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Standard Specification for ~~Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service~~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 service. The term~~ *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 14.

1.4 Supplementary Requirements S1 through ~~S9~~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:*~~ *ASTM Standards:* [3]

A 153/A 153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

~~A29/A29M Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished~~

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

~~A194/A194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service~~

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

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~~[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel, and Related Alloys and is the direct responsibility of Subcommittee A01.22 on Valves, Fittings, Bolting, and Flanges for High and Subatmospheric Temperatures.~~

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[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* ~~, Vol 01.05.~~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.**

A320/A320M Specification for Alloy Steel Bolting Materials for Low-Temperature Service[4]
A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
A 788/A 788M Specification for Steel Forgings, General Requirements
A370Test Methods and Definitions for Mechanical Testing of Steel Products[4] 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
B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
B 696 Specification for Coatings of Cadmium Mechanically Deposited
B 766 Specification for Electrodeposited Coatings of Cadmium
A484/A484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings[6]
A751Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products[6]
A788Specification for Steel Forgings, General Requirements[3]
E 18Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
Test Methods for Rockwell Hardness of Metallic Materials
E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials
E 112Standard Test Methods for Determining the Average Grain Size[7]
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 Recommended Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times[4]
E 151 Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures withWith Rapid Heating and Conventional or Rapid Strain Rates[4]
E 292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials
E 328Methods for Stress-Relaxation Tests for Materials and Structures[7]
Test Methods for Stress Relaxation for Materials and Structures
E381Method of Macroetch Testing Steel Bars, Billets, Blooms and Forgings[7]
E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
E 709 Guide for Magnetic Particle Examination
FE 606Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets[5] Practice for Strain-Controlled Fatigue Testing
F 1940 Test Method for Process Control Verification to Prevent Hydrogen Embrittlement in Plated or Coated Fasteners
F 1941 Specification for Electrodeposited Coatings on Threaded Fasteners (Unified Inch Screw Threads (UN/UNR))
2.2 *ANSI Standards:*[5]
B1.1 Screw Threads B1.13M Metric Screw Threads
B18.2.1 Square and Hex Bolts and Screws
B18.2.3.1M Metric Hex Cap Screws
B18.3
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 order for material under this specification orders shall include the following, as required, to describe the desired material adequately:
3.1.1Specification, designation, year date, and grade,
3.1.2Heat-treated 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),
3.1.3Quantity (that is, number 3.1.2 Description of pieces or weight),

[4] Annual Book of ASTM Standards, Vol 01.01.
[4] Withdrawn.
[5] Annual Book of ASTM Standards, Vol 15.08.
[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.
[6] Annual Book of ASTM Standards, Vol 01.03.
[6] Available from Automotive Industry Action Group, 26200 Lahser, Suite 200, Southfield, MI 48034.

3.1.4Description of items required (that is, bars, bolts, screws, or studs),

3.1.5Dimensions (that is, diameter, length of point, overall length, finish, shape, and threads),

3.1.6Nuts, 3.1.3 Nuts, if required by purchaser, in accordance with 14.1,

3.1.7Supplementary requirements, if any, and

3.1.8Special requirements, in accordance with 6.3, 6.5.1, 11.3,

3.1.4 Supplementary requirements, if any, and

3.1.5 Special requirements, in accordance with 7.3, 7.5.1, 11.2, 15.1, , and 16.1, 18.1, and 17.1.

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 primary melting method may incorporate separate degassing or refining. The molten steel may be vacuum-treated prior to or during pouring of the ingot or strand casting. The basic-oxygen process shall be limited to steels containing not over 6% chromium.

4.2

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.

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*—To ensure soundness, ferritic steel bars and wire shall be tested in accordance with Method E381, or other suitable method as agreed upon between the purchaser and the producer. When bar or wire is supplied, the bar or wire producer shall perform the test. When fasteners are supplied, either the bar or wire producer or the fastener producer, as agreed upon between them, shall perform the test. Quality control procedures shall be sufficient to demonstrate that the testing was performed and that the results were acceptable. A bar lot consisting of one heat or 10 000 lbs, whichever is smaller, shall be represented by a minimum of one macroetch. Visual examination of transverse sections shall show no imperfections worse than the macrographs of Method E381 S4-R4-C4 or equivalent as agreed upon. Distinct zones of solidification shall not be present.

