SPECIFICATION FOR ALLOY-STEEL AND STAINLESS STEEL BOLTING MATERIALS FOR HIGH-TEMPERATURE SERVICE

SA-193/SA-193M

(Identical with ASTM Specification A 193/A 193M-98a except for differences in 3.1.1, 19.4, and Note 6 of Table 1, and editorial differences in Table 2.)

1. Scope

1.1 This specification 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 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, 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 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 S8 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.

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-Finished

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

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

A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 479/A 479M Specification for Stainless and Heat-Resisting Bars and Shapes for Use in Boilers and Other Pressure Vessels

A 484/484M Specification for General Requirements for Stainless and Heat-Resisting Bars, Billets, and Forgings

A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

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A 788 Specification for Steel Forgings, General Requirements
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E 21 Practice for Elevated Temperature Tension Tests of Metallic Materials
E 139 Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
E 150 Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of Rapid Heating and Short Times
E 151 Practice for Tension Tests of Metallic Materials at Elevated Temperatures with Rapid Heating and Conventional or Rapid Strain Rates
E 292 Practice for Conducting Time-for-Rupture Notch Tension Tests of Materials
E 328 Methods for Stress-Relaxation Tests for Materials and Structures
E 381 Method of Macroetch Testing Products, Inspection, and Rating Comprising Steel Bars, Billets, Blooms and Forgings
E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals
E 709 Guide for Magnetic Particle Examination
F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

2.2 *ANSI Standards:*
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 Hexagon Socket and Spline Socket Screws
B18.3.1M Metric Socket Head Cap Screws

2.3 *AIAG Standard:*
AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

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 Specification, designation, year date, and grade.

3.1.2 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),

3.1.3 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, 11.3, 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* — To ensure soundness, ferritic steel bars and wire shall be tested in accordance with Method E 381, 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 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.

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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. 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 of 1700°F to 1750°F [925°C 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.

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 All austenitic stainless steels shall receive a carbide solution treatment (see 6.3.1, 6.3.4 for specific requirements for each class). Classes 1, 1B, 1C (Grades B8R and B8S only), 2, 2B, and 2C can apply to bar, wire, and finished fasteners. Class 1A (all grades) and Class 1C (Grades B8RA and B8SA only) can apply to finished fasteners. Class 1D applies only to bar and wire and finished fasteners that are machined directly from Class 1D bar or wire without any subsequent hot or cold working.

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

6.3.2 *Class 1D* — Rolled or forged Grades B8, B8M, B8P, B8LN, B8MLN, 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 are in solution (see A 479-88b and subsequent revisions). Class 1D shall be restricted to applications at temperatures less than 850°F [455°C].

6.3.3 *Class 1A and Class 1C Grades B8RA and B8SA* — Finished fasteners 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. Fasteners shall be heated from ambient temperature and held a sufficient time at a temperature at which the chromium carbide will go into solution and then shall be cooled at a rate sufficient to prevent the precipitation of the carbide.

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

NOTE 4 — 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.

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

6.5 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.

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

NOTE 5 — It should be taken into consideration that stress-relaxation properties may vary from heat lot to heat lot or these properties

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may vary from one heat treating method to another. The purchaser may specify Requirement S8, if stress-relaxation testing is desired.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 1. Steels with added lead shall not be used.

7.2 The steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element. Furthermore, elements present in concentrations greater than 0.75 weight/% shall be reported. Chemical analysis shall be performed in accordance with Test Methods A 751.

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. This analysis shall be made from a test specimen taken during the pouring of the heat. 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. For strand cast materials, the requirements of 8.2 and 8.3 of Specification A 788 shall be met. 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 A 788.

9. Product Analysis

9.1 An analysis may be made by the purchaser from samples representing the bolting material. The chemical composition thus determined shall conform to the requirements of Section 7.

10. Mechanical Properties

10.1 *Tensile Properties;*

10.1.1 *Requirements* — The material as represented by the tension specimens shall conform to the requirements prescribed in Table 2 at room temperature after heat treatment.

10.1.2 *Method of Test* — Tension test shall be made in accordance with Test Methods and Definitions A 370, including the parts of Annex A3 "Steel Fasteners" applicable to machined test specimens. The speed of testing shall not exceed the limits specified in 7.4.1 of Test Methods and Definitions A 370. The yield strength corresponding to a limiting permanent offset of 0.2% of the gage length of the specimen shall be determined.

