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Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications[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 or high pressure service, or other special purpose applications. 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~~14.

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 153/A 153M~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

A 194/A 194M~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

A 320/A 320M~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service

A 354~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

A 788/A 788M~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System~~

[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.**

~~Performance~~ Specification for Steel Forgings, General Requirements
A 962/A 962M~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range
B 633~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Specification for Electrodeposited Coatings of Zinc on Iron and Steel
B 695~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
B 696~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Specification for Coatings of Cadmium Mechanically Deposited
B 766~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Specification for Electrodeposited Coatings of Cadmium
E 18~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Test Methods for Rockwell Hardness of Metallic Materials
E 21~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Test Methods for Elevated Temperature Tension Tests of Metallic Materials
E 112~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Test Methods for Determining Average Grain Size
E 139~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
E 150~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Recommended Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times[4]
E 151~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures With Rapid Heating and Conventional or Rapid Strain Rates[4]
E 292~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials
E 328~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Test Methods for Stress Relaxation for Materials and Structures
E381~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
E 566~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
E 709~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Guide for Magnetic Particle Examination
E 606~~Practice for Applying Statistical Quality Assurance Techniques to Evaluate Analytical Measurement System Performance~~ Practice for Strain-Controlled Fatigue Testing

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~~

~~3.1Material supplied to this material specification shall conform to Specification A962/A962M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, etc.~~

~~3.2It 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 A962/A962M and the following:~~

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

~~3.2.1Heat-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),~~

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

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

3.1.2 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.~~2~~1.4 Supplementary requirements, if any, and

3.~~2~~1.5 Special requirements, in accordance with ~~6.3~~7.3, ~~6.5.1~~7.5.1, ~~10.2~~11.2, ~~14.1, and~~ 15.1, and 16.1.

~~3.3~~

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

~~3.4If the requirements of this specification are in conflict with the requirements of Specification A962/A962M the requirements of this specification shall prevail.~~

~~**4.Manufacture (Process)**~~

~~4.1The 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~~

4. Common Requirements

4.1 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 this specification and Specification A 962/A 962M, 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 A 962/A 962M for requirements.

~~**5.Discard**~~

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

6. Discard

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

7. Heat Treatment

6~~7~~.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.

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	. . .	. . .	. . .	. . .

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

TABLE 1 *Continued*

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] ¾ and under	carbide solution treated and strain hardened	125	100	12	35	321 HB or 35 HRC
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] ¾ and under	carbide solution treated and strain hardened	110	95	15	45	321 HB or 35 HRC
over ¾ to 1 incl		100	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] 2 and under	carbide solution treated and strain hardened	95	75	25	40	321 HB or 35 HRC