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Designation: A193/A193M – 20

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 U.S. Department of Defense.

1. Scope*

1.1 This specification[2] covers alloy and stainless steel bolting materials and bolting components 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 stainless 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 several 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 13.

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.

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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 Steel, Alloy Steel, and Stainless 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

[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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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
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 (Withdrawn 1984)[4]
E151 Recommended Practice for Tension Tests of Metallic Materials at Elevated Temperatures with Rapid Heating and Conventional or Rapid Strain Rates (Withdrawn 1984)[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/Magnetic Induction) Sorting of Ferrous Metals
E709 Guide for Magnetic Particle Testing
F606/F606M 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/F1941M Specification for Electrodeposited Coatings on Mechanical Fasteners, Inch and Metric
F2329/F2329M 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
B18.2.3.3M Metric Heavy Hex 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 bolting material or bolting components 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 bolting material that is 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 13.1,

3.1.4 Supplementary requirements, if any, and

3.1.5 Special requirements, in accordance with 6.1.5.1, 6.2.6, 8.1, and 13.1.

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

4. Common Requirements

4.1 Bolting materials and bolting components 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 *Melting*—See Specification A962/A962M for requirements.

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

6. Heat Treatment

6.1 *Ferritic Steels:*

6.1.1 Ferritic steels shall be allowed to cool to a temperature below the cooling transformation range immediately after rolling or forging. Bolting 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

[4] 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, Two 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.

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

Grade	Description and UNS Designation	Class	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Cooper	Niobium[F]	Titanium	Vanadium	Aluminum	Nitrogen
Ferritic Steels																
B5	5 % Chromium		0.10 min	1.00	0.040	0.030	1.00	4.0–6.0	. . .	0.40–0.65	. . .	. . .	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.01	0.03	0.005	0.005	0.05	0.10	. . .	0.05	. . .	. . .	. . .	. . .	. . .	. . .
B6, B6X	12 % Chromium (410), S41000		0.08–0.15	1.00	0.040	0.030	1.00	11.5–13.5	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.01 over	0.03	0.005	0.005	0.05	0.15	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
B7, B7M	Chromium-Molybdenum[C]		0.38–0.48[D]	0.75–1.00	0.035	0.040	0.15–0.35	0.80–1.10	. . .	0.15–0.25	. . .	. . .	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.02	0.04	0.005	0.005	0.02	0.05	. . .	0.02	. . .	. . .	. . .	. . .	. . .	. . .
B16	Chromium-Molybdenum-Vanadium		0.36–0.47	0.45–0.70	0.035	0.040	0.15–0.35	0.80–1.15	. . .	0.50–0.65	. . .	. . .	. . .	0.25–0.35	0.015[E]	. . .
Product Analysis Variation[B]			0.02	0.03	0.005	0.005	0.02	0.05	. . .	0.03	. . .	. . .	. . .	0.03	. . .	. . .
Austenitic Steels																
Grade	Description and UNS Designation	Classes	Carbon	Manganese	Phosphorous	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Copper	Niobium[F]	Titanium	Vanadium	Aluminum	Nitrogen
B8, B8A	304, S30400	1, 1A, 1D, 2	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	. . .	. . .	. . .	. . .	. . .	. . .	. . .
B8C, B8CA	347, S34700	1, 1A, 1D, 2	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	10 × C to 1.10	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	. . .	. . .	0.05 under	. . .	. . .	. . .	. . .
B8M, B8MA, B8M2, B8M3	316, S31600	1, 1A, 1D, 2	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	0.10	. . .	. . .	. . .	. . .	. . .	. . .