10.1.3 *Full Size Fasteners, Wedge Tensile Testing* — When applicable, see 13.1.4, headed fasteners shall be wedge tested full size in accordance with Annex A3 of A 370 and shall conform to the tensile strength shown in Table 2. The minimum full size breaking strength (lbf) for individual sizes shall be as follows:

$$Ts = UTS \times As \quad (1)$$

where:

Ts = wedge tensile strength
UTS = tensile strength specified in Table 2, and
As = stress area, square inches, as shown in ANSI B1.1 or calculated as follows:

$$As = 0.785\,(D - (0.974/n))^2 \quad (2)$$

where:

D = nominal thread size, and
n = the number of threads per inch

10.2 *Hardness Requirements:*

10.2.1 The hardness shall conform to the requirements prescribed in Table 2. Hardness testing shall be performed in accordance with either Test Methods and Definitions A 370 or with Test Methods F 606. In the event a controversy exists relative to minimum strength, tension tests shall prevail over hardness readings.

10.2.2 *Grade B7M* — The maximum hardness of the grade shall be 235 HB or 99 HRB (conversion in accordance with Table 2B of Test Methods and Definitions A 370). The minimum hardness shall not be less than 200 HB or 93 HRB. Conformance to this hardness shall be insured by testing the hardness of each stud or bolt by Brinell or Rockwell B methods in accordance with 10.2.1. The use of 100% electromagnetic testing for hardness as an alternative to 100% indentation hardness testing is permissible when qualified by sampling using indentation hardness testing. Each lot tested for hardness electromagnetically shall be 100% examined in accordance with Practice E 566. Following electromagnetic testing for hardness a random sample of a minimum of 100 pieces of each heat of steel in each lot (as defined in 13.1.2) shall be tested by indentation hardness methods. All samples must meet hardness requirements to permit acceptance of the lot.

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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. Product which has been 100% tested and found acceptable shall have a line under the grade symbol.

10.2.2.1 Surface preparation for indentation hardness testing shall be in accordance with Test Methods E 18. Hardness tests shall be performed on the end of the bolt or stud. When this is impractical, the hardness test shall be performed elsewhere.

11. Workmanship, Finish, and Appearance

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

11.2 Standard permissible variations for dimensions of bars shall be as prescribed in Specification A 29/A 29M and Specification A 484/A 484M, latest revisions.

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

12. Retests

12.1 If the results of the mechanical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot not more than twice, in which case two additional tension tests shall be made from such lot, all of which shall conform to the requirements specified.

13. Test Specimens

13.1 Tension test specimens taken from finished bolts, screws, studs, or stud bolts shall be machined to the form and dimensions and shall be taken from positions shown in A3.2.1.7 of Test Methods and Definitions A 370. Tension test specimens from bar stock are covered by Annex A1.3 of Test Methods and Definitions A 370, Annex A1.

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

13.1.2 For studs, bolts, screws, etc., 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
$1\frac{1}{8}$ [30] and under	1500 lb [780 kg] or fraction thereof
Over $1\frac{1}{8}$ [30] to $1\frac{3}{4}$ [42], incl	4500 lb [2000 kg] or fraction thereof
Over $1\frac{3}{4}$ [42] to $2\frac{1}{2}$ [64], incl	6000 lb [2700 kg] or fraction thereof
Over $2\frac{1}{2}$ [64]	100 pieces or fraction thereof

13.1.3 Tension tests are not required to be made on bolts, screws, studs, or stud bolts that are fabricated from heat-treated bars furnished in accordance with the requirements of this specification and tested in accordance with 13.1.1, provided they are not given a subsequent heat treatment.

13.1.4 *Full Size Specimens, Headed Fasteners* — Headed fasteners $1\frac{1}{2}$ in. in body diameter and smaller, with body length three times the diameter or longer, and which are produced by upsetting or forging (hot or cold) shall be subjected to full size testing in accordance with 10.1.3. This testing shall be in addition to tensile testing as specified in 10.1.1 and 10.1.2. The lot size shall be as shown in 13.1.2. 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.

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14. Nuts

14.1 Bolts, studs, and stud bolts shall be furnished with nuts, when specified in the purchase order. Nuts shall conform to Specification A 194/A 194M.

15. Threads

15.1 When inch series product is ordered, all bolts, studs, stud bolts, and accompanying nuts, unless otherwise specified in the purchase order shall be threaded in accordance with ANSI B1.1 Class 2A fit, sizes 1 in. and smaller in diameter with the coarse-thread series, and $1\frac{1}{8}$ in. and larger in diameter with the 8-pitch-thread series. When metric product is ordered, threads shall be metric coarse thread series as specified in ANSI B1.13M, and shall have Grade 6G tolerances.

