



**Designation: A 193/A 193M – 01b**

## **Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service<sup>1</sup>**

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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

### **1. Scope**

1.1 This specification<sup>2</sup> 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, and so forth. Selection will depend upon design, service conditions, mechanical properties, and high-temperature characteristics.

NOTE 1—The committee formulating this specification has included fifteen steel types that have been rather extensively used for the present purpose. Other compositions will be considered for inclusion by the committee from time to time as the need becomes apparent.

NOTE 2—For grades of alloy-steel bolting material suitable for use at the lower range of high-temperature applications, reference should be made to Specification A 354.

NOTE 3—For grades of alloy-steel bolting material suitable for use in low-temperature applications, reference should be made to Specification A 320/A 320M.

1.3 Nuts for use with this bolting material are covered in Section 13.

1.4 Supplementary Requirements S1 through S10 are provided for use when additional tests or inspection are desired. These shall apply only when specified in the purchase order.

1.5 This specification is expressed in both inch-pound units and in SI units. However, unless the order specifies the applicable *M* specification designation (SI units), the material shall be furnished to inch-pound units.

1.6 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

### **2. Referenced Documents**

#### **2.1 ASTM Standards:**

A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both<sup>3</sup>

A 320/A 320M Specification for Alloy/Steel Bolting Materials for Low-Temperature Service<sup>3</sup>

A 354 Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners<sup>4</sup>

A 962/A 962M Specification for Common Requirements for Steel Fasteners or Fastener Materials, or Both, Intended for Use at Any Temperature from Cryogenic to the Creep Range<sup>3</sup>

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials<sup>5</sup>

E 21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials<sup>5</sup>

E 112 Test Methods for Determining Average Grain Size<sup>5</sup>

E 139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials<sup>5</sup>

E 150 Practice for Conducting Creep and Creep-Rupture Tension Tests of Metallic Materials Under Conditions of

<sup>1</sup> 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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<sup>2</sup> For ASME Boiler and Pressure Vessel Code applications, see related Specification SA-193 in Section II of that Code.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.01.

<sup>4</sup> Annual Book of ASTM Standards, Vol 01.08.

<sup>5</sup> Annual Book of ASTM Standards, Vol 03.01.

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Rapid Heating and Short Times<sup>6</sup>

E 151 Practice for Tension Tests of Metallic Materials at Elevated Temperatures with Rapid Heating and Conventional or Rapid Strain Rates<sup>6</sup>

E 292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials<sup>5</sup>

E 328 Methods for Stress-Relaxation Tests for Materials and Structures<sup>5</sup>

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings<sup>5</sup>

E 566 Practice for Electromagnetic (Eddy-Current) Sorting of Ferrous Metals<sup>7</sup>

E 709 Guide for Magnetic Particle Examination<sup>7</sup>

F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets<sup>4</sup>

2.2 *ANSI Standards*:<sup>8</sup>

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*:<sup>9</sup>

AIAG B-5 02.00 Primary Metals Identification Tag Application Standard

**3. General Requirements and Ordering Information**

3.1 Material supplied to this material specification shall conform to Specification A 962/A 962M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions, and mass, quality and repair of defects, etc.

3.2 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to purchase the needed material. Examples of such information include, but are not limited to, the ordering information in Specification A 962/A 962M and the following:

3.2.1 Heat-treated condition (that is, normalized and tempered, or quenched and tempered, for the ferritic materials, and carbide solution treated (Class 1), carbide solution treated after finishing (Class 1A), and carbide solution treated and strain-hardened (Classes 2, 2B and 2C), for the austenitic stainless steels; Classes 1B and 1C apply to the carbide solution-treated nitrogen-bearing stainless steels; Class 1D applies to material carbide solution treated by cooling rapidly from the rolling temperature),

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

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

3.2.4 Supplementary requirements, if any, and

3.2.5 Special requirements, in accordance with 6.3, 6.5.1, 10.2, 14.1, and 15.1.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A 962/A 962M the requirements of this specification shall prevail.

