

# **Pipe Hangers and Supports - Materials, Design, and Manufacture**

**Standard Practice  
Developed and Approved by the  
Manufacturers Standardization Society of the  
Valve and Fittings Industry, Inc.  
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This MSS Standard Practice was developed under the consensus of the MSS Technical Committee 403 and the MSS Coordinating Committee. The content of this Standard Practice is the result of the efforts of competent and concerned volunteers to provide an effective, clear, and non-exclusive specification that will benefit the industry as a whole. This MSS Standard Practice is intended as a basis for common practice by the manufacturer, the user, and the general public. The existence of an MSS Standard Practice does not in itself preclude the manufacture, sale, or use of products not conforming to the Standard Practice. Mandatory conformance is established only by reference in a code, specification, sales contract, or public law, as applicable.

This document has been substantially revised from the previous 1993 edition, INCLUDING A CHANGE IN ALLOWABLE STRESSES, WHICH MAY AFFECT PRODUCT LOAD RATINGS AND SAFETY FACTORS. It is suggested that if the user is interested in knowing what changes have been made, that direct page by page comparison should be made of this document.

Unless otherwise specifically noted in this MSS SP, any standard referred to herein is identified by the date of issue that was applicable to the referenced standard(s) at the date of issue of this MSS SP. (See Annex A).

In this Standard Practice all notes, annexes, tables, and figures are construed to be essential to the understanding of the message of the standard, and are considered part of the text unless noted as "supplemental". "Supplemental" information does not include mandatory requirements.

U.S. customary units in this SP are the standard; the metric (SI) units are only for reference.

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## FOREWORD

This standard was developed by a cooperative effort of representatives of the pipe hanger manufacturers. It is based on the best practice current at this time and on the collective experience of the industry. There are three companion standards—MSS SP-69 and MSS SP-89 relate to hanger and support fabrication, selection, application, and installation; MSS SP-127 relates to the design, selection, and application of bracing for piping systems subject to seismic - wind - dynamic loading. In addition, the MSS Hanger Committee has developed guidelines for pipe supports contractual relationships and on hanger terminology as covered in MSS SP-77 and MSS SP-90 respectively.

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## PIPE HANGERS AND SUPPORTS - MATERIALS, DESIGN, AND MANUFACTURE

### 1. SCOPE

1.1 This Standard Practice establishes the material, design, fabrication, and inspection criteria to be used in the manufacture of standard types of pipe hanger components.

1.2 This Standard Practice establishes the allowable tensile stress and design criteria for materials used in the design of hanger assemblies.

1.3 This Standard Practice also establishes minimum design load ratings for rigid pipe hanger assemblies (see Table 1).

1.4 This Standard Practice includes design criteria for springs and design characteristics for spring hangers.

1.5 Where applicable, design and manufacture of these products must also conform to Codes and Standards, such as:

ASME B31 Codes for Pressure Piping,

ASME Boiler and Pressure Vessel Codes,

UL203 Standard for Pipe Hanger Equipment for Fire Protection Service,

Factory Mutual FM 1951/1952/1953 Approval Standard for Pipe Hanger Components for Automatic Sprinkler Systems,

Local Building Codes.

### 2. OBJECTIVES

2.1 To serve as a guide for pipe hanger material selection, design, and manufacturing.

2.2 To enable the user to specify a minimum level of acceptance for pipe hanger design and performance.

2.3 To define types of hangers and supports that are illustrated in the Type Chart, Figure 1. Hangers and supports shown on the Type Chart indicate general types only and manufacturers' other standard products shall be acceptable under this Standard Practice if they meet dimensional and load rating limitations set forth in this Standard Practice.

2.4 To serve as a companion document to MSS SP-69 that provides recommendations for the selection and application of the types of pipe hangers and supports illustrated in the Type Chart, Figure 1.

2.5 To serve as a companion document to MSS SP-89 that provides recommendations for fabrication and installation of pipe hangers and supports.

### 3. MATERIALS

3.1 Materials commonly used in manufacturing pipe hangers and supports are listed in Tables 2 and A2.

3.2 Other materials may be used provided they comply with the allowable stress requirements of Sections 4.4 or 4.6.

3.3 Transfer of compressive loading from piping and equipment through a non-metallic material to the metallic components of a piping support is permissible, provided the transfer material complies with the requirements of Section 4.12.

**TABLE 1**  
**Minimum Design Load Ratings for Pipe Hanger Assemblies**

| Applicable to all components of complete assembly; including pipe attachment, rod, fixtures, and building attachment. |     |  |       | Notes:  |
|---|-----|--|-------|---|
| Nominal Pipe or Tube Size   |     | Minimum Design Load Ratings at Normal Temperature Range <sup>2</sup> |       |   |
| Inch  | mm  | Pounds   | kN    |   |
| 3/8   | 10  | 150  | 0.67  | 1. See Section 4 for allowable stresses and temperatures.   |
| 1/2   | 15  | 150  | 0.67  |   |
| 3/4   | 20  | 150  | 0.67  |   |
| 1   | 25  | 150  | 0.67  |   |
| 1 1/4   | 32  | 150  | 0.67  |   |
| 1 1/2   | 40  | 150  | 0.67  |   |
| 2   | 50  | 150  | 0.67  | 2. Normal temperature range is -20°F to 650°F (-29°C to 343°C) for carbon steel, -20°F to 450°F (-29°C to 231°C) for malleable iron and -20°F to 400°F (-29°C to 204°C) for gray iron.                      |
| 2 1/2   | 65  | 150  | 0.67  |   |
| 3   | 80  | 200  | 0.89  | 3. See Section 7.3 for minimum rod diameter restrictions.   |
| 3 1/2   | 90  | 210  | 0.93  |   |
| 4   | 100 | 250  | 1.11  | 4. For loads greater than those tabulated, hanger component load ratings shall be established by the manufacturer. Design shall be in accordance with all criteria as outlined in this document.            |
| 5   | 125 | 360  | 1.60  |   |
| 6   | 150 | