Designation: A193/A193M – 10a

Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications[1]

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 specification[2] 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.

1.5 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

[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.

[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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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 Times[4]
E151 Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures with Rapid Heating and Conventional or Rapid Strain Rates[4]
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:

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 treated 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.

[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.

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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	. . .

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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.

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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 or 96 HRB[C]
Class 1: B8C, B8T, all diameters	carbide solution treated	75	30	30	50	223 HB 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 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, B8MLCuN, all diameters	carbide solution treated	80	35	30	40	223 HB or 96 HRB[C]
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, 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		95	15	45	321 HB or 35 HRC
¾ and under						
over ¾ to 1 incl		0	80	20	45	321 HB or 35 HRC
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

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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 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	585	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 or 96 HRB[C]
Class 1: B8C, B8T, all diameters	carbide solution treated	515	205	30	50	223 HB or 96HRB[C]
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, B8MLCuN, all diameters	carbide solution treated		240	30	40	223 HB or 96 HRB[C]
Classes 1C and 1D: B8R, all diameters	carbide solution treated	690	380	35	55	271 HB or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	690	380	35	55	271 HB or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	655	345	35	55	271 HB or 28 HRC
Classes 1C: B8SA,	carbide solution treated in the finished	655	345	35	55	271 HB or 28 HRC

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TABLE 3 *Continued*

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				
all diameters	condition					
Class 2: B8, B8C, B8P, B8T, B8N,[D] M20 and under	carbide solution treated and strain hardened	860	690	12	35	321 HB or 35 HRC
over M20 to M24, incl		795	550	15	35	321 HB or 35 HRC
over M24 to M30, incl		725	450	20	35	321 HB or 35 HRC
over M30 to M36, incl		690	345	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN,[D] M20 and under	carbide solution treated and strain hardened	760	655	15	45	321 HB or 35 HRC
over M20 to M24, incl		690	550	20	45	321 HB or 35 HRC
over M24 to M30, incl		655	450	25	45	321 HB or 35 HRC
over M30 to M36, incl		620	345	30	45	321 HB or 35 HRC
Class 2B: B8, B8M2,[D] M48 and under	carbide solution treated and strain hardened	655	515	25	40	321 HB or 35 HRC
over M48 to M64, incl		620	450	30	40	321 HB or 35 HRC
over M64 to M72, incl		550	380	30	40	321 HB or 35 HRC
Class 2C: B8M3,[D] M48 and under	carbide solution treated and strain hardened	585	450	30	60	321 HB or 35 HRC
over M48		585	415	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 M20 mm in diameter

[C] For sizes M20 mm in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.

[D] For diameters M38 and over, center (core) properties may be lower than indicated by test reports which are based on values determined at ½ radius.

7.1.2 Use of water quenching is prohibited for any ferritic grade when heat treatment is performed after heading or threading.

7.1.3 Except as permitted below for B6X; material that is subsequently cold drawn for dimensional control shall be stress-relieved after cold drawing. The minimum stress-relief temperature shall be 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

7.1.4 B6 and B6X shall be held at the tempering temperature for a minimum time of 1 h. B6X material may be furnished in the as-rolled-and-tempered condition. Cold working after heat treatment is permitted for B6X material provided the final hardness meets the requirements of Tables 2 and 3.

7.1.5 B7 and B7M shall be heat treated by quenching in a liquid medium and tempering. For B7M fasteners, the final heat treatment, which may be the tempering operation if conducted at 1150 °F [620 °C] minimum, shall be done after all machining and forming operations, including thread rolling and any type of cutting. Surface preparation for hardness testing, nondestructive evaluation, or ultrasonic bolt tensioning is permitted.

7.1.5.1 Unless otherwise specified, material for Grade B7 may be heat treated by the Furnace, the Induction or the Electrical Resistance method.

NOTE 4—Stress-relaxation properties may vary from heat lot to heat lot or these properties may vary from one heat-treating method to another. The purchaser may specify Supplementary Requirement S8, when stress relaxation testing is desired.

7.1.6 Material Grade B16 shall be heated to a temperature range from 1700 to 1750 °F [925 to 955 °C] and oil quenched. The minimum tempering temperature shall be as specified in Tables 2 and 3.

7.2 *Austenitic Stainless Steels*

7.2.1 All austenitic stainless steels shall receive a carbide solution treatment (see 7.2.2-7.2.5 for specific requirements for each class). Classes 1, 1B, 1C (Grades B8R and B8S only), 2, 2B, and 2C can apply to bar, wire, and finished fasteners. Class 1A (all grades) and Class 1C (grades B8RA and B8SA only) can apply to finished fasteners. Class 1D applies only to bar and wire and finished fasteners that are machined directly from Class 1D bar or wire without any subsequent hot or cold working.

