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Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service¹

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 specification has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification² covers alloy and stainless steel bolting material for pressure vessels, valves, flanges, and fittings for high-temperature service. 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 solution-annealed or annealed and strain-hardened.

1.2 Several grades are covered, including ferritic steels and austenitic stainless steels designated B5, B8, etc. 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 S7 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:

- A 29/A 29M Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished³
- A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service⁴
- A 320/A 320M Specification for Alloy Steel Bolting Materials for Low-Temperature Service⁴
- A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners^{4,5}
- A 370 Test Methods and Definitions for Mechanical Testing of Steel Products^{4,6}
- A 484/484 M Specification for General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings³
- A 788 Specification for Steel Forgings, General Requirements³
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials⁷
- E 21 Practice for Elevated Temperature Tension Tests of Metallic Materials⁷
- E 139 Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials⁷
- E 150 Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times⁸
- E 151 Practice for Tension Tests of Metallic Materials at Elevated Temperatures with Rapid Heating and Conventional or Rapid Strain Rates⁸
- E 292 Practice for Conducting Time-for-Rupture Notch Tension Tests of Materials⁷
- E 328 Practice for Stress-Relaxation Tests for Materials and Structures⁷
- E 381 Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms and Forgings⁷

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 and Fittings.

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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 Annual Book of ASTM Standards, Vol 01.05.

⁴ Annual Book of ASTM Standards, Vol 01.01.

⁵ Annual Book of ASTM Standards, Vol 15.08.

⁶ Annual Book of ASTM Standards, Vol 01.03.

⁷ Annual Book of ASTM Standards, Vol 03.01.

⁸ Discontinued, see 1983 Annual Book of ASTM Standards, Vol 03.01.

- E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals⁹
- E 709 Practice for Magnetic Particle Examination⁹
- F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets¹⁰
- 2.2 *ANSI Standards*:¹¹
 - B1.1 Screw Threads
 - B18.2.1 Square and Hex Bolts and Screws
 - B18.3 Hexagon Socket and Spline Socket Screws

3. Ordering Information

3.1 The inquiry and order for material under this specification shall include the following as required to describe the material adequately:

- 3.1.1 ASTM Specification designation and grade, issue date and revision letter, and analysis by grade as selected from Table 1.
- 3.1.2 Heat-treated condition (that is, normalized and tempered, or quenched and tempered, for the ferritic materials, and solution treated (Class 1), solution treated after finishing (Class 1A), and annealed-and-strain-hardened (Class 2), for the austenitic stainless steels; Classes 1B and 1C apply to the solution-treated nitrogen-bearing stainless steels),
- 3.1.3 Quantity (that is, number of pieces or weight),
- 3.1.4 Description of items required (that is, bars, bolts, screws, or studs),
- 3.1.5 Dimensions (that is, diameter, length of point, overall length, finish, shape, and threads),
- 3.1.6 Nuts, if required by purchaser, in accordance with 14.1,
- 3.1.7 Supplementary requirements, if any, and
- 3.1.8 Special requirements, in accordance with 6.3, 6.6, 13.3, 15.1, 16.1, 17.1, and 18.1.

4. Manufacture (Process)

4.1 The 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 *Quality*—The producer quality control procedures shall provide sufficient testing of Carbon and Alloy Steels in accordance with Method E 381 as stipulated in Sections 5, 7, and 8 or other suitable method as agreed upon between the purchaser and the producer to assure the internal quality of the product. 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 E 381 S4-R4-C4 or equivalent as agreed upon. Distinct zones of solidification shall not be present.

5. Discard

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

6. Heat Treatment

6.1 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. 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.

6.1.1 Quenched and tempered or normalized and tempered ferritic 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.

6.2 Both B6 and B6X materials shall be held, at the tempering temperature for a minimum time of 1 h. Identification Symbol B6X material may be furnished in the as-rolled-and-tempered condition. Cold working is permitted with the hardness limitation (26 HRC maximum) of Table 2 for the B6X grade.

6.3 Austenitic stainless steels shall receive a carbide solution treatment. After rolling or forging and cooling to ambient temperature, the material shall be reheated and held a sufficient time at a temperature at which the chromium carbide will go into solution and shall then be cooled at a rate sufficient to prevent the precipitation of the carbide. Material thus treated is described as Class 1, Class 1B, or Class 1C. If specified in the purchase order, material shall be solution treated in the finished condition; material so treated is described as Class 1A.

6.4 If scale-free bright finish is required, this shall be specified in the purchase order.

6.5 When increased mechanical properties are desired, the austenitic bolting materials shall be solution annealed and strain hardened if specified in the purchase order; material so treated is identified as Class 2.

6.6 B7 and B7M bolting shall be heat treated by quenching in a liquid medium and tempering. For B7M bolting, 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, are complete.

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

⁹ *Annual Book of ASTM Standards*, Vol 03.03.

¹⁰ *Annual Book of ASTM Standards*, Vol 15.08.

¹¹ Available from American National Standards Institute, 1430 Broadway, New York, NY 10018.

TABLE 1 Chemical Requirements (Composition, percent)^A

Type	Ferritic Steels					
Identification	B5		B6 and B6X			
Symbol						
Grade	5 % Chromium (AISI Type 501)		12 % Chromium (AISI Type 410)			
			AISI Type 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		
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	0.03	0.005 over		
Silicon	1.00 max	0.05 over	1.00 max	0.05 over		
Chromium	4.00–6.00	0.10	11.50–13.50	0.15		
Molybdenum	0.40–0.65	0.05	...	...		
Type	Ferritic Steels					
Identification	B7, B7M		B16			
Symbol						
Grade	Chromium-Molybdenum (AISI 4140, 4142, 4145, 4140 H, 4142 H, and 4145 H)		Chromium-Molybdenum-Vanadium			
	Range	Product Variation, Over or Under ^B	Range	Product Variation, Over or Under ^B		
Carbon	0.37–0.49 ^C	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		
Type	Austenitic Steels, ^D Classes 1, 1A, and 2					
Identification	B8, B8A		B8C, B8CA		B8M, B8MA B8M2, B8M3	
Symbol						
Grade	Unstabilized 18 Chromium-8 Nickel (AISI Type 304)		Stabilized 18 Chromium-8 Nickel (AISI Type 347)		18 Chromium-10 Nickel-2 Molybdenum (AISI Type 316)	
	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
Manganese, max	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
Sulfur, max	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
Chromium	18.00–20.00	0.20	17.00–19.00	0.20	16.00–18.00	0.20
Nickel	8.00–10.50	0.15	9.00–13.00	0.15	10.00–14.00	0.15
Molybdenum	...	...	...	...	2.00–3.00	0.10
Columbium + tantalum	...	...	10 × carbon content, min	0.05 under	...	...
Type	Austenitic Steels, ^D Classes 1, 1A, 1B, and 2					
Identification	B8N, B8NA		B8MN, B8MNA		B8P, B8PA	
Symbol						
Grade	(AISI Type 304N)		(AISI Type 316N)		Unstabilized 18 Chromium-8 Nickel (AISI Type 305 with restricted carbon)	
	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
Manganese, max	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
Sulfur, max	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
Chromium	18.00–20.00	0.20	16.00–18.00	0.20	17.00–19.00	0.20
Nickel	8.00–10.50	0.15	10.00–14.00	0.15	10.50–13.00	0.15
Molybdenum	...	...	2.00–3.00	0.10	...	...
Nitrogen	0.10–0.16	0.01	0.10–0.16	0.01	...	...

(Continued)