**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 molten steel may be vacuum-treated prior to or during pouring of the ingot or strand casting.

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.

**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 from 1700 to 1750°F [925 to 954°C] and oil quenched. The materials that are to be furnished in the normalized or air-quenched condition shall be reheated to the proper temperature to refine the grain and cooled uniformly in air to a temperature below the transformation temperature range. The material, whether liquid-quenched or normalized, shall then be uniformly reheated for tempering. The minimum tempering temperature shall be as specified in Table 2 and Table 3.

<sup>6</sup> Discontinued, see 1983 Annual Book of ASTM Standards, Vol 03.01.

<sup>7</sup> Annual Book of ASTM Standards, Vol 03.03.

<sup>8</sup> Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

<sup>9</sup> Available from Automotive Industry Action Group, 26200 Lahser, Suite 200, Southfield, MI 48034.

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**TABLE 1 Chemical Requirements (Composition, percent)<sup>A</sup>**

| Type . . . . .            |           | Ferritic Steels                                  |  |           |   |  |  |
|---------------------------|-----------|--|--|-----------|---|--|--|
| Grade . . . . .           |           | B5   |  |           | B6 and B6X                                      |  |  |
| UNS Designation . . . . . |           | 5% Chromium                                      |  |           | 12 % Chromium                                   |  |  |
|                           |           | S 41000 (410)                                    |  |           |   |  |  |
|                           | Range     | Product Variation,<br>Over or Under <sup>B</sup> |  | Range     | Product Variation<br>Over or Under <sup>B</sup> |  |  |
| 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                                       |  | 0.030     | 0.005 over                                      |  |  |
| Silicon                   | 1.00 max  | 0.05 over  |  | 1.00 max  | 0.05 over                                       |  |  |
| Chromium                  | 4.0-6.0   | 0.10   |  | 11.5-13.5 | 0.15  |  |  |
| Molybdenum                | 0.40-0.65 | 0.05   |  | ...       | ...   |  |  |

  

| Type . . . . .               |                        | Ferritic Steels                                  |  |           |  |  |  |
|------------------------------|------------------------|--|--|-----------|--|--|--|
| Grade . . . . .              |                        | B7, B7M  |  |           | B16  |  |  |
| Description . . . . .        |                        | Chromium-Molybdenum <sup>C</sup>                 |  |           | Chromium-Molybdenum-Vanadium                     |  |  |
|                              | Range                  | Product Variation,<br>Over or Under <sup>B</sup> |  | Range     | Product Variation,<br>Over or Under <sup>B</sup> |  |  |
| Carbon                       | 0.37-0.49 <sup>D</sup> | 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 % <sup>E</sup> | ...                    | ...  |  | 0.015     | ...  |  |  |

  

| Type                      |           | Austenitic Steels, <sup>F</sup> Classes 1, 1A, 1D, and 2 |  |                                    |  |                       |           |  |  |
|---------------------------|-----------|--|--|------------------------------------|--|-----------------------|-----------|--|--|
| Grade . . . . .           |           | B8, B8A  |  | B8C, B8CA                          |  | B8M, B8MA, B8M2, B8M3 |           | B8P, B8PA  |  |
| UNS Designation . . . . . |           | S 30400 (304)  |  | S 34700 (347)                      |  | S 31600 (316)         |           | S 30500  |  |
|                           | Range     | Product Variation,<br>Over or Under <sup>B</sup>         |  | Range                              | Product Variation,<br>Over or Under <sup>B</sup> |                       | Range     | Product Variation,<br>Over or Under <sup>B</sup> |  |
| 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                  | 18.0-20.0 | 0.20   |  | 17.0-19.0                          | 0.20   |                       | 16.0-18.0 | 0.20   |  |
| Nickel                    | 8.0-11.0  | 0.15   |  | 9.0-12.0                           | 0.15   |                       | 10.0-14.0 | 0.15   |  |
| Molybdenum                | ...       | ...  |  | ...                                | ...  |                       | 2.00-3.00 | 0.10   |  |
| Columbium + tantalum      | ...       | ...  |  | 10 x carbon content, min; 1.10 max | 0.05 under                                       |                       | ...       | ...  |  |