7.2.2 *Classes 1 and 1B, and Class 1C Grades B8R and B8S*—After rolling of the bar, forging, or heading, whether done hot or cold, the material shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

7.2.3 *Class 1D*—Rolled or forged Grades B8, B8M, B8P, B8LN, B8MLN, B8N, B8MN, B8R, and B8S bar shall be cool[illegible] rapidly immediately following hot working while the tem[illegible]ure is above 1750 °F [955 °C] so that grain boundary [illegible]des remain in solution. Class 1D shall be restricted to [illegible]plications at temperatures less than 850 °F [455 °C].

7.2.4 *Class 1A and Class 1C Grades B8RA and B8SA*—Finished fasteners shall be carbide solution treated after all

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rolling, forging, heading, and threading operations are complete. This designation does not apply to starting material such as bar. Fasteners shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

7.2.5 *Classes 2, 2B, and 2C*—Material shall be carbide solution treated by heating from ambient temperature and holding a sufficient time at a temperature at which the chromium carbide will go into solution and then cooling at a rate sufficient to prevent the precipitation of the carbide. Following this treatment the material shall then be strain hardened to achieve the required properties.

NOTE 5—Heat treatment following operations performed on a limited portion of the product, such as heading, may result in non-uniform grain size and mechanical properties through the section affected.

7.2.6 If a scale-free bright finish is required; this shall be specified in the purchase order.

8. Chemical Composition

8.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1.

8.2 The steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element. Furthermore, elements present in concentrations greater than 0.75 weight/% shall be reported.

9. Heat Analysis

9.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 8. The chemical composition thus determined shall be reported to the purchaser or the purchaser's representative, and shall conform to the requirements specified in Section 8. Should the purchaser deem it necessary to have the transition zone of two heats sequentially cast discarded, the purchaser shall invoke Supplementary Requirement S3 of Specification A788/A788M.

10. Mechanical Properties

10.1 *Tensile Properties*:

10.1.1 *Requirements*—The material as represented by the tension specimens shall conform to the requirements prescribed in Tables 2 and 3 at room temperature after heat treatment. Alternatively, stainless strain hardened fasteners (Class 2, 2B, and 2C) shall be tested full size after strain hardening to determine tensile strength and yield strength and shall conform to the requirements prescribed in Tables 2 and 3. Should the results of full size tests conflict with results of tension specimen tests, full size test results shall prevail.

10.1.2 *Full Size Fasteners, Wedge Tensile Testing*—When applicable, see 13.1.3, headed fasteners shall be wedge tested full size. The minimum full size load applied (lbf or kN) for individual sizes shall be as follows:

$$W = T_s \times A_t \quad (1)$$

where:

W = minimum wedge tensile load without fracture,

T_s = tensile strength specified in ksi or MPa in Tables 2 and 3, and

A_t = stress area of the thread section, square inches or square milimetres, as shown in the Cone Proof Load Tables in Specification A962/A962M.

10.2 *Hardness Requirements*:

10.2.1 The hardness shall conform to the requirements prescribed in Tables 2 and 3. Hardness testing shall be performed in accordance with either Specification A962/A962M or with Test Methods F606.

10.2.2 *Grade B7M*—The maximum hardness of the grade shall be 235 HB or 99 HRB. The minimum hardness shall not be less than 200 HB or 93 HRB. Conformance to this hardness shall be ensured by testing the hardness of each stud or bolt by Brinell or Rockwell B methods in accordance with 10.2.1. The use of 100 % electromagnetic testing for hardness as an alternative to 100 % indentation hardness testing is permissible when qualified by sampling using indentation hardness testing. Each lot tested for hardness electromagnetically shall be 100 % examined in accordance with Practice E566. Following electromagnetic testing for hardness a random sample of a minimum of 100 pieces of each heat of steel in each lot (as defined in 13.1.1) shall be tested by indentation hardness methods. All samples must meet hardness requirements to permit acceptance of the lot. If any one sample is outside of the specified maximum or minimum hardness, the lot shall be rejected and either reprocessed and resampled or tested 100 % by indentation hardness methods.

10.2.2.1 Surface preparation for indentation hardness testing shall be in accordance with Test Methods E18. Hardness tests shall be performed on the end of the bolt or stud. When this is impractical, the hardness test shall be performed elsewhere.

