



Designation: A 354 – 01

# Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners<sup>1</sup>

This standard is issued under the fixed designation A 354; 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 reappraisal. A superscript epsilon (ε) indicates an editorial change since the last revision or reappraisal.

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

## 1. Scope \*

1.1 This specification<sup>2</sup> covers the chemical and mechanical requirements of quenched and tempered alloy steel bolts, studs, and other externally threaded fasteners 4 in. and under in diameter for application at normal atmospheric temperatures, where high strength is required and for limited application at elevated temperature (Note 1). Any alloy steel capable of meeting the minimum mechanical and chemical properties set forth in this specification may be used.

NOTE 1—For bolts, studs, or other externally threaded fasteners, to be used at elevated temperatures, refer to Specification A 193/A 193M.

1.2 Two levels of bolting strength are covered, designated Grades BC and BD. Selection will depend upon design and the stresses and service for which the product is to be used.

NOTE 2—Quenched and tempered alloy steel bolts for structural steel joints up through 1½ in. in diameter are covered in Specification A 490. Alloy steel bolts, studs, and other externally threaded fasteners (that is, heavy hex-structural bolts over 1½ in., hex bolts, anchor bolts, and countersunk bolts) exhibiting similar mechanical properties to bolts conforming to Specification A 490 shall be covered by Grade BD of this specification.

When bolts of Grade BD of this specification are considered for pretensioned applications in excess of 50 % of the bolt tensile strength, the additional requirements of head size, maximum tensile strength, nut size and strength, washer hardness, tests, and inspections contained in Specification A 490 should be carefully considered.

1.3 Nuts are covered in Specification A 563. Unless otherwise specified, the grade and style of nut for each grade of fastener shall be as follows:

| Grade of Fastener and Surface Finish  | Nut Grade and Style <sup>4</sup> |
|---|----------------------------------|
| BC, plain (or with a coating of insufficient thickness to require over-tapped nuts) | C, heavy hex                     |
| BC, zinc-coated (or with a coating thickness requiring over-tapped nuts)            | DH, heavy hex                    |
| BD, all finishes  | DH, heavy hex                    |

<sup>4</sup>Nuts of other grades and styles having specified proof load stresses (Specification A 563, Table 3) greater than the specified grade and style of nut are suitable.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- A 153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware<sup>3</sup>
- A 193/A193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service<sup>4</sup>
- A 490 Specification for Heat-Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength<sup>5</sup>
- A 563 Specification for Carbon and Alloy Steel Nuts<sup>5</sup>
- A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products<sup>6</sup>
- B 695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel<sup>7</sup>
- D 3951 Practice for Commercial Packaging<sup>8</sup>
- F 436 Specification for Hardened Steel Washers<sup>5</sup>
- F 606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets<sup>5</sup>
- F 788/F 788M Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series<sup>5</sup>
- F 1470 Guide for Fastener Sampling for Specified Mechanical Properties and Performance Inspection<sup>5</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets, and Washers.

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<sup>2</sup> For ASME Boiler and Pressure Vessel Code applications see related Specification SA-354 in Section II of that Code.

<sup>3</sup> Annual Book of ASTM Standards, Vol 01.06.

<sup>4</sup> Annual Book of ASTM Standards, Vol 01.01.

<sup>5</sup> Annual Book of ASTM Standards, Vol 01.08.

<sup>6</sup> Annual Book of ASTM Standards, Vol 01.03.

<sup>7</sup> Annual Book of ASTM Standards, Vol 02.05.

<sup>8</sup> Annual Book of ASTM Standards, Vol 15.09.

\*A Summary of Changes section appears at the end of this standard.

2.2 *ASME Standards:*

- B1.1 Unified Screw Threads<sup>9</sup>
- B18.2.1 Square and Hex Bolts and Screws, Inch Series<sup>9</sup>
- B18.24.1 Part Identifying Number (PIN) Code System<sup>10</sup>

**3. Ordering Information**

3.1 Orders for bolts and studs (including nuts and accessories) under this specification shall include the following:

- 3.1.1 ASTM designation and year of issue,
- 3.1.2 Name of product (that is, bolt or stud),
- 3.1.3 Grade (that is, BC or BD),
- 3.1.4 Quantities (number of pieces by size, including nuts),
- 3.1.5 Size and length,
- 3.1.6 Washers—Specify quantity and size (separate from bolts) (4.3),
- 3.1.7 *Zinc Coating*—When zinc-coated Grade BC fasteners are required, specify the zinc-coating process required, for example hot-dip, mechanically deposited, or no preference (see 4.4).

3.1.8 *Other Finishes*—Specify other protective finish, if required.

3.1.9 Specify if inspection at point of manufacture is required,

3.1.10 Specify if Certification (Section 14) is required, and

3.1.11 Specify additional testing (Section 9) or special requirements.

3.1.12 For establishment of a part identifying system, see ASME B18.24.1.

**4. Materials and Manufacture**

4.1 The steel shall be made by the open-hearth, electric-furnace, or basic-oxygen process.

4.2 All fasteners shall be heat-treated. At the option of the manufacturer, heat treatment may be performed on the raw material, during the manufacturing operations, or after final machining. Heat treatment shall consist of quenching in a liquid medium (except Grade BD sizes 1½ in. and smaller shall be quenched in oil) from above the transformation temperature and then tempering by reheating to a temperature of not less than 800°F (427°C) for Grade BC and for Grade BD.