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TABLE 1 *Continued*

B8P, B8PA	S30500	1, 1A, 1D, 2	0.12	2.00	0.045	0.030	1.00	17.0–19.0	11.0–13.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	. . .	. . .	. . .	. . .	. . .	. . .	. . .
B8N, B8NA	304N, S30451	1A, 1B, 1D, 2	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	. . .	. . .	. . .	0.10–0.16
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	. . .	. . .	. . .	. . .	. . .	. . .	0.01
B8MN, B8MNA	316N, S31651	1A, 1B, 1D, 2	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	0.10–0.16
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	0.10	. . .	. . .	. . .	. . .	. . .	0.01
B8MLCuN, B8MLCuNA	S31254	1A, 1B, 1D, 2	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	6.0–6.5	0.50–1.00	. . .	. . .	. . .	. . .	0.18–0.25
Product Analysis Variation[B]			0.005	0.03	0.005	0.002	0.05	0.20	0.15	0.10	. . .	. . .	. . .	. . .	. . .	0.02
B8T, B8TA	321, S32100	1, 1A, 2	0.08	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	. . .	5 × (C + N) to 0.70	. . .	. . .	0.10
Product Analysis Variation[B]			0.01	0.04	0.010	0.005	0.05	0.20	0.15	. . .	. . .	. . .	0.05 under	. . .	. . .	. . .
B8R, B8RA	S20910	1C, 1D	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	1.50–3.00	. . .	0.10–0.30	. . .	0.10–0.30	. . .	0.20–0.40
Product Analysis Variation[B]			0.01	0.05	0.005	0.005	0.05	0.25	0.15	0.10	. . .	0.05	. . .	0.02	. . .	0.02
B8S, B8SA	S21800	1C, 1D	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	. . .	. . .	. . .	. . .	. . .	. . .	0.08–0.18
Product Analysis Variation[B]			0.01	0.06	0.005	0.005	0.15	0.20	0.10	. . .	. . .	. . .	. . .	. . .	. . .	0.01
B8LN, B8LNA	S30453	1, 1A, 1D	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	. . .	. . .	. . .	. . .	. . .	. . .	0.10–0.16
Product Analysis Variation[B]			0.005	0.04	0.010	0.005	0.05	0.20	0.15	. . .	. . .	. . .	. . .	. . .	. . .	0.01

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TABLE 1 *Continued*

B8MLN, B8MLNA	S31653	1, 1A, 1D	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–13.0	2.00–3.00	. . .	. . .	. . .	. . .	. . .	0.10–0.16
Product Analysis Variation[B]			0.005	0.04	0.010	0.005	0.05	0.20	0.15	0.10	. . .	. . .	. . .	. . .	. . .	0.01
B8CLN, B8CLNA	347LN, S34751	1, 1A, 1D	0.005–0.020	2.00	0.045	0.030	1.00	17.0–19.0	9.0–13.0	. . .	. . .	0.20–0.50; 15 × carbon content, min	. . .	. . .	. . .	0.06–0.10
Product Analysis Variation[B]			0.002 under, 0.005 over	0.04	0.01	0.005	0.05	0.20	0.15	. . .	. . .	0.05	. . .	. . .	. . .	0.01
B8CLNCuB B8CLNCuBA	S34752[G]	1,1A,1D	0.005-0.02	2.00	0.035	0.010	0.60	17.0-19.0	10.0-13.0	0.20-1.20	2.50-3.50	0.20–0.50; 15 × carbon content, min	. . .	. . .	. . .	0.06-0.12
Product Analysis Variation			0.002 under, 0.005 over	0.04	0.01	0.005	0.05	0.20	0.15		0.15	0.05	. . .	. . .	. . .	0.01
B8ML4CuN, B8ML4CuNA	S31730	1, 1A, 1D	0.030	2.00	0.040	0.010	1.00	17.0–19.0	15.0–16.5	3.0–4.0	4.0–5.0	. . .	. . .	. . .	. . .	0.045
Product Analysis Variation[B]			0.005	0.04	0.005	0.002	0.05	0.20	0.15	0.10	0.15	. . .	. . .	. . .	. . .	0.01

[A]Values are maximums unless a range or a minimum is indicated. Where ellipses appear in this table, there is no requirement and the element need not be determined or reported. The intentional addition of Bi, Se, Te, and Pb is not permitted.
[B]Product Analysis—Individual determinations sometimes vary from the specified limits 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. Product variation limits are over for maximums, over or under for ranges, and under for minimums, unless otherwise indicated.
[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 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]Columbium and Niobium are alternate names for element 41 in the Periodic Table of the Elements.
[G]For S34752 – Boron content shall be 0.001-0.005 for both heat and product analysis.