11. Workmanship, Finish, and Appearance

11.1 Bolts, screws, studs, and stud bolts shall be pointed and shall have a workmanlike finish. Points shall be flat and chamfered or rounded at option of the manufacturer. Length of point on studs and stud bolts shall be not less than one nor more than two complete threads as measured from the extreme end parallel to the axis. Length of studs and stud bolts shall be measured from first thread to first thread.

11.2 Bolt heads shall be in accordance with the dimensions of ASME B18.2.1 or ASME B18.2.3.1M. Unless otherwise specified in the purchase order, the Heavy Hex Screws Series should be used, except the maximum body diameter and radius of fillet may be the same as for the Heavy Hex Bolt Series. The body diameter and head fillet radius for sizes of Heavy Hex Cap Screws and Bolts that are not shown in their respective tables in ASME B18.2.1 or ASME B18.2.3.1M may be that shown in the corresponding Hex Cap Screw and Bolt Tables respectively. Socket head fasteners shall be in accordance with ASME B18.3 or ASME B18.3.1M.

12. Retests

12.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two

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additional tension tests shall be made from such lot, all of which shall conform to the requirements specified.

13. Test Specimens

13.1 *Number of Tests*—For heat-treated bars, one tension test shall be made for each diameter of each heat represented in each tempering charge. When heat treated without interruption in continuous furnaces, the material in a lot shall be the same heat, same prior condition, same size, and subjected to the same heat treatment. Not fewer than two tension tests are required for each lot containing 20 000 lb [9000 kg] or less. Every additional 10 000 lb [4500 kg] or fraction thereof requires one additional test.

13.1.1 For studs, bolts, screws, and so forth, one tension test shall be made for each diameter of each heat involved in the lot. Each lot shall consist of the following:

Diameter, in. [mm]	Lot Size
1⅛ [30] and under	1500 lb [780 kg] or fraction thereof
Over 1⅛ [30] to 1¾ [42], incl	4500 lb [2000 kg] or fraction thereof
Over 1¾ [42] to 2½ [64], incl	6000 lb [2700 kg] or fraction thereof
Over 2½ [64]	100 pieces or fraction thereof

13.1.2 Tension tests are not required to be made on bolts, screws, studs, or stud bolts that are fabricated from heat-treated bars furnished in accordance with the requirements of this specification and tested in accordance with 13.1, provided they are not given a subsequent heat treatment.

13.1.3 *Full Size Specimens, Headed Fasteners*—Headed fasteners 1½ in. in body diameter and smaller, with body length three times the diameter or longer, and that are produced by upsetting or forging (hot or cold) shall be subjected to full size testing in accordance with 10.1.2. This testing shall be in addition to tensile testing as specified in 10.1.1. The lot size shall be as shown in 13.1.1. Failure shall occur in the body or threaded section with no failure, or indications of failure, such as cracks, at the junction of the head and shank.

14. Nuts

14.1 Bolts, studs, and stud bolts shall be furnished with nuts, when specified in the purchase order. Nuts shall conform to Specification A194/A194M.

15. Rejection and Rehearing

15.1 Unless otherwise specified in the basis of purchase, any rejection based on product analysis shall be reported to the manufacturer within 30 days from the receipt of samples by the purchaser.

15.2 Material that shows defects subsequent to its acceptance at the place of manufacture shall be rejected, and the manufacturer shall be notified.

15.3 *Product Analysis*—Samples that represent rejected material shall be preserved for two weeks from the date of the test report. In the case of dissatisfaction with the results of the test, the manufacturer may make claim for a rehearing within that time.

16. Certification

16.1 The producer of the raw material or finished fasteners shall furnish a certification to the purchaser or his representative showing the results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), and mechanical tests, and state the method of heat treatment employed.

16.2 Certification shall also include at least the following:

16.2.1 A statement that the material or the fasteners, or both, were manufactured, sampled, tested, and inspected in accordance with the specification and any supplementary requirements or other requirements designated in the purchase order or contract and was found to meet those requirements.

16.2.2 The specification number, year date, and identification symbol.

17. Product Marking

17.1 See Specification A962/A962M. The marking symbol shall be as shown in Table 4 and Table 5. Grade B7M shall be 100 % evaluated in conformance with the specification and shall have a line under the marking symbol.