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**TABLE 1** *Continued*

| Type . . . . .            | Austenitic Steels, <sup>F</sup> Classes 1A, 1B, 1D, and 2 |  |                |  |                   |
|---------------------------|---|--|----------------|--|-------------------|
| Grade . . . . .           | B8N, B8NA   |  | B8MN, B8MNA    |  | B8MLCuN, B8MLCuNA |
| UNS Designation . . . . . | S 30451 (304N)  |  | S 31651 (316N) |  | S 31254           |
|                           | Range   | Product Variation,<br>Over or Under <sup>B</sup> | Range          | Product Variation,<br>Over or Under <sup>B</sup> | 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 <sup>F</sup> , Classes 1, 1A, and 2 |  |  |
|---------------------------|---|--|--|
| Grade . . . . .           | B8T, B8TA   |  |  |
| UNS Designation . . . . . | S 32100 (321)   |  |  |

|                 | Range                     | Product Variation,<br>Over or Under <sup>B</sup> |
|-----------------|---------------------------|--|
| Carbon, max     | 0.08                      | 0.01 over  |
| Manganese, max  | 2.00                      | 0.04 over  |
| Phosphorus, max | 0.045                     | 0.010 over                                       |
| Sulfur, max     | 0.030                     | 0.005 over                                       |
| Silicon, max    | 1.00                      | 0.05 over  |
| Nickel          | 9.0-12.0                  | 0.15   |
| Chromium        | 17.0-19.0                 | 0.20   |
| Titanium        | 5 x (C + N) min, 0.70 max | 0.05 under                                       |

| Type            | Austenitic Steels <sup>F</sup> , Classes 1C and 1D |           |
|-----------------|--|-----------|
| Grade           | B8R, B8RA  | B8S, B8SA |
| UNS Designation | S 20910  | S 21800   |

|                      | Range     | Product Variation,<br>Over or Under <sup>B</sup> | Range     | Product Variation,<br>Over or Under <sup>B</sup> |
|----------------------|-----------|--|-----------|--|
| Carbon, max          | 0.06      | 0.01 over  | 0.10      | 0.01 over  |
| Manganese            | 4.0-6.0   | 0.05   | 7.0-9.0   | 0.06   |
| Phosphorus, max      | 0.045     | 0.005 over                                       | 0.060     | 0.005 over                                       |
| Sulfur, max          | 0.030     | 0.005 over                                       | 0.030     | 0.005 over                                       |
| Silicon              | 1.00 max  | 0.05 over  | 3.5-4.5   | 0.15   |
| Chromium             | 20.5-23.5 | 0.25   | 16.0-18.0 | 0.20   |
| Nickel               | 11.5-13.5 | 0.15   | 8.0-9.0   | 0.10   |
| Molybdenum           | 1.50-3.00 | 0.10   | . . .     | . . .  |
| Nitrogen             | 0.20-0.40 | 0.02   | 0.08-0.18 | 0.01   |
| Columbium + tantalum | 0.10-0.30 | 0.05   | . . .     | . . .  |
| Vanadium             | 0.10-0.30 | 0.02   | . . .     | . . .  |

| Type            | Austenitic Steels <sup>F</sup> , Classes 1, 1A and 1D |               |
|-----------------|---|---------------|
| Grade           | B8LN, B8LNA   | B8MLN, B8MLNA |
| UNS Designation | S 30453   | S 31653       |

|                 | Range     | Product Variation,<br>Over or Under <sup>B</sup> | Range     | Product Variation,<br>Over or Under <sup>B</sup> |
|-----------------|-----------|--|-----------|--|
| 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   |

<sup>A</sup> The intentional addition of Bi, Se, Te, and Pb is not permitted.

