCuN, all diameters	carbide solution treated	550	240	30	40	223 HB[C] or 96 HRB
Classes 1C and 1D: B8R, all diameters	carbide solution treated	690	380	35	55	271 HB or 28 HRC