18. Keywords

18.1 alloy steel bars; alloy steel bolting; fasteners; hardness; heat treatment; stainless steel bolting

TABLE 4 Marking of Ferritic Steels

Grade	Marking Symbol
B5	B5
B6	B6
B6X	B6X
B7	B7
B7M	B7M
B16	B16
B16 + Supplement S12	B16R

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TABLE 5 Marking of Austenitic Steels

Class	Grade	Marking Symbol
Class 1	B8	B8
	B8C	B8C
	B8M	B8M
	B8P	B8P
	B8T	B8T
	B8LN	B8F or B8LN
	B8MLN	B8G or B8MLN
Class 1A	B8A	B8A
	B8CA	B8B or B8CA
	B8MA	B8D or B8MA
	B8PA	B8H or B8PA
	B8TA	B8J or B8TA
	B8LNA	B8L or B8LNA
	B8MLNA	B8K or B8MLNA
	B8NA	B8V or B8MA
	B8MNA	B8W or B8MNA
	B8MLCuNA	B9K or B8MLCuNA
Class 1B	B8N	B8N
	B8MN	B8Y or B8MN
	B8MLCuN	B9J or B8MLCuN
Class 1C	B8R	B9A or B8R
	B8RA	B9B or B8RA
	B8S	B9D or B8S
	B8SA	B9F or B8SA
Class 1D	B8	B94
	B8M	B95
	B8P	B96
	B8LN	B97
	B8MLN	B98
	B8N	B99
	B8MN	B100
	B8R	B101
	B8S	B102
Class 2	B8	B8SH
	B8C	B8CSH
	B8P	B8PSH
	B8T	B8TSH
	B8N	B8NSH
	B8M	B8MSH
	B8MN	B8YSH
	B8MLCuN	B0JSH
Class 2B	B8M2	B9G or B8M2
	B8	B9
Class 2C	B8M3	B9H or B8M3

SUPPLEMENTARY REQUIREMENTS

These requirements shall not apply unless specified in the order and in the Ordering Information, in which event the specified tests shall be made before shipment of the product.

S1. High Temperature Tests

S1.1 Tests to determine high temperature properties shall be made in accordance with Test Methods E21, E139, and E292, and Practices E150 and E151.

S2. Charpy Impact Tests

S2.1 Charpy impact tests based on the requirements of Specification A320/A320M, Sections 6 and 7, shall be made as agreed between the manufacturer and the purchaser. When testing temperatures are as low as those specified in Specification A320/A320M, bolting should be ordered to that specification in preference to this specification.

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S3. 100 % Hardness Testing of Grade B7M

S3.1 Each Grade B7M bolt or stud shall be tested for hardness by indentation method and shall meet the requirements specified in Tables 2 and 3.

S4. Hardness Testing of Grade B16

S4.1 For bolts or studs 2½ in. [65 mm] or smaller, the hardness for Grade B16 shall be measured on or near the end of each bolt or stud using one of the methods prescribed in 10.2.1 for the Brinell or Rockwell C test. The hardness shall be in the range 253–319 HB or 25–34 HRC.

S5. Product Marking

S5.1 Marking and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. (If the available area is inadequate, the marking symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts smaller than ¼ in. [6 mm] in diameter and studs smaller than ⅜ in. [10 mm] in diameter and for ¼ in. [6 mm] in diameter studs requiring more than a total of three symbols, the marking shall be a matter of agreement between the purchaser and the manufacturer.

S6. Stress Relieving

S6.1 A stress-relieving operation shall follow straightening after heat treatment.

S6.2 The minimum stress-relieving temperature shall be 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

S7. Magnetic Particle Inspection

S7.1 Bars shall be magnetic particle examined in accordance with Guide E709. Bars with indications of cracks or seams are subject to rejection if the indications extend more than 3 % of the diameter into the bar.

S8. Stress-Relaxation Testing

S8.1 Stress-Relaxation Testing, when required, shall be done in accordance with Test Methods E328. The test shall be performed at 850 °F [454 °C] for a period of 100 h. The initial stress shall be 50 M psi [345 MPa]. The residual stress at 100 h shall be 17 M psi [117 MPa] minimum.

S9. Grain Size Requirements for Non H Grade Austenitic Steels Used Above 1000 °F

S9.1 For design metal temperatures above 1000 °F [540 °C], the material shall have a grain size of No. 7 or coarser as determined in accordance with Test Methods E112. The grain size so determined shall be reported on the Certificate of Test.

S10. Hardness Testing of Class 2 Bolting for ASME Applications

S10.1 The maximum hardness shall be Rockwell C35 immediately under the thread roots. The hardness shall be taken on a flat area at least ⅛ in. [3 mm] across, prepared by removing threads, and no more material than necessary shall be removed to prepare the flat areas. Hardness determinations shall be made at the same frequency as tensile tests.