15.2 Where practical, all threads shall be formed after heat treatment. Class 1A, Grades B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA, and B8MLCuNA, and Class 1C Grades B8RA and B8SA are to be solution treated in the finished condition.

16. Inspection

16.1 The inspector representing the purchaser shall have entry, at all time while work on the contract of the purchaser is being performed, to all parts of the place of manufacture that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified in the purchase order and shall be so conducted as not to interfere unnecessarily with the operation of the works.

17. Rejection and Rehearing

17.1 Unless otherwise specified in the basis of purchase, any rejection based on tests made in accordance with Section 9 shall be reported to the manufacturer within 30 days from the receipt of samples by the purchaser.

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

17.3 Samples tested in accordance with Section 9 that represent rejected material shall be preserved for 2 weeks from the date of the test report. In the case of dissatisfaction with the results of the test, the manufacturer may make claim for a rehearing within that time.

18. Certification

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

18.2 Certification shall also include at least the following:

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

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

19. Product Marking

19.1 Grade/class and manufacturer's identification symbols shall be applied to one end of studs $\frac{3}{8}$ in. [10 mm] in diameter and larger and to the heads of bolts $\frac{1}{4}$ in. [6 mm] in diameter and larger. (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.) The identification symbol shall be as shown in Table 4 and 5. Grade B7M which has been 100% evaluated in conformance with the specification, shall have a line under the grade symbol to distinguish it from B7M produced to previous specification revisions not requiring 100% hardness testing.

19.2 For bolting materials, including threaded bars, that are furnished bundled and tagged or boxed, the tags and boxes shall carry the grade symbol for the material identification and the manufacturer's identification mark or name.

19.3 For purposes of identification marking, the manufacturer is considered the organization that certifies the fastener was manufactured, sampled, tested, and

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inspected in accordance with the specification and the results have been determined to meet the requirements of this specification.

19.4 *Bar Coding* — In addition to the requirements in 19.1, 19.2, and 19.3, bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with AIAG Standard B-5 02.00. If used on small items, the bar code may be applied to the box or a substantially applied tag.

20. Keywords

20.1 hardness; heat treatment

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TABLE 1
CHEMICAL REQUIREMENTS (COMPOSITION, PERCENT) [NOTE (1)]

Type	Ferritic Steels			
Grade	B5		B6 and B6X	
Description	5% Chromium		12% Chromium	
			AISI Type 410	
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]
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	4.0–6.0	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 [Note (3)]		Chromium-Molybdenum-Vanadium	
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]
Carbon	0.37–0.49 [Note (4)]	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 % [Note (5)]	. . .	. . .	0.015	. . .

Type	Austenitic Steels, [Note (6)] Classes 1, 1A, 1D, and 2							
Grade	B8, B8A		B8C, B8CA		B8M, B8MA, B8M2, B8M3		B8P, B8PA	
Description	AISI Type 304		AISI Type 347		AISI Type 316		AISI Type 305 with restricted carbon	
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]
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 × carbon content, min; 1.10 max	0.05 under	. . .	. . .	. . .	. . .

(continued)

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TABLE 1
CHEMICAL REQUIREMENTS (COMPOSITION, PERCENT) [NOTE (1)] (CONT'D)

Type	Austenitic Steels, [Note (6)] Classes 1A, 1B, 1D, and 2				
Grade	B8N, B8NA		B8MN, B8MNA		B8MLCuN, B8MLCuNA
Description	AISI Type 304N		AISI Type 316N		Unstabilized, 20 Chromium, 18 Nickel, 6 Molybdenum with restricted carbon
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]	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

Type	Austenitic Steels [Note (6)], Classes 1, 1A, and 2	
Grade	B8T, B8TA	
Description	AISI Type 321	
	Range	Product Variation, Over or Under [Note (2)]
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	$5 \times (C + N)$ min, 0.70 max	0.05 under

Type	Austenitic Steels [Note (6)], Classes 1C and 1D			
Grade	B8R, B8RA		B8S, B8SA	
Description	22 Chromium-13 Nickel-5 Manganese		18 Chromium-8 Nickel-4 Silicon + Nitrogen	
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]
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	. . .	. . .