5.Discard

5.1A sufficient discard shall be made to secure freedom from injurious piping and undue segregation. —See Specification A 962/A 962M for requirements.

6. Discard

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

7. Heat Treatment

67.1 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. Material Grade B16 shall be heated to a temperature range from 1700 to 1750°F [925 to 954°C] and oil quenched. 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	
Description.	5% Chromium		12 % Chromium	
12 % Chromium UNS Designation		AISI Type 410	S41000 (410)	
	Range	Product Variation, Over or Under[B]	Range	Product Variation Over or Under[B]
Carbon	0.10 min	0.01 under	0.15 max	0.01 over
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
Chromium	4.0–6.0	0.10	11.5–13.5	0.15
Molybdenum	0.40-0.65	0.05	. . .	. . .
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
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
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
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
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
Molybdenum	0.15–0.25	0.02	0.50–0.65	0.03
Vanadium	. . .	. . .	0.25-0.35	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		B8C, B8CA		B8M, B8MA, B8M2, B8M3		B8P, B8PA
Description . . . . UNS Designation	AISI Type 304 S30400 (304)		AISI Type 347		AISI Type 316		AISI Type 305 with restricted carbon S34700 (347)		S31600 (316)S3
	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	1.01 over	0.08	0.01 over	0.12	0.01 over	
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	
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	
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	. . .	. . .	
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		B8MN, B8MNA	B8MLCuN, B8MLCuNA
DescriptionUNS Designation	AISI Type 304NS30451 (304N)		AISI Type 316N		Unstabilized, 20 Chromium, 18 Nickel, 6 Molybdenum with restricted carbon 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 19.5-20.5	0.20
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 17.5-18.5	0.15
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 6.0-6.5	0.10
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 0.18-0.22	0.02
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01	0.18–0.22	0.02
Copper	. . .	. . .	. . .	. . .	0.50-1.00 0.50-1.00	. . .
Copper	. . .	. . .	. . .	. . .	0.50–1.00	. . .

Type.	Austenitic Steels[F], Classes 1, 1A, and 2	
Grade	B8T, B8TA	
DescriptionUNS Designation	AISI Type 321 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
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
Titanium	5 x (C + N) min, 0.70 max[G]	0.05 under

Type	Austenitic Steels[F], Classes 1C and 1D			
Grade	B8R, B8RA		B8S, B8SA	
Description	22 Chromium-13 Nickel-5 Manganese		18 Chromium-8 Nickel-4 Silicon + Nitrogen UNS Designation	S20910S218(
	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
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
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
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
Nickel	11.5–13.5	0.15	8.0–9.0	0.10
Molybdenum	1.50-3.00	0.10	. . .	. . .
Molybdenum	1.50–3.00	0.10	. . .	. . .
Nitrogen	0.20-0.40	0.02	0.08-0.18	0.01
Nitrogen	0.20–0.40	0.02	0.08–0.18	0.01
Columbium + tantalum	0.10-0.30	0.05	. . .	. . .
Columbium + tantalum	0.10–0.30	0.05	. . .	. . .
Vanadium	0.10-0.30	0.02	. . .	. . .
Vanadium	0.10–0.30	0.02	. . .	. . .

Type	Austenitic Steels[F], Classes 1, 1A and 1D

Type	Austenitic Steels[F], Classes 1C and 1D			
Grade	B8R, B8RA		B8S, B8SA	
~~Description~~	~~22 Chromium-13 Nickel-5 Manganese~~		~~18 Chromium-8 Nickel-4 Silicon + Nitrogen~~ UNS Designation	S20910S21800
	Range	Product Variation, Over or Under[B]	Range	Product Variation, Over or Under[B]
Grade	B8LN, B8LNA		B8MLN, B8MLNA	
~~Description~~	~~AISI Type 304N with restricted carbon~~		~~AISI Type 316N with restricted carbon~~ UNS Designation	S30453S31653
	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~~
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~~
Nickel	8.0–11.0	0.15	10.0–13.0	0.15
~~Molybdenum~~	~~. . .~~	~~. . .~~	~~2.00-3.00~~	~~0.10~~
Molybdenum	. . .	. . .	2.00–3.00	0.10
~~Nitrogen~~	~~0.10-0.16~~	~~0.01~~	~~0.10-0.16~~	~~0.01~~
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.

[G] Nitrogen content is to be reported for this grade.