S11. Thread Forming

S11.1 Threads shall be formed after heat treatment. Application of this supplemental requirement to grade B7M or the grades listed in 7.2.4 is prohibited.

S12. Stress Rupture Testing of Grade B16

S12.1 One test shall be made for each heat treat lot. Testing shall be conducted using a combination test bar in accordance with Test Methods E292. Rupture shall occur in the smooth section of each test specimen. The test shall be conducted at 1100 °F [595 °C] and 20 ksi [140 MPa]. The test shall be continued until the sample ruptures. Rupture life shall be 25 h minimum. Testing is not required on material less than ½ in. [12 mm] thick.

S12.2 When a purchase order for fasteners invokes S12, the product marking supplied shall be "B16R."

S13. Coatings on Fasteners

S13.1 It is the purchaser's responsibility to specify in the purchase order all information required by the coating facility. Examples of such information may include but are not limited to the following:

S13.1.1 Reference to the appropriate coating specification and type, thickness, location, modification to dimensions, and hydrogen embrittlement relief.

S13.1.2 Reference to Specifications A153/A153M, B633, B695, B696, B766, or F1941, F2329, or Test Method F1940, or other standards.

S14. Marking Coated Fasteners

S14.1 Material coated with zinc shall have ZN marked after the grade symbol. Material coated with cadmium shall have CD marked after the grade symbol.

NOTE S14.1—As an example, the marking for zinc-coated B7 will now be B7ZN rather than B7*.

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APPENDIXES

(Nonmandatory Information)

X1. STRAIN HARDENING OF AUSTENITIC STEELS

X1.1 Strain hardening is the increase in strength and hardness that results from plastic deformation below the recrystallization temperature (cold work). This effect is produced in austenitic stainless steels by reducing oversized bars or wire to the desired final size by cold drawing or other process. The degree of strain hardening achievable in any alloy is limited by its strain hardening characteristics. In addition, the amount of strain hardening that can be produced is further limited by the variables of the process, such as the total amount of cross-section reduction, die angle, and bar size. In large diameter bars, for example, plastic deformation will occur principally in the outer regions of the bar so that the increased strength and hardness due to strain hardening is achieved predominantly near the surface of the bar. That is, the smaller the bar, the greater the penetration of strain hardening.

X1.2 Thus, the mechanical properties of a given strain hardened fastener are dependent not just on the alloy, but also on the size of bar from which it is machined. The minimum bar size that can be used, however, is established by the configuration of the fastener so that the configuration can affect the strength of the fastener.

X1.3 For example, a stud of a particular alloy and size may be machined from a smaller diameter bar than a bolt of the same alloy and size because a larger diameter bar is required to accommodate the head of the bolt. The stud, therefore, is likely to be stronger than the same size bolt in a given alloy.

X2. COATINGS AND APPLICATION LIMITS

X2.1 Use of coated fasteners at temperatures above approximately one-half the melting point (Fahrenheit or Celsius) of the coating is not recommended unless consideration is given to the potential for liquid and solid metal embrittlement, or both. The melting point of elemental zinc is approximately 780 °F [415 °C]. Therefore, application of zinc-coated fasteners should be limited to temperatures less than 390 °F [210 °C]. The melting point of cadmium is approximately 600 °F [320 °C]. Therefore, application of cadmium-coated fasteners should be limited to temperatures less than 300 °F [160 °C].

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A193/A193M–10, that may impact the use of this specification. (Approved May 15, 2010).

(*1*) Revised title and replaced “bolting materials” with “bolting.” Dropped definition for “bolting material” because it is in Specification A962/A962M. Updated Scope relative to supplementary requirements, use of SI units as per Guide A994, and added reference to Specification A962/A962M as indispensable for application of this specification. Dropped wording covering marking of B7M produced to prior revisions where an underline was not required. Dropped marking sections now covered by or being added to Specification A962/A962M.

Committee A01 has identified the location of selected changes to this specification since the last issue, A193/A193M–09, that may impact the use of this specification. (Approved May 1, 2010).

(*1*) Deleted the word “headed” from 10.1.1.

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Committee A01 has identified the location of selected changes to this specification since the last issue, A193/A193M–08b, that may impact the use of this specification. (Approved June 1, 2009).

(*1*) Changed marking of coated material from an asterisk (*) for zinc to "ZN" and from a plus (+) for cadmium to "CD" in Supplementary Requirement S14.1.

(*2*) Deleted terms "normalized and tempered" and "air quenched and tempered" in 3.1.1 and 7.1.1.

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