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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 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, B8CLN, all diameters	carbide solution treated	75	30	30	50	223 HBW or 96 HRB[C]
Classes 1 and 1D; B8, B8CLNCuB, all diameters	carbide solution treated	75	30	35	50	223 HBW or 96 HRB[C]
Classes 1 and 1D: B8ML4CuN, all diameters	carbide solution treated	70	25	35	50	90 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated	75	30	30	50	223 HBW or 96HRB[C]
Class 1A: B8A, B8CA, B8CLNA, 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
Class 1A: B8ML4CuNA, all diameters	carbide solution treated	70	25	35	50	90 HRB
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

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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 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
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	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 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 M200	650	690	585	16	45	321 HBW or 35 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				
Classes 1 and 1D; B8, B8M, B8P, B8LN, B8MLN, B8CLN, all diameters	carbide solution treated	515	205	30	50	223 HBW or 96 HRB[C]
Classes 1,1A,1D, B8CLNCuB, all diameters 1	carbide solution treated	515	205	30	50	223 HBW or 96 HRB[C]
Classes 1 and 1D: B8ML4CuN, all diameters	carbide solution treated	480	175	35	50	90 HRB
Class 1: B8C, B8T, all diameters	carbide solution treated	515	205	30	50	223 HBW or 96HRB[C]
Class 1A: B8A, B8CA, B8CLNA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA, B8MLCuNA, all diameters	carbide solution treated in the finished condition	515	205	30	50	192 HBW or 90 HRB
Class 1A: B8ML4CuNA, all diameters	carbide solution treated	480	175	35	50	90 HRB
Classes 1B and 1D: B8N, B8MN, B8MLCuN, all diameters	carbide solution treated	550	240	30	40	223 HBW or 96 HRB[C]
Classes 1C and 1D: B8R, all diameters	carbide solution treated	690	380	35	55	271 HBW or 28 HRC
Class 1C: B8RA, all diameters	carbide solution treated in the finished condition	690	380	35	55	271 HBW or 28 HRC
Classes 1C and 1D: B8S, all diameters	carbide solution treated	655	345	35	55	271 HBW or 28 HRC
Classes 1C: B8SA, all diameters	carbide solution treated in the finished condition	655	345	35	55	271 HBW or 28 HRC
Class 2: B8, B8C, B8P, B8T, B8N,[D] M20 and under	carbide solution treated and strain hardened	860	690	12	35	321 HBW or 35 HRC
over M20 to M24, incl		795	550	15	35	321 HBW or 35 HRC
over M24 to M30, incl		725	450	20	35	321 HBW or 35 HRC
over M30 to M36, incl		690	345	28	45	321 HBW or 35 HRC
Class 2: B8M, B8MN, B8MLCuN,[D] M20 and under	carbide solution treated and strain hardened	760	655	15	45	321 HBW or 35 HRC
over M20 to M24, incl		690	550	20	45	321 HBW or 35 HRC
over M24 to M30, incl		655	450	25	45	321 HBW or 35 HRC
over M30 to M36, incl		620	345	30	45	321 HBW or 35 HRC
Class 2B: B8, B8M2,[D] M48 and under	carbide solution treated and strain hardened	655	515	25	40	321 HBW or 35 HRC
over M48 to M64, incl		620	450	30	40	321 HBW or 35 HRC
over M64 to M72, incl		550	380	30	40	321 HBW or 35 HRC
Class 2C: B8M3,[D] M48 and under	carbide solution treated and strain hardened	585	450	30	60	321 HBW or 35 HRC
over M48		585	415	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 M20 mm in diameter.
[C] For sizes M20 mm in diameter and smaller, a maximum hardness of 241 HBW (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.

