



Designation: A193/A193M – 11a

Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications¹

This standard is issued under the fixed designation A193/A193M; 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 specification² covers alloy and stainless steel bolting for pressure vessels, valves, flanges, and fittings for high temperature or high pressure service, or other special purpose applications. See Specification [A962/A962M](#) for the definition of bolting. Bars and wire shall be hot-wrought and 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.

1.3 The following referenced general requirements are indispensable for application of this specification: Specification [A962/A962M](#).

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 suitable for use at the lower range of high temperature applications, reference should be made to Specification [A354](#).

NOTE 3—For grades of alloy-steel bolting suitable for use in low temperature applications, reference should be made to Specification [A320/A320M](#).

1.4 Nuts for use with bolting are covered in Section 14.

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-193 in Section II of that Code.

1.5 Supplementary Requirements are provided for use at the option of the purchaser. The supplementary requirements shall apply only when specified in the purchase order or contract.

1.6 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.

1.7 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

[A153/A153M](#) Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

[A194/A194M](#) Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

[A320/A320M](#) Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service

[A354](#) Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

[A788/A788M](#) Specification for Steel Forgings, General Requirements

[A962/A962M](#) Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range

[B633](#) Specification for Electrodeposited Coatings of Zinc on Iron and Steel

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.

- B695** Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
- B696** Specification for Coatings of Cadmium Mechanically Deposited
- B766** Specification for Electrodeposited Coatings of Cadmium
- E18** Test Methods for Rockwell Hardness of Metallic Materials
- E21** Test Methods for Elevated Temperature Tension Tests of Metallic Materials
- E112** Test Methods for Determining Average Grain Size
- E139** Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
- E150** Recommended Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times⁴
- E151** Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures with Rapid Heating and Conventional or Rapid Strain Rates⁴
- E292** Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials
- E328** Test Methods for Stress Relaxation for Materials and Structures
- E566** Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
- E709** Guide for Magnetic Particle Testing
- F606** Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets
- F1940** Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
- F1941** Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))
- F2329** Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners

2.2 ASME Standards:⁵

- 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 The inquiry and orders shall include the following, as required, to describe the desired material adequately:

⁴ Withdrawn. The last approved version of this historical standard is referenced on www.astm.org.

⁵ Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

⁶ Available from Automotive Industry Action Group (AIAG), 26200 Lahser Rd., Suite 200, Southfield, MI 48033, <http://www.aiag.org>.

3.1.1 Heat-treated condition (that is 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),

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

3.1.3 Nuts, if required by purchaser, in accordance with 14.1,

3.1.4 Supplementary requirements, if any, and

3.1.5 Special requirements, in accordance with 7.1.5.1, 7.2.6, 9.1, 14.1, and 15.1.

3.2 *Coatings*—Coatings are prohibited unless specified by the purchaser (See Supplementary Requirements S13 and S14). When coated fasteners are ordered the purchaser should take special care to ensure that **Appendix X2** is thoroughly understood.

4. Common Requirements

4.1 Bolting supplied to this specification shall conform to the requirements of Specification **A962/A962M**. These requirements include test methods, finish, thread dimensions, macroetch (alloy steels only), 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 this specification and Specification **A962/A962M**, this specification shall prevail.

5. Manufacture (Process)

5.1 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.

5.2 *Quality*—See Specification **A962/A962M** for requirements.

6. Discard

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

7. Heat Treatment

7.1 Ferritic Steels

7.1.1 Ferritic steels shall be allowed to cool to a temperature below the cooling transformation range immediately after rolling or forging. Materials shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a *quenching charge*), quenched in a liquid medium under substantially uniform conditions for each quenching charge, and tempered. The minimum tempering temperature shall be as specified in **Tables 2 and 3**.

TABLE 1 Chemical Requirements (Composition, percent)^A

Type	Ferritic Steels			
Grade	B5		B6 and B6X	
Description	5% Chromium		12 % Chromium	
UNS Designation	S41000 (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	S30400 (304)		S34700 (347)		S31600 (316)		S30500	
	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	...	...	...	...

Type	Austenitic Steels, ^F Classes 1A, 1B, 1D, and 2					
Grade	B8N, B8NA		B8MN, B8MNA		B8MLCuN, B8MLCuNA	
UNS Designation	S30451 (304N)		S31651 (316N)		S31254	
	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	0.020	0.005 over
Manganese, max	2.00	0.04 over	2.00	0.04 over	1.00	0.03 over
Phosphorus, max	0.045	0.010 over	0.045	0.010 over	0.030	0.005 over
Sulfur, max	0.030	0.005 over	0.030	0.005 over	0.010	0.002 over
Silicon, max	1.00	0.05 over	1.00	0.05 over	0.80	0.05 over
Chromium	18.0–20.0	0.20	16.0–18.0	0.20	19.5–20.5	0.20
Nickel	8.0–11.0	0.15	10.0–13.0	0.15	17.5–18.5	0.15
Molybdenum	...	...	2.00–3.00	0.10	6.0–6.5	0.10
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01	0.18–0.22	0.02
Copper	...	...	...	...	0.50–1.00	...