4.3 When used, suitable hardened washers shall be quenched and tempered (non-carburized) in accordance with Specification F 436.

4.4 *Zinc Coatings, Hot-Dip and Mechanically Deposited:*

4.4.1 When zinc-coated fasteners are required, the purchaser shall specify the zinc coating process, for example, hot-dip, mechanically deposited, or no preference.

4.4.2 When “hot-dip” is specified, the fasteners shall be zinc coated by the hot-dip process in accordance with the requirements of Class C of Specification A 153.

4.4.3 When mechanically deposited is specified, the fasteners shall be zinc-coated by the mechanical-deposition process in accordance with the requirements of Class 50 of Specification B 695.

4.4.4 When no preference is specified, the supplier may furnish either a hot-dip zinc coating in accordance with Specification A 153, Class C or a mechanically deposited zinc coating in accordance with Specification B 695, Class 50. Threaded components (bolts and nuts) shall be coated by the same zinc-coating process and the supplier’s option is limited to one process per item with no mixed processes in a lot.

NOTE 3—When the intended application requires that assembled tension exceeds 50 % of minimum bolt proof load, an anti-galling lubricant may be needed. Application of such a lubricant to nuts and a test of the lubricant efficiency are provided in Supplementary Requirement S1 of Specification A 563 and should be specified when required.

4.5 Zinc-coated bolts and nuts shall be shipped in the same container unless specifically requested otherwise by the purchaser.

NOTE 4—Research conducted on bolts of similar material and manufacture indicates that hydrogen-stress cracking or stress cracking corrosion may occur on hot-dip galvanized Grade BD bolts.

**5. Chemical Composition**

5.1 All fasteners shall be made from alloy steel conforming to the chemical composition requirements in accordance with Table 1. The steel shall contain sufficient alloying elements to qualify it as an alloy steel.

NOTE 5—Steel is considered to be alloy, by the American Iron and Steel Institute, when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese, 1.65 %; silicon, 0.60 %; copper, 0.60 %; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized field of constructional alloy steels: aluminum, chromium up to 3.99 %, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying elements added to obtain a desired alloying effect.

5.2 Product analysis may be made by the purchaser from finished material representing each lot of fasteners. The chemical composition thus determined shall conform to the requirements given in Table 1. Choice of alloy steel composition necessary to ensure meeting the specified mechanical requirements shall be made by the manufacturer and shall be reported to the purchaser for information purposes only.

5.3 Application of heats of steel to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

5.4 Chemical analyses shall be performed in accordance with Test Methods A 751.

**6. Mechanical Properties**

6.1 Fasteners shall not exceed the maximum hardness specified in Table 2. Fasteners less than three diameters in length

**TABLE 1 Chemical Requirements**

| Element                      | Heat Analysis, % | Product Analysis, % |
|------------------------------|------------------|---------------------|
| Carbon:                      |                  |                     |
| For sizes through 1½ in.     | 0.30 to 0.53     | 0.28 to 0.55        |
| For sizes larger than 1½ in. | 0.35 to 0.53     | 0.33 to 0.55        |
| Phosphorus, max              | 0.035            | 0.040               |
| Sulfur, max                  | 0.040            | 0.045               |

<sup>9</sup> Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

<sup>10</sup> Available from American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

**TABLE 2 Hardness Requirements for Full-Size Fasteners**

| Size, in. | Grade | Hardness |         |            |         |
|-----------|-------|----------|---------|------------|---------|
|           |       | Brinell  |         | Rockwell C |         |
|           |       | Minimum  | Maximum | Minimum    | Maximum |
| ¼ to 2½   | BC    | 255      | 331     | 26         | 36      |
| Over 2½   | BC    | 235      | 311     | 22         | 33      |
| ¼ to 2½   | BD    | 311      | 363     | 33         | 39      |
| Over 2½   | BD    | 293      | 363     | 31         | 39      |

| Diameter, in.   | Oversize Limit, in. (mm) <sup>A</sup> |
|-----------------|---------------------------------------|
| ¼               | 0.016                                 |
| 5/16, 3/8       | 0.017                                 |
| 7/16, ½         | 0.018                                 |
| 9/16 to ¾, incl | 0.020                                 |
| 7/8             | 0.022                                 |
| 1.0 to 1¼, incl | 0.024                                 |
| 1⅜, 1½          | 0.027                                 |
| 1¾ to 4.0, incl | 0.050                                 |

<sup>A</sup> These values are the same as the overlapping required for zinc-coated nuts in Specification A 563.

and studs less than four diameters in length shall have hardness values not less than the minimum nor more than the maximum hardness limits required in Table 2, as hardness is the only requirement.

6.2 Fasteners 1⅜ in. in diameter or less for Grade BC and 1¼ in. in diameter or less for Grade BD, other than those excepted in 6.1, shall be tested full size and shall conform to the tensile strength and either the proof load or the yield strength requirements in accordance with Table 3.