<sup>B</sup> 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.

<sup>C</sup> Typical steel compositions used for this grade include 4140, 4142, 4145, 4140H, 4142H, and 4145H.

<sup>D</sup> For bar sizes over 3½ in. [90 mm], inclusive, the carbon content may be 0.50 %, max. For the B7M grade, a minimum carbon content of 0.28 % is permitted, provided that the required tensile properties are met in the section sizes involved; the use of AISI 4130 or 4130H is allowed.

<sup>E</sup> Total of soluble and insoluble.

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<sup>F</sup> Classes 1 and 1D are solution treated. Classes 1, 1B, and some 1C (B8R and B8S) products are made from solution treated material. Class 1A (B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, and B8MNA) and some Class 1C (B9RA and B8SA) products are solution treated in the finished condition. Class 2 products are solution treated and strain hardened.

**TABLE 2 Mechanical Requirements — Inch Products**

| Grade  | Diameter, in.                                      | Minimum Tempering Temperature, °F | Tensile Strength, min, ksi | Yield Strength, min, 0.2 % offset, ksi | Elongation in 4D, min, % | Reduction of Area, min, % | Hardness, max                 |
|--|--|-----------------------------------|----------------------------|--|--------------------------|---------------------------|-------------------------------|
| <b>Ferritic Steels</b>   |  |                                   |                            |  |                          |                           |                               |
| B5<br>4 to 6 % chromium  | up to 4, incl                                      | 1100                              | 100                        | 80                                     | 16                       | 50                        | ...                           |
| B6<br>13 % chromium  | up to 4, incl                                      | 1100                              | 110                        | 85                                     | 15                       | 50                        | ...                           |
| B6X<br>13 % chromium   | up to 4, incl                                      | 1100                              | 90                         | 70                                     | 16                       | 50                        | 26 HRC                        |
| B7<br>Chromium-molybdenum  | 2½ and under                                       | 1100                              | 125                        | 105                                    | 16                       | 50                        | 321 HB or 35 HRC              |
|  | over 2½ to 4                                       | 1100                              | 115                        | 95                                     | 16                       | 50                        | 321 HB or 35 HRC              |
|  | over 4 to 7  | 1100                              | 100                        | 75                                     | 18                       | 50                        | 321 HB or 35 HRC              |
| B7M <sup>A</sup> Chromium-molybdenum   | 4 and under  | 1150                              | 100                        | 80                                     | 18                       | 50                        | 235 HB or 99 HRB              |
|  | over 4 to 7  | 1150                              | 100                        | 75                                     | 18                       | 50                        | 235 BHN or 99 HRB             |
| B16<br>Chromium-molybdenum-vanadium  | 2½ and under                                       | 1200                              | 125                        | 105                                    | 18                       | 50                        | 321 HB or 35 HRC              |
|  | over 2½ to 4                                       | 1200                              | 110                        | 95                                     | 17                       | 45                        | 321 HB or 35 HRC              |
|  | over 4 to 8  | 1200                              | 100                        | 85                                     | 16                       | 45                        | 321 HB or 35 HRC              |
| <b>Austenitic Steels</b>   |  |                                   |                            |  |                          |                           |                               |
| Classes 1 and 1D; B8, B8M, B8P, carbide solution treated<br>B8LN, <sup>B</sup><br>B8MLN, all diameters |  |                                   | 75                         | 30                                     | 30                       | 50                        | 223 HB <sup>C</sup> or 96 HRB |
| Class 1: B8C, B8T, all diameters   | carbide solution treated                           |                                   | 75                         | 30                                     | 30                       | 50                        | 223 HB <sup>C</sup> or 96HRB  |
| Class 1A: B8A, B8CA, B8MA, B8PA, B8TA, B8LNA, B8MLNA, B8NA, B8MNA<br>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<br>B8MLCuN, all diameters  | carbide solution treated                           |                                   | 80                         | 35                                     | 30                       | 40                        | 223 HB <sup>C</sup> or 96 HRB |
| Classes 1C and 1D: B8R, all diameters  | carbide solution treated                           |                                   | 100                        | 55                                     | 35                       | 55                        | 271 HB or 28 HRC              |
| Class 1C: B8RA, all diameters  | carbide solution treated in the finished condition |                                   | 100                        | 55                                     | 35                       | 55                        | 271 HB or 28 HRC              |
| Classes 1C and 1D: B8S, all diameters  | carbide solution treated                           |                                   | 95                         | 50                                     | 35                       | 55                        | 271 HB or 28 HRC              |
| Classes 1C: B8SA, all diameters  | carbide solution treated in the finished condition |                                   | 95                         | 50                                     | 35                       | 55                        | 271 HB or 28 HRC              |
| Class 2: B8, B8C, B8P, B8T, and B8N, <sup>D</sup><br>¾ and under                                       | carbide solution treated and strain hardened       |                                   | 125                        | 100                                    | 12                       | 35                        | 321 HB or 35 HRC              |
|  | over ¾ to 1, incl                                  |                                   | 115                        | 80                                     | 15                       | 35                        | 321 HB or 35 HRC              |
|  | over 1 to 1¼, incl                                 |                                   | 105                        | 65                                     | 20                       | 35                        | 321 HB or 35 HRC              |
|  | over 1¼ to 1½, incl                                |                                   | 100                        | 50                                     | 28                       | 45                        | 321 HB or 35 HRC              |
| Class 2: B8M, B8MN, B8MLCuN <sup>D</sup><br>¾ and under  | carbide solution treated and strain hardened       |                                   | 110                        | 96                                     | 15                       | 45                        | 321 HB or 35 HRC              |
|  | over ¾ to 1 incl                                   |                                   | 100                        | 80                                     | 20                       | 45                        | 321 HB or 35 HRC              |