(continued)

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TABLE 1
CHEMICAL REQUIREMENTS (COMPOSITION, PERCENT) [NOTE (1)] (CONT'D)

Type	Austenitic Steels [Note (6)], Classes 1, 1A and 1D			
Grade	B8LN, B8LNA		B8MLN, B8MLNA	
Description	AISI Type 304N with restricted carbon		AISI Type 316N with restricted carbon	
	Range	Product Variation, Over or Under [Note (2)]	Range	Product Variation, Over or Under [Note (2)]
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

NOTES:
(1) The intentional addition of Bi, Se, Te, and Pb is not permitted.
(2) 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.
(3) Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.
(4) For bar sizes over $3\frac{1}{2}$ 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.
(5) Total of soluble and insoluble.
(6) 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 (B8RA and B8SA) products are solution treated in the finished condition. Class 2 products are solution treated and strain hardened.

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TABLE 2
MECHANICAL REQUIREMENTS

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	$2\frac{1}{2}$ and under	1100	125	105	16	50	321 HB or 35 HRC
	over $2\frac{1}{2}$ to 4	1100	115	95	16	50	302 HB or 33 HRC
	over 4 to 7	1100	100	75	18	50	277 HB or 29 HRC
B7M [Note (1)]	$2\frac{1}{2}$ and under	1150	100	80	18	50	235 HB or 99 HRB
Chromium-molybdenum	4 and under	1150	100	80	18	50	235 BHN or 99 R/B
	over 4 to 7	1150	100	75	18	50	235 BHN or 99 R/B
B16							
Chromium-molybdenum-vanadium	$2\frac{1}{2}$ and under	1200	125	105	18	50	321 HB or 35 HRC
	over $2\frac{1}{2}$ to 4	1200	110	95	17	45	302 HB or 33 HRC
	over 4 to 7	1200	100	85	16	45	277 HB or 29 HRC

(continued)

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TABLE 2
MECHANICAL REQUIREMENTS (CONT'D)

Grade, Diameter, in.	Heat Treatment [Note (2)]	Tensile Strength, min, ksi	Yield Strength, min, 0.2 % offset, ksi	Elongation in 4D, min, %	Reduction of Area, min %	Hardness, max
Austenitic Steels						
Classes 1 and 1D: B8, B8M, B8P, B8LN, B8MLN, all diameters	carbide solution treated	75	30	30	50	223 HB or 96 HRB [Note (3)]
Class 1: B8C, B8T, all diameters	carbide solution treated	75	30	30	50	223 HB or 96 HRB [Note (3)]
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 or 96 HRB [Note (3)]
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
Class 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 [Note (4)]	carbide solution treated and strain hardened	125	100	12	35	321 HB or 35 HRC
¾ and under						
over ¾ to 1, incl		115	80	15	35	321 HB or 35 HRC
over 1 to 1¼ incl		105	65	20	35	321 HB or 35 HRC
over 1¼ to 1½ incl		100	50	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN [Note (4)]	carbide solution treated and strain hardened	110	95	15	45	321 HB or 35 HRC
¾ and under						
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 [Note (4)]	carbide solution treated and strain hardened	95	75	25	40	321 HB or 35 HRC
2 and under						
over 2 to 2½ incl		90	65	30	40	321 HB or 35 HRC
over 2½ to 3 incl		80	55	30	40	321 HB or 35 HRC
Class 2C: B8M3 [Note (4)]	carbide solution treated and strain hardened	85	65	30	60	321 HB or 35 HRC
2 and under						
over 2		85	60	30	60	321 HB or 35 HRC

NOTES:
(1) To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).
(2) 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.
(3) For sizes ¾ in. in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.
(4) 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.

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TABLE 3
MECHANICAL REQUIREMENTS — METRIC PRODUCTS

Class	Diameter, mm	Minimum Tempering Temperature, °C	Tensile Strength, min, MPa	Yield Strength, min, 0.2% offset, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
			Ferritic Steels				
B5							
4 to 6% chromium	up to M100, incl	593	690	550	16	50	...
B6							
13% chromium	up to M100, incl	593	760	585	15	50	...
B6X							
13% chromium	up to M100, incl	593	620	485	16	50	26 HRC
B7							
Chromium-molybdenum	M64 and under	593	860	720	16	50	321 HB or 35 HRC
	over M64 to M100	593	795	655	16	50	302 HB or 33 HRC
	over M100 to M180	593	690	515	18	50	277 HB or 29 HRC
B7M[A]							
Chromium-molybdenum	M64 and under	620	690	550	18	50	235 HB or 99 HRB
	M100 and under	620	690	550	18	50	235 BHN or 99 R/B
	over M100 to M180	620	690	515	18	50	235 BHN or 99 R/B
B16							
Chromium-molybdenum-vanadium	M64 and under	650	860	725	18	50	321 HB or 35 HRC
	over M64 to M100	650	760	655	17	45	302 HB or 33 HRC
	over M100 to M180	650	690	586	16	45	277 HB or 29 HRC