6.3 Fasteners larger than 1⅜ in. in diameter for Grade BC and fasteners larger than 1¼ in. in diameter for Grade BD, other than those excepted in 6.1, shall preferably be tested full size and when so tested, shall conform to the tensile strength and either the proof load or yield strength requirements in accordance with Table 3 or Table 4. When equipment of sufficient capacity for full-size testing is not available, or when the length of the fastener makes full-size testing impractical, machined specimens shall be tested and shall conform to the requirements in accordance with Table 5. In the event that fasteners are tested by both full-size and by the machined test specimen methods, the full-size test shall govern if a controversy between the two methods exists.

6.4 For fasteners on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event that there is controversy over low readings of hardness tests.

**7. Dimensions**

7.1 *Bolts*—Unless otherwise specified, the bolts shall be Hex Head with dimensions conforming to the latest issue of ASME B18.2.1.

7.2 *Studs*—Studs shall have dimensions conforming to those specified by the purchaser.

7.3 *Threads:*

7.3.1 Unless otherwise specified, threads shall be the Unified National Coarse Thread Series as specified in ANSI B1.1, and shall have Class 2 A tolerances.

7.3.2 When specified, threads shall be the Unified National Fine Thread Series, 8-Pitch Thread Series for sizes over 1 in. or 14-Pitch UNS on 1 in. size as specified in ANSI B1.1 and shall have Class 2A tolerances.

7.3.3 Unless otherwise specified, bolts and studs to be used with nuts or tapped holes that have been tapped oversize, in accordance with Specification A 563, shall have Class 2A threads before hot dip or mechanically deposited zinc coating. After zinc coating, the maximum limit of pitch and major diameter may exceed the Class 2A limit by the following amount:

**8. Workmanship**

8.1 Surface discontinuity limits shall be in accordance with Specification F 788/F 788M.

**9. Number of Tests**

9.1 *Testing Responsibility:*

9.1.1 Each lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 9.2 through 9.6.

9.1.2 When fasteners are furnished by a source other than the manufacturer, the responsible party as defined in 12.1 shall be responsible for ensuring that all tests have been performed and the fasteners comply with the requirements of this specification.

9.2 *Purpose of Lot Inspection*—The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective it is essential that secondary processors, distributors, and purchasers maintain the identification and integrity of each lot until the product is installed.

9.3 *Lot Processing*—All fasteners shall be processed in accordance with a lot identification-control quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each lot of fasteners from raw-material selection through all processing operations and treatments to final packing and shipment. Each lot shall be assigned its own lot-identification number, each lot shall be tested, and the inspection test reports for each lot shall be retained.

9.4 *Lot Definition*—A lot is a quantity of a uniquely identified fastener product of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and heat treatment lot and processed at one time, by the same process, in the same manner so that statistical sampling is valid. The identity of the lot is maintained throughout all subsequent operations and packaging.

9.5 *Number of Tests*—The minimum number of tests from each production lot for the tests specified below shall be in accordance with Guide F 1470 .

|            |   |
|------------|---|
| Hardness   | Coating Weight/Thickness                        |
| Tensile    | Workmanship (Surface Discontinuities Section 8) |
| Proof Load |   |

9.5.1 The number of tests for dimensional and thread fit compliance shall be in accordance with the quality assurance provisions of the referenced dimensional standards.