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**TABLE 2** *Continued*

| Grade, Diameter, in.            | Heat Treatment <sup>B</sup>                  | 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              |  | 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 <sup>D</sup> | 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 <sup>D</sup>     | 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 |

<sup>A</sup> To meet the tensile requirements, the Brinell hardness shall be over 200 HB (93 HRB).

<sup>B</sup> 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

<sup>C</sup> For sizes ¾ in. in diameter and smaller, a maximum hardness of 241 HB (100 HRB) is permitted.

<sup>D</sup> 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 HB or 35 HRC  |
|                                      | over M64 to M100  | 593                               | 795                        | 655                                    | 16                       | 50                        | 321 HB or 35 HRC  |
|                                      | over M100 to M180 | 593                               | 690                        | 515                                    | 18                       | 50                        | 321 HB or 35 HRC  |
| B7M <sup>A</sup> Chromium-molybdenum | M100 and under    | 620                               | 690                        | 550                                    | 18                       | 50                        | 235 HB or 99 HRB  |
|                                      | over M100 to M180 | 620                               | 690                        | 515                                    | 18                       | 50                        | 235 BHN or 99 HRB |
| 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                        | 321 HB or 35 HRC  |
|                                      | over M100 to M180 | 650                               | 690                        | 586                                    | 16                       | 45                        | 321 HB or 35 HRC  |

| Class Diameter, mm   | Heat Treatment <sup>B</sup>                        | 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, all diameters                                 | carbide solution treated                           | 515                        | 205                                    | 30                       | 50                       | 223 HB <sup>C</sup> or 96 HRB |
| Class 1: B8C, B8T, all diameters   | carbide solution treated                           | 515                        | 205                                    | 30                       | 50                       | 223 HB <sup>C</sup> or 96HRB  |
| 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 <sup>C</sup> or 96 HRB |
| Classes 1C and 1D: B8R, all diameters  | carbide solution treated                           | 690                        | 380                                    | 35                       | 55                       | 271 HB or 28 HRC              |