Class	Diameter, mm	Heat Treatment[B]	Tensile Strength, min, MPa	Yield Strength, min, 0.2% offset, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
			Austenitic Steels				
Classes 1 and 1D: B8, B8M, B8P, B8LN, B8MLN, all diameters		carbide solution treated	515	205	30	50	223 HB[C] or 96 HRB
Class 1: B8C, B8T, all diameters		carbide solution treated	515	205	30	50	223 HB[C] or 96 HRB
Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA, B8MLCuNA, all diameters		carbide solution treated in the finished condition	515	205	30	50	192 HB or 90 HRB
Classes 1B and 1D: B8N, B8MN, and B8MLCuN, all diameters		carbide solution treated	550	240	30	40	223 HB[C] or 96 HRB
Classes 1C and 1D: B8R, all diameters		carbide solution treated	690	380	35	55	271 HB[C] or 28 HRC
Class 1C: B8RA, all diameters		carbide solution treated in the finished condition	690	380	35	55	271 HB or 28 HRC
Classes 1C and 1D: B8S, all diameters		carbide solution treated	655	345	35	55	271 HB or 28 HRC
Class 1C: B8SA, all diameters		carbide solution treated in the finished condition	655	345	35	55	271 HB or 28 HRC

(continued)

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TABLE 3
MECHANICAL REQUIREMENTS — METRIC PRODUCTS (CONT'D)

Class Diameter, mm	Heat Treatment[B]	Tensile Strength, min, MPa	Yield Strength, min, 0.2% offset, MPa	Elongation in 4D, min, %	Reduction of Area, min, %	Hardness, max
		Austenitic Steels				
Class 2: B8, B8C, B8P, B8T, and B8N,[D]	carbide solution treated and strain hardened	860	690	12	35	321 HB or 35 HRC
M20 and under						
over M20 to M24, incl		795	550	15	35	321 HB or 35 HRC
over M24 to M30, incl		725	450	20	35	321 HB or 35 HRC
over M30 to M36, incl		690	345	28	45	321 HB or 35 HRC
Class 2: B8M, B8MN, B8MLCuN[D]	carbide solution treated and strain hardened	760	665	15	45	321 HB or 35 HRC
M20 and under						
over M20 to M24, incl		690	550	20	45	321 HB or 35 HRC
over M24 to M30, incl		655	450	25	45	321 HB or 35 HRC
over M30 to M36, incl		620	345	30	45	321 HB or 35 HRC
Class 2B: B8, B8M2[D]	carbide solution treated and strain hardened	655	515	25	40	321 HB or 35 HRC
M48 and under						
over M48 to M64, incl		620	450	30	40	321 HB or 35 HRC
over M64 to M72, incl		550	380	30	40	321 HB or 35 HRC
Class 2C: B8M3[D]	carbide solution treated and strain hardened	585	450	30	60	321 HB or 35 HRC
M48 and under						
over M48		585	415	30	60	321 HB or 35 HRC

[A] To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).
[B] Class 1 is solution treated. Class 1A is solution treated in the finished condition for corrosion resistance; heat treatment is critical due to physical property requirement. Class 2 is solution treated and strain hardened. Austenitic steels in the strain-hardened condition may not show uniform properties throughout the section particularly in sizes over M20 mm in diameter.
[C] For sizes M20 mm in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.
[D] For diameters M38 and over, center (core) properties may be lower than indicated by test reports which are based on values determined at ½ radius.

TABLE 4
MARKING OF FERRITIC STEELS

Grade	Marking
B5	B5
B6	B6
B6X	B6X
B7	B7
B7M [Note (1)]	B7M
	B7M
B16	B16

NOTE:
(1) For explanations, see 10.2.2 and 19.1.

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TABLE 5
MARKING OF AUSTENITIC STEELS [NOTE (1)]

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

NOTE:
(1) Classes 1, 1A, 1B, 1C, 2, 2B, and 2C may be marked with either grade or marking listed. Class 1D may only be marked with marking listed.

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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 Practice E 21, and Practices E 139, E 292, E 150, and E 151.