9.6 If any test specimen shows defective machining it may be discarded and another specimen substituted.



**TABLE 3 Tensile Requirements for All Full-Size Fasteners—Inch-Pound Units**

| Bolt Size, in. | Threads per inch | Stress Area, <sup>A</sup> in. <sup>2</sup> | Grade BC                                |                                   |  | Grade BD                                |                                   |  |
|----------------|------------------|--|---|-----------------------------------|--|---|-----------------------------------|--|
|                |                  |  | Tensile Strength, min, lbf <sup>E</sup> | Proof Load, min, lbf <sup>C</sup> | Yield Strength (0.2 % offset), min, lbf <sup>D</sup> | Tensile Strength, min, lbf <sup>F</sup> | Proof Load, min, lbf <sup>F</sup> | Yield Strength (0.2 % offset), min, lbf <sup>G</sup> |
| 1              | 2                | 3  | 4                                       | 5                                 | 6  | 7                                       | 8                                 | 9  |
| 1/4            | 20               | 0.0318                                     | 4 000                                   | 3 350                             | 3 450  | 4 750                                   | 3 800                             | 4 100  |
| 1/4            | 28               | 0.0364                                     | 4 550                                   | 3 820                             | 3 950  | 5 450                                   | 4 350                             | 4 700  |
| 5/16           | 18               | 0.0524                                     | 6 550                                   | 5 500                             | 5 700  | 7 850                                   | 6 300                             | 6 800  |
| 5/16           | 24               | 0.0580                                     | 7 250                                   | 6 090                             | 6 300  | 8 700                                   | 6 950                             | 7 500  |
| 3/8            | 16               | 0.0775                                     | 9 700                                   | 8 150                             | 8 450  | 11 650                                  | 9 300                             | 10 075   |
| 3/8            | 24               | 0.0878                                     | 11 000                                  | 9 220                             | 9 550  | 13 200                                  | 10 500                            | 11 400   |
| 7/16           | 14               | 0.1063                                     | 13 300                                  | 11 150                            | 11 600   | 15 950                                  | 12 750                            | 13 850   |
| 7/16           | 20               | 0.1187                                     | 14 840                                  | 12 470                            | 12 900   | 17 800                                  | 14 200                            | 15 400   |
| 1/2            | 13               | 0.1419                                     | 17 750                                  | 14 900                            | 15 450   | 21 300                                  | 17 050                            | 18 500   |
| 1/2            | 20               | 0.1599                                     | 19 990                                  | 16 790                            | 17 400   | 24 000                                  | 19 200                            | 20 750   |
| 9/16           | 12               | 0.182                                      | 22 750                                  | 19 100                            | 19 850   | 27 300                                  | 21 850                            | 23 600   |
| 9/16           | 18               | 0.203                                      | 25 400                                  | 21 400                            | 22 100   | 30 400                                  | 24 400                            | 26 350   |
| 5/8            | 11               | 0.226                                      | 28 250                                  | 23 750                            | 24 650   | 33 900                                  | 27 100                            | 29 400   |
| 5/8            | 18               | 0.256                                      | 32 000                                  | 26 800                            | 27 900   | 38 400                                  | 30 700                            | 33 250   |
| 3/4            | 10               | 0.334                                      | 41 750                                  | 35 050                            | 36 400   | 50 100                                  | 40 100                            | 43 400   |
| 3/4            | 16               | 0.373                                      | 46 600                                  | 39 100                            | 40 650   | 56 000                                  | 44 800                            | 48 450   |
| 7/8            | 9                | 0.462                                      | 57 750                                  | 48 500                            | 50 350   | 69 300                                  | 55 450                            | 60 100   |
| 7/8            | 14               | 0.509                                      | 63 600                                  | 53 400                            | 55 450   | 76 400                                  | 61 100                            | 66 150   |
| 1              | 8                | 0.606                                      | 75 750                                  | 63 650                            | 66 050   | 90 900                                  | 72 700                            | 78 800   |
| 1              | 12               | 0.663                                      | 82 900                                  | 69 700                            | 72 250   | 99 400                                  | 79 600                            | 86 150   |
| 1              | 14 UNS           | 0.679                                      | 84 900                                  | 71 300                            | 74 400   | 101 900                                 | 81 500                            | 88 250   |
| 1 1/8          | 7                | 0.763                                      | 95 400                                  | 80 100                            | 83 150   | 114 450                                 | 91 550                            | 99 200   |
| 1 1/8          | 8                | 0.790                                      | 98 750                                  | 82 950                            | 86 200   | 118 500                                 | 94 800                            | 102 700  |
| 1 1/8          | 12               | 0.856                                      | 107 000                                 | 89 800                            | 93 300   | 128 400                                 | 102 700                           | 111 250  |
| 1 1/4          | 7                | 0.969                                      | 121 150                                 | 101 750                           | 105 600  | 145 350                                 | 116 300                           | 126 000  |
| 1 1/4          | 8                | 1.000                                      | 125 000                                 | 105 000                           | 109 000  | 150 000                                 | 120 000                           | 130 000  |
| 1 1/4          | 12               | 1.073                                      | 134 100                                 | 112 600                           | 116 950  | 161 000                                 | 128 800                           | 139 450  |
| 1 3/8          | 6                | 1.155                                      | 144 400                                 | 121 300                           | 125 900  | 173 250                                 | 138 600                           | 150 200  |
| 1 3/8          | 8                | 1.233                                      | 154 150                                 | 129 450                           | 134 400  | 185 000                                 | 148 000                           | 160 300  |
| 1 3/8          | 12               | 1.315                                      | 164 400                                 | 138 100                           | 143 300  | 197 200                                 | 157 800                           | 170 950  |
| 1 1/2          | 6                | 1.405                                      | 175 650                                 | 147 550                           | 153 150  | 210 750                                 | 168 600                           | 182 500  |
| 1 1/2          | 8                | 1.492                                      | 186 500                                 | 156 650                           | 162 250  | 233 800                                 | 175 050                           | 194 000  |
| 1 1/2          | 12               | 1.581                                      | 197 600                                 | 166 000                           | 172 300  | 237 200                                 | 189 700                           | 205 500  |
| 1 3/4          | 5                | 1.90                                       | 237 500                                 | 199 500                           | 207 100  | 285 000                                 | 228 000                           | 247 000  |
| 1 3/4          | 8                | 2.08                                       | 260 000                                 | 218 400                           | 226 700  | 312 000                                 | 249 600                           | 270 000  |
| 2              | 4 1/2            | 2.50                                       | 312 500                                 | 262 500                           | 272 500  | 375 000                                 | 300 000                           | 325 000  |
| 2              | 8                | 2.77                                       | 346 250                                 | 290 850                           | 301 950  | 415 000                                 | 332 400                           | 360 000  |
| 2 1/4          | 4 1/2            | 3.25                                       | 406 250                                 | 341 250                           | 354 250  | 487 000                                 | 390 000                           | 422 500  |
| 2 1/4          | 8                | 3.56                                       | 445 000                                 | 373 800                           | 388 050  | 534 000                                 | 422 200                           | 462 800  |
| 2 1/2          | 4                | 4.00                                       | 500 000                                 | 420 000                           | 436 000  | 600 000                                 | 480 000                           | 520 000  |
| 2 1/2          | 8                | 4.44                                       | 550 000                                 | 466 200                           | 483 950  | 666 000                                 | 532 800                           | 577 200  |
| 2 3/4          | 4                | 4.93                                       | 566 950                                 | 468 350                           | 488 050  | 690 200                                 | 517 650                           | 566 950  |
| 2 3/4          | 8                | 5.43                                       | 624 450                                 | 515 850                           | 537 550  | 750 200                                 | 570 150                           | 624 450  |
| 3              | 4                | 5.97                                       | 686 550                                 | 567 150                           | 591 050  | 835 800                                 | 626 850                           | 686 550  |
| 3              | 8                | 6.51                                       | 748 650                                 | 618 450                           | 644 500  | 911 400                                 | 683 550                           | 748 650  |
| 3 1/4          | 4                | 7.10                                       | 816 500                                 | 674 500                           | 702 900  | 994 000                                 | 745 500                           | 816 500  |
| 3 1/4          | 8                | 7.69                                       | 884 350                                 | 730 550                           | 761 300  | 1 076 600                               | 807 650                           | 884 350  |
| 3 1/2          | 4                | 8.33                                       | 957 950                                 | 791 350                           | 824 650  | 1 166 200                               | 874 650                           | 957 950  |
| 3 1/2          | 8                | 8.96                                       | 1 030 400                               | 851 200                           | 887 050  | 1 254 400                               | 940 800                           | 1 030 400  |
| 3 3/4          | 4                | 9.66                                       | 1 110 900                               | 917 700                           | 956 350  | 1 352 400                               | 1 014 300                         | 1 110 900  |
| 3 3/4          | 8                | 10.34                                      | 1 199 100                               | 983 300                           | 1 023 650  | 1 447 600                               | 1 085 700                         | 1 189 100  |
| 4              | 4                | 11.08                                      | 1 274 200                               | 1 052 600                         | 1 096 900  | 1 551 200                               | 1 163 400                         | 1 274 200  |
| 4              | 8                | 11.81                                      | 1 358 200                               | 1 122 000                         | 1 169 200  | 1 653 400                               | 1 240 050                         | 1 358 150  |