TABLE 1 *Continued*

Type	Austenitic Steels ^F , Classes 1, 1A, and 2			
Grade	B8T, B8TA			
UNS Designation	S32100 (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		
Chromium	17.0–19.0	0.20		
Nickel	9.0–12.0	0.15		
Titanium	5 x (C + N) min, 0.70 max	0.05 under		
Nitrogen	0.10 max	...		
Type	Austenitic Steels ^F , Classes 1C and 1D			
Grade	B8R, B8RA	B8S, B8SA		
UNS Designation	S20910	S21800		
	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	S30453	S31653		
	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 HBW or 35 HRC
	over 2½ to 4	1100	115	95	16	50	321 HBW or 35 HRC
	over 4 to 7	1100	100	75	18	50	321 HBW or 35 HRC
B7M ^A Chromium-molybdenum	4 and under	1150	100	80	18	50	235 HBW or 99 HRB
	over 4 to 7	1150	100	75	18	50	235 HBW or 99 HRB
B16 Chromium-molybdenum-vanadium	2½ and under	1200	125	105	18	50	321 HBW or 35 HRC
	over 2½ to 4	1200	110	95	17	45	321 HBW or 35 HRC
	over 4 to 8	1200	100	85	16	45	321 HBW 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 HBW or 96 HRB ^C
Class 1: B8C, B8T, all diameters	carbide solution treated	75	30	30	50	223 HBW or 96HRB ^C
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 HBW or 90 HRB ^A
Classes 1B and 1D: B8N, B8MN, B8MLCuN, all diameters	carbide solution treated	80	35	30	40	223 HBW or 96 HRB ^C
Classes 1C and 1D: B8R, all diameters	carbide solution treated	100	55	35	55	271 HBW or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	100	55	35	55	271 HBW or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	95	50	35	55	271 HBW or 28 HRC
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	95	50	35	55	271 HBW or 28 HRC
Class 2: B8, B8C, B8P, B8T, B8N, ^D ¾ and under	carbide solution treated and strain hardened	125	100	12	35	321 HBW or 35 HRC
over ¾ to 1, incl		115	80	15	35	321 HBW or 35 HRC
over 1 to 1¼, incl		105	65	20	35	321 HBW or 35 HRC
over 1¼ to 1½, incl		100	50	28	45	321 HBW or 35 HRC
Class 2: B8M, B8MN, B8MLCuN ^D ¾ and under	carbide solution treated and strain hardened	110	95	15	45	321 HBW 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 ¾ to 1 incl		100	80	20	45	321 HBW or 35 HRC
Over 1 to 1¼, incl		95	65	25	45	321 HBW or 35 HRC
over 1¼ to 1½, incl		90	50	30	45	321 HBW or 35 HRC
Class 2B: B8, B8M2 ^D 2 and under	carbide solution treated and strain hardened	95	75	25	40	321 HBW or 35 HRC
over 2 to 2½ incl		90	65	30	40	321 HBW or 35 HRC
over 2½ to 3 incl		80	55	30	40	321 HBW or 35 HRC
Class 2C: B8M3 ^D 2 and under	carbide solution treated and strain hardened	85	65	30	60	321 HBW or 35 HRC
over 2		85	60	30	60	321 HBW or 35 HRC

^A To meet the tensile requirements, the Brinell hardness shall be over 200 HBW (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 HBW (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 B6	up to M100, incl	593	690	550	16	50	...
13 % chromium B6X	up to M100, incl	593	760	585	15	50	...
13 % chromium B7	up to M100, incl	593	620	485	16	50	26 HRC
Chromium-molybdenum	M64 and under	593	860	720	16	50	321 HBW or 35 HRC
	over M64 to M100	593	795	655	16	50	321 HBW or 35 HRC
	over M100 to M180	593	690	515	18	50	321 HBW or 35 HRC
B7M ^A Chromium-molybdenum	M100 and under	620	690	550	18	50	235 HBW or 99 HRB
	over M100 to M180	620	690	515	18	50	235 HBW or 99 HRB
B16 Chromium-molybdenum-vanadium	M64 and under	650	860	725	18	50	321 HBW or 35 HRC
	over M64 to M100	650	760	655	17	45	321 HBW or 35 HRC
	over M100 to M180	650	690	585	16	45	321 HBW 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, carbide solution treated			515	205	30	50	223 HBW or 96 HRB ^C
B8MLN, all diameters							
Class 1: B8C, B8T, all diameters		carbide solution treated	515	205	30	50	223 HBW or 96HRB ^C