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

6.1.3 Except as permitted below for B6X; bolting material that is subsequently cold drawn for dimensional control shall be stress-relieved after cold drawing. The minimum stress-relief temperature shall be within not more than 100 °F [55 °C] below the tempering temperature. Tests for mechanical properties shall be performed after stress relieving.

6.1.4 B6 and B6X shall be held at the tempering temperature for a minimum time of 1 h. B6X bolting 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.

6.1.5 B7 and B7M shall be heat treated by quenching in a liquid medium and tempering. For B7M bolting components, such as bolts, studs, or screws, 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.

6.1.5.1 Unless otherwise specified, bolting 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.

6.1.6 Bolting 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.

6.2 *Austenitic Stainless Steels:*

6.2.1 All austenitic stainless steels shall receive a carbide solution treatment (see 6.2.2 – 6.2.5 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 bolting components. Class 1A (all grades) and Class 1C (grades B8RA and B8SA only) can apply to finished bolting components. Class 1D applies only to bar and wire and finished bolting components that are machined directly from Class 1D bar or wire without any subsequent hot or cold working.

6.2.2 *Classes 1 and 1B, and Class 1C Grades B8R and B8S*—After rolling of the bar, forging, or heading, whether done hot or cold, bolting 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.

6.2.3 *Class 1D*—Rolled or forged Grades B8, B8M, B8P, B8LN, B8MLN, B8CLNCuB, B8N, B8MN, B8R, and B8S bar shall be cooled rapidly immediately following hot working while the temperature is above 1750 °F [955 °C] so that grain boundary carbides remain in solution. Class 1D shall be restricted to applications at temperatures less than 850 °F [455 °C].

6.2.4 *Class 1A and Class 1C Grades B8RA and B8SA*—Finished bolting components shall be carbide solution treated after all rolling, forging, heading, and threading operations are complete. This designation does not apply to starting material such as bar. Components 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.

6.2.5 *Classes 2, 2B, and 2C*—Bolting 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 bolting 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.

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

7. Chemical Composition

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

8. Heat Analysis

8.1 An analysis of each heat of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 7. 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 7. 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.

9. Mechanical Properties

9.1 *Tensile Properties:*

9.1.1 *Requirements*—Bolting material as represented by the tension specimens shall conform to the requirements prescribed in Tables 2 and 3 at room temperature after heat treatment. Stainless strain hardened bolting components (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. In cases where tensile testing equipment of sufficient capacity is not available, stainless strain hardened bolting components greater than 1.500 in. diameter may be tested using machined specimen. Should the results of full size tests conflict with results of tension specimen tests, full size test results shall prevail.

9.1.2 *Full Size Bolting Components, Wedge Tensile Testing*—When applicable, see 12.1.3, headed components 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 millimetres, as shown in the Cone Proof Load Tables in Specification A962/A962M.

9.2 *Hardness Requirements:*

9.2.1 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/F606M.

9.2.2 *Grade B7M*—The maximum hardness of the grade shall be 235 HBW or 99 HRB. The minimum hardness shall not be less than 200 HBW 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 9.2.1. 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 12.1.1) 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.

9.2.2.1 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.

10. Workmanship, Finish, and Appearance

10.1 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.

10.2 Unless otherwise specified in the purchase order, bolt heads shall be in accordance with the dimensions of ASME B18.2.1 or ASME B18.2.3.3M. Unless otherwise specified in the purchase order, the Heavy Hex Screws Series should be used for nominal body diameters of 1¼ in. [30 mm] and less. For larger sizes, the Heavy Hex Screw 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 B18.2.3.3M may be that shown in the corresponding Hex Cap Screw and Bolt Tables respectively. Socket head screws or bolts shall be in accordance with ASME B18.3 or ASME B18.3.1M.

11. Retests

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

12. Test Specimens

12.1 *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.