<sup>A</sup> Stress Area, in.<sup>2</sup> = 0.7854 [D - 0.9743/n]<sup>2</sup> where D = nominal diameter, in., and n = threads/in.  
<sup>B</sup> Based on 125 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 115 000 psi for sizes over 2 1/2 to 4 in., inclusive.  
<sup>C</sup> Based on 105 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 95 000 psi for sizes over 2 1/2 to 4 in., inclusive.  
<sup>D</sup> Based on 109 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 99 000 psi for sizes over 2 1/2 to 4 in., inclusive.  
<sup>E</sup> Based on 150 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 140 000 psi for sizes over 2 1/2 to 4 in., inclusive.  
<sup>F</sup> Based on 120 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 105 000 psi for sizes over 2 1/2 to 4 in., inclusive.  
<sup>G</sup> Based on 130 000 psi for sizes 1/4 to 2 1/2 in., inclusive, and on 115 000 psi for sizes over 2 1/2 to 4 in., inclusive.



**TABLE 4 Tensile Requirements for All Full-Size Fasteners—SI Units**

| Bolt Size, in. | Threads per inch | Stress Area, <sup>A</sup> mm <sup>2</sup> | Grade BC                               |                                  |  | Grade BD                               |                                  |  |
|----------------|------------------|---|--|----------------------------------|--|--|----------------------------------|--|
|                |                  |   | Tensile Strength, min, kN <sup>B</sup> | Proof Load, min, kN <sup>C</sup> | Yield Strength (0.2% offset), min, kN <sup>D</sup> | Tensile Strength, min, kN <sup>E</sup> | Proof Load, min, kN <sup>F</sup> | Yield Strength (0.2% offset), min, kN <sup>G</sup> |
| 1              | 2                | 3   | 4                                      | 5                                | 6  | 7                                      | 8                                | 9  |
| 1/4            | 20               | 20.5                                      | 17.7                                   | 14.9                             | 15.4   | 21.2                                   | 17.0                             | 18.4   |
| 1/4            | 28               | 23.5                                      | 20.2                                   | 17.0                             | 17.7   | 24.3                                   | 19.4                             | 21.1   |
| 5/16           | 18               | 33.8                                      | 29.1                                   | 24.5                             | 25.4   | 35.0                                   | 28.0                             | 30.3   |
| 5/16           | 24               | 37.4                                      | 32.2                                   | 27.1                             | 28.1   | 38.7                                   | 30.9                             | 33.5   |
| 3/8            | 16               | 50.0                                      | 43.1                                   | 36.2                             | 37.6   | 51.7                                   | 41.4                             | 44.8   |
| 3/8            | 24               | 56.6                                      | 48.8                                   | 41.0                             | 42.6   | 58.5                                   | 46.8                             | 50.7   |
| 7/16           | 14               | 68.6                                      | 59.1                                   | 49.6                             | 51.5   | 70.9                                   | 56.7                             | 61.5   |
| 7/16           | 20               | 76.6                                      | 66.0                                   | 55.5                             | 57.6   | 79.2                                   | 63.3                             | 68.6   |
| 1/2            | 13               | 91.5                                      | 78.9                                   | 66.3                             | 68.8   | 94.7                                   | 75.7                             | 82.1   |
| 1/2            | 20               | 103                                       | 88.8                                   | 74.6                             | 77.5   | 106.5                                  | 85.2                             | 92.3   |
| 9/16           | 12               | 111                                       | 101.2                                  | 85.0                             | 88.2   | 121.4                                  | 97.1                             | 105.2  |
| 9/16           | 18               | 131                                       | 112.9                                  | 94.8                             | 98.5   | 135.4                                  | 108.3                            | 117.4  |
| 5/8            | 11               | 146                                       | 125.7                                  | 105.6                            | 109.6  | 150.8                                  | 120.6                            | 130.7  |
| 5/8            | 18               | 165                                       | 142.2                                  | 119.5                            | 124.1  | 170.6                                  | 136.5                            | 147.8  |
| 3/4            | 10               | 215                                       | 185.7                                  | 156.0                            | 161.9  | 222.9                                  | 178.3                            | 193.1  |
| 3/4            | 16               | 241                                       | 207.7                                  | 174.5                            | 181.2  | 249.2                                  | 199.3                            | 215.9  |
| 7/8            | 9                | 298                                       | 256.9                                  | 215.8                            | 224.0  | 308.3                                  | 246.6                            | 267.2  |
| 7/8            | 14               | 328                                       | 282.3                                  | 237.5                            | 246.6  | 339.2                                  | 271.3                            | 293.9  |
| 1              | 8                | 391                                       | 337.0                                  | 283.0                            | 293.8  | 404.3                                  | 323.5                            | 350.4  |
| 1              | 12               | 428                                       | 368.9                                  | 309.9                            | 321.8  | 442.6                                  | 354.0                            | 383.5  |
| 1              | 14 UNS           | 438                                       | 377.6                                  | 317.1                            | 329.4  | 452.9                                  | 362.2                            | 392.4  |
| 1 1/8          | 7                | 492                                       | 424.2                                  | 356.4                            | 369.9  | 509.1                                  | 407.3                            | 441.2  |
| 1 1/8          | 8                | 510                                       | 439.3                                  | 369.0                            | 383.0  | 527.1                                  | 421.7                            | 456.8  |