S2. Charpy Impact Tests

S2.1 Charpy impact tests based on the requirements of Specification A 320/A 320M, Section 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 A 320/A 320M, 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 Table 2.

S4. Hardness Testing of Grade B16

S4.1 For bolts or studs $2\frac{1}{2}$ in. [65 mm] or smaller, the hardness for Grade B16 shall be measured on or near the end of each bolt or stud using one of the methods prescribed in 10.2.1 for the Brinell or Rockwell C test. The hardness shall be in the range 253-319 HB or 25-34 HRC.

S5. Product Marking

S5.1 Grade and manufacturer's identification symbols shall be applied to one end of studs and to the heads of bolts of all sizes. (If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end.) For bolts smaller than $\frac{1}{4}$ in. [6 mm] in diameter and studs smaller than $\frac{3}{8}$ in. [10 mm] in diameter and for $\frac{1}{4}$ 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 E 709. 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 Practice E 328. 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.

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APPENDIX

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

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

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

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X2. COMPARISON OF GRADE DESIGNATION MARKING USED FOR AUSTENITIC STEEL IN VARIOUS EDITIONS OF A 193/A 193M

X2.1 See Table X2.1 for Marking Cross References:

TABLE X2.1
MARKING SYMBOL CROSS REFERENCE

Class	Grade Designation	Marking Symbol Used Prior to A 193/A 193M–89	Marking Symbol Used in A 193/A 193M–89 through A 193/A 193M–91a	Marking Symbol Used in A 193/A 193M–92 and Later Versions
1	B8	B8	B8	B8
1	B8C	B8C	B8C	B8C
1	B8M	B8M	B8M	B8M
1	B8P	B8P	B8P	B8P
1	B8T	B8T	B8T	B8T
1	B8LN	B8LN	B80 or B8LN[A]	B8F or B8LN
1	B8MLN	B8MLN	B81 or B8MLN[A]	B8G or B8MLN
1A	B8A	B8A	B8A	B8A
1A	B8CA	B8CA	B82 or B8CA[A]	B8B or B8CA
1A	B8MA	B8MA	B83 or B8MA[A]	B8D or B8MA
1A	B8PA	B8PA	B84 or B8PA[A]	B8H or B8PA
1A	B8TA	B8TA	B85 or B8TA[A]	B8J or B8TA
1A	B8LNA	B8LNA	B86 or B8LNA[A]	B8L or B8LNA
1A	B8MLNA	B8MLNA	B87 or B8MLNA[A]	B8K or B8MLNA
1A	B8NA	B8NA	B88 or B8NA[A]	B8V or B8NA
1A	B8MNA	B8MNA	B89 or B8MNA[A]	B8W or B8MNA
1A	B8MLCuNA			B9K[B] or B8MLCuNA
1B	B8N	B8N	B8N	B8N
1B	B8MN	B8MN	B90 or B8MN[A]	B8Y or B8MN
1B	B8MLCuNA		B103[C] or B8MLCuNA[A]	[B]
1B	B8MLCuN			B9J[B] or B8MLCuN
1C	B8R	B8R	B8R	B9A or B8R
1C	B8RA	B8RA	B91 or B8RA[A]	B9B or B8RA
1C	B8S	B8S	B8S	B9D or B8S
1C	B8SA	B8SA	B92 or B8SA[A]	B9F or B8SA
1D	B8		B94[C]	B94
1D	B8M		B95[C]	B95
1D	B8P		B96[C]	B96
1D	B8LN		B97[C]	B97
1D	B8MLN		B98[C]	B98
1D	B8N		B99[C]	B99
1D	B8MN		B100[C]	B100
1D	B8R		B101[C]	B101
1D	B8S		B102[C]	B102
2	B8	B8	B8	B8
2	B8C	B8C	B8C	B8C
2	B8P	B8P	B8P	B8P
2	B8T	B8T	B8T	B8T
2	B8N	B8N	B8N	B8N
2	B8M	B8M	B8M	B8M
2	B8MN	B8MN	B93 or B8MN[A]	B8Y or B8MN
2	B8MLCuN		B104[C] or B8MLCuN[A]	B9J[B] or B8MLCuN
2B	B8M2	B8M2	B8M2	B9G or B8M2
2B	B8			B9
2C	B8M3	B8M3	B8M3	B9H or B8M3

[A] Option to mark with grade symbol added when A 193/A 193M–91a was published.
[B] Class designation corrected when A 193/A 193M–93a was published.
[C] Class or Grade added when A 193/A 193M–91a was published.

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