12.1.1 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 [680 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

12.1.2 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 12.1, provided they are not given a subsequent heat treatment.

12.1.3 *Full Size Specimens, Headed Bolting Components*—Headed bolts or screws 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 9.1.2. This testing shall be in addition to tensile testing as specified in 9.1.1. Wedge tensile testing shall be limited to product with socket head cap screw, hexagon, square, hex flange, or twelve point flange heads. The lot size shall be as shown in 12.1.1. 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. Wedge tensile testing is not required for flat countersunk head or socket button products.

13. Nuts

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

14. Certification

14.1 Certification is required. In addition to the requirements of Specification A962/A962M the report shall include results of the chemical analysis, macroetch examination (Carbon and Alloy Steels Only), and mechanical tests, and state the method of heat treatment employed.

TABLE 4 Marking of Ferritic Steels

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

15. Product Marking

15.1 See Specification A962/A962M. The grade symbol shall be as shown in Table 4 and Table 5. Grade B7M no longer requires a line under the grade symbol. However, a line is permitted.

16. Keywords

16.1 alloy steel bars; alloy steel bolting; bolting components; bolting materials; hardness; heat treatment; stainless steel bolting

TABLE 5 Marking of Austenitic Steels

Class	Grade	Grade Symbol
Class 1	B8	B8
	B8C	B8C
	B8M	B8M
	B8P	B8P
	B8T	B8T
	B8LN	B8F or B8LN
	B8MLN	B8G or B8MLN
	B8CLN	B8Y or B8CLN
	B8CLNCuB	B8CLNCuB
	B8ML4CuN	B8YY or B8ML4CuN
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
	B8CLNA	B8Z or B8CLNA
	B8CLNCuBA	B8ZA or B8CLNCuBA
	B8ML4CuNA	B8ZZ 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
	B8CLN	B103
	B8ML4CuN	B104
	B8CLNCuB	B105
Class 2	B8	B8SH
	B8C	B8CSH
	B8P	B8PSH
	B8T	B8TSH
	B8N	B8NSH
	B8M	B8MSH
	B8MN	B8YSH
	B8MLCuN	B8JSH
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.

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 9.2.1 for the Brinell or Rockwell C test. The hardness shall be in the range 253–319 HBW or 25–34 HRC.

S5. Product Marking

S5.1 Grade and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts and screws of all sizes. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts and screws 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 6.2.4 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 bolting components invokes S12, the grade symbol applied shall be "B16R."

S13. Coatings on Bolting Components

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/F1941M, F2329/F2329M, or Test Method F1940, or other standards.

S14. Marking Coated Bolting Components

S14.1 Bolting components coated with zinc shall have ZN marked after the grade symbol. Bolting components 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*.

S15. Requirements for Service Temperature Exceeding 1000°F

S15.1 For bolting of Class 1 Grades B8, B8C, B8M, and B8T, to be used in service at temperatures exceeding 1000°F, the following shall apply:

S15.1.1 The minimum carbon content shall be 0.04 %.

S15.1.2 Carbide solution treatment shall be between 1900°F and 1950°F followed by quenching in water or rapid cooling by other means.

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 bolting component 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 component so that the configuration can affect the strength of the componoent.

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 bolting components 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 bolting components 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 bolting components should be limited to temperatures less than 300 °F [160 °C].

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SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this specification since the last issue, A193/A193M – 19, that may impact the use of this specification. (Approved May 15, 2020.)

(1) Revised Table 1 to add alloy S34752.
(2) Added same alloy to Table 2.
(3) Added same alloy to Table 3.
(4) Added B8MLNCuB to 6.2.3.
(5) Added same alloy to Table 5.

Committee A01 has identified the location of selected changes to this specification since the last issue, A193/A193M – 17, that may impact the use of this specification. (Approved Nov. 1, 2019.)

(1) Revised 9.1.1 to allow for machined specimen testing for bolting greater than 1.500 in. in diameter.

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