| 1 1/8          | 12               | 552                                       | 475.8                                  | 399.6                            | 415.1  | 570.8                                  | 456.5                            | 494.6  |
| 1 1/4          | 7                | 625                                       | 538.8                                  | 452.6                            | 469.8  | 646.5                                  | 517.2                            | 560.3  |
| 1 1/4          | 8                | 645                                       | 556.0                                  | 467.1                            | 484.9  | 667.2                                  | 533.8                            | 578.3  |
| 1 1/4          | 12               | 692                                       | 596.5                                  | 501.0                            | 520.4  | 715.5                                  | 572.3                            | 620.0  |
| 1 3/8          | 6                | 745                                       | 642.2                                  | 539.5                            | 560.0  | 770.7                                  | 616.5                            | 667.9  |
| 1 3/8          | 8                | 795                                       | 685.6                                  | 575.9                            | 597.8  | 822.7                                  | 658.2                            | 713.0  |
| 1 3/8          | 12               | 848                                       | 731.0                                  | 614.0                            | 637.7  | 876.8                                  | 701.3                            | 759.8  |
| 1 1/2          | 6                | 906                                       | 781.2                                  | 656.2                            | 681.2  | 937.5                                  | 750.0                            | 812.5  |
| 1 1/2          | 8                | 963                                       | 829.6                                  | 696.9                            | 723.4  | 995.5                                  | 796.4                            | 862.8  |
| 1 1/2          | 12               | 1020                                      | 879.2                                  | 738.5                            | 767.0  | 1054.7                                 | 843.5                            | 913.9  |
| 1 3/4          | 5                | 1226                                      | 1056                                   | 887.4                            | 921.2  | 1268                                   | 1014                             | 1099   |
| 1 3/4          | 8                | 1342                                      | 1157                                   | 971.5                            | 1009   | 1388                                   | 1110                             | 1203   |
| 2              | 4 1/2            | 1613                                      | 1390                                   | 1168                             | 1212   | 1668                                   | 1334                             | 1446   |
| 2              | 8                | 1787                                      | 1540                                   | 1294                             | 1343   | 1848                                   | 1479                             | 1602   |
| 2 1/4          | 4 1/2            | 2097                                      | 1807                                   | 1518                             | 1576   | 2169                                   | 1735                             | 1879   |
| 2 1/4          | 8                | 2297                                      | 1979                                   | 1663                             | 1726   | 2375                                   | 1900                             | 2059   |
| 2 1/2          | 4                | 2581                                      | 2224                                   | 1868                             | 1939   | 2669                                   | 2135                             | 2313   |
| 2 1/2          | 8                | 2865                                      | 2469                                   | 2074                             | 2153   | 2963                                   | 2370                             | 2568   |
| 2 3/4          | 4                | 3181                                      | 2741                                   | 2303                             | 2390   | 3289                                   | 2632                             | 2851   |
| 2 3/4          | 8                | 3503                                      | 3019                                   | 2536                             | 2633   | 3623                                   | 2898                             | 3140   |
| 3              | 4                | 3852                                      | 3319                                   | 2788                             | 2895   | 3983                                   | 3187                             | 3452   |
| 3              | 8                | 4200                                      | 3620                                   | 3041                             | 3156   | 4344                                   | 3475                             | 3765   |
| 3 1/4          | 4                | 4581                                      | 3948                                   | 3316                             | 3442   | 4737                                   | 3790                             | 4106   |
| 3 1/4          | 8                | 4961                                      | 4276                                   | 3592                             | 3729   | 5131                                   | 4105                             | 4447   |
| 3 1/2          | 4                | 5374                                      | 4632                                   | 3891                             | 4039   | 5558                                   | 4446                             | 4817   |
| 3 1/2          | 8                | 5781                                      | 4982                                   | 4185                             | 4344   | 5978                                   | 4783                             | 5181   |
| 3 3/4          | 4                | 6232                                      | 5371                                   | 4512                             | 4684   | 6445                                   | 5156                             | 5586   |
| 3 3/4          | 8                | 6671                                      | 5749                                   | 4829                             | 5013   | 6899                                   | 5519                             | 5979   |
| 4              | 4                | 7148                                      | 6161                                   | 5175                             | 5372   | 7393                                   | 5914                             | 6407   |
| 4              | 8                | 7619                                      | 6567                                   | 5516                             | 5726   | 7880                                   | 6304                             | 6829   |

<sup>A</sup> Stress Area, mm<sup>2</sup> = 0.7854 (D - 0.9382 P)<sup>2</sup>, where D = nominal product size, mm, and P = thread pitch, mm.

<sup>B</sup> Based on 862 MPa for sizes 1/4 to 2 1/2 in., inclusive, and on 793 MPa for sizes over 2 1/2 to 4 in., inclusive.

<sup>C</sup> Based on 724 MPa for sizes 1/4 to 2 1/2 in., inclusive, and on 655 MPa for sizes over 2 1/2 to 4 in., inclusive.

<sup>D</sup> Based on 752 MPa for sizes 1/4 to 2 1/2 in., inclusive, and on 683 MPa for sizes over 2 1/2 to 4 in., inclusive.

<sup>E</sup> Based on 1034 MPa for sizes 1/4 to 2 1/2 in., inclusive, and on 965 MPa for sizes over 2 1/2 to 4 in., inclusive.

<sup>F</sup> Based on 827 MPa for sizes 1/4 to 2 1/2 in., inclusive, and on 724 MPa for sizes over 2 1/2 to 4 in., inclusive.

<sup>G</sup> Based on 896 MPa for sizes 1/4 to 2 1/2 in., inclusive, and on 793 MPa for sizes over 2 1/2 to 4 in., inclusive.

**TABLE 5 Mechanical Requirements for Machined Specimens**

| Grade | Size, in.     | Tensile Strength<br>min, psi<br>(MPa) | Yield Strength<br>(0.2 % offset),<br>min, psi<br>(MPa) | Elonga-<br>tion in<br>2 in. or<br>50 mm,<br>min, % | Reduc-<br>tion<br>of<br>Area,<br>min, % |
|-------|---------------|---------------------------------------|--|--|---|
| BC    | ¼ to 2½, incl | 125 000 (862)                         | 109 000 (752)  | 16   | 50                                      |
| BC    | Over 2½       | 115 000 (793)                         | 99 000 (683)   | 16   | 45                                      |
| BD    | ¼ to 2½, incl | 150 000 (1034)                        | 130 000 (896)  | 14   | 40                                      |
| BD    | Over 2½       | 140 000 (965)                         | 115 000 (793)  | 14   | 40                                      |

## 10. Test Methods

10.1 Test methods shall be conducted in accordance with Test Methods F 606.

10.2 Proof load, rather than yield strength determination is preferred and shall be the arbitration method for fasteners 1¼ in. and under in diameter.

10.3 Hexagon bolts shall be tested by the wedge tension method. Fracture shall be in the body or threads of the bolt without any fracture at the junction of the head and body.

10.3.1 At the option of the manufacturer, the yield strength test (Method 2, Yield Strength paragraph of Test Method F 606) and the wedge tension test (Wedge Tension Testing of Full-Size Product paragraph, both from the Test Method section of Test Method F 606) may be accomplished concurrently to satisfy 10.2 and 10.3.

10.4 Studs and bolts other than those in 10.3 shall be tested by the axial tension method.

10.4.1 At the option of the manufacturer, the yield strength test and the axial tension test may be accomplished concurrently to satisfy 10.2 and 10.4.

10.5 The speed of testing determined with a free running crosshead shall be a maximum of ⅛ in. (3.2 mm)/min for the bolt proof load (or yield strength) determination and a maximum of 1 in. (25.4 mm)/min for the tensile strength determination.

## 11. Inspection

11.1 If the inspection described in 11.2 is required by the purchaser, it shall be specified in the inquiry and contract or purchase order.

11.2 The inspector representing the purchaser shall have free entry to all parts of the manufacturer's works 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 and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted as not to interfere unnecessarily with the operation of the works.

## 12. Responsibility

12.1 The party responsible for the fastener shall be the organization that supplies the fastener to the purchaser and certifies that the fastener was manufactured, sampled, tested, and inspected in accordance with this specification and meets all of its requirements.

## 13. Rejection and Reheating

13.1 Material that fails to conform to the requirements of

this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a reheating.

## 14. Certification

14.1 When specified on the purchase order, the manufacturer or supplier, whichever is the responsible party in accordance with Section 12, shall furnish the purchaser a test report which includes the following:

14.1.1 Product description, grade, quantity, ASTM Specification Number and issue date,

14.1.2 Alloy grade (AISI, SAE, UNS, etc.), heat analysis, and heat number, and type of quench,

14.1.3 Results of hardness, tensile, and proof load tests, as applicable,

14.1.4 Statement of compliance to Protective Coating Specification (if applicable) and baking time and temperature. If not baked state "Not baked",

14.1.5 Statement of compliance with the surface discontinuity requirements of Specification F 788/F 788M,

14.1.6 Statement of compliance dimensionally,

14.1.7 Report, describe, or illustrate manufacturer's markings and their location,

14.1.8 Lot number, purchase order number, and date shipped,

14.1.9 Country of origin, and

14.1.10 Title and signature of the individual assigned certification responsibility by the company officers, with complete mailing address.

14.2 Failure to include all the required information on the test report shall be cause for rejection.

## 15. Product Marking

15.1 *Manufacturers Identification*—All products shall be marked by the manufacturer with a unique identifier to identify the manufacturer or private label distributor, as appropriate.

15.2 *Grade Identification:*

15.2.1 All Grade BC products shall be marked "BC".

15.2.2 All Grade BD products shall be marked "BD". In addition to the "BD" marking, the product may be marked with 6 radial lines 60° apart if manufactured from alloy steel conforming to the requirements of this specification.

15.2.3 Grade BD product in stock marked to the requirements of the —95 issue, shall be considered acceptable until October 1, 1999, to allow disposition of existing stock.

15.3 *Marking Location and Methods:*

15.3.1 Bolts shall be marked on the top of the bolt head.

15.3.2 Where studs have both coarse and fine threads, all markings shall appear on the coarse thread end or, if preferred, the manufacturer's identification shall appear on the fine thread end and the grade marking on the coarse thread end.

15.3.3 Continuous thread studs may be marked on either end.

15.3.4 All markings may be raised or depressed at the manufacturer's option.

15.3.5 Grade and manufacturer's or private label distributor's identification shall be separate and distinct. The two identifications shall preferably be in different locations and

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when on the same level shall be separated by at least two spaces.

**16. Packaging and Package Marking**

*16.1 Packaging:*

16.1.1 Unless otherwise specified, packaging shall be in accordance with Practice D 3951.

16.1.2 When special packaging requirements are required, they shall be defined at the time of the inquiry and order.

*16.2 Package Marking:*

16.2.1 Each shipping unit shall include or be plainly marked

with the following information:

- 16.2.1.1 ASTM designation and grade,
- 16.2.1.2 Size,
- 16.2.1.3 Name and brand or trademark of the manufacturer,
- 16.2.1.4 Number of pieces,
- 16.2.1.5 Purchase order number, and
- 16.2.1.6 Country of origin.

**17. Keywords**

17.1 alloy steel; bolts; steel; studs

**SUPPLEMENTARY REQUIREMENTS**

**S1. Marking**

S1.1 Studs that are continuously threaded with the same class of thread shall be marked on each end with the marking in accordance with Section 15.

S1.2 Marking small sizes (customarily less than 0.375 in. (9.525 mm)) may not be practical. Consult the producer for the minimum size that can be marked.

**SUMMARY OF CHANGES**

This section identifies the location of selected changes to this specification that have been incorporated since the –00 issue. For the convenience of the user, Committee F16 has highlighted those changes that may impact the use of this specification. This section may also include descriptions of the changes or reasons for the changes, or both.

**(1) Deleted the former 7.3.4 thread gaging limits. Not need. The requirements are covered in the referenced B 18 dimensional standards.**

**(2) Deleted the former Table 6 “Sample Sizes and acceptance Numbers for Inspection of Hot Dip or Mechanically Deposited Zinc Coated Threads” and the associated references to MIL-STD 105. Not needed.**

**(3) Revised 9.5, “Number of Tests,” to delete reference to Table 7 “Sample Sizes and Acceptance Numbers for Inspection of Mechanical and Dimensional Requirements.” Referenced Guide F 1470 for mechanical tests. Dimensional sampling is covered in the referenced dimensional standards.**

**(4) Deleted the former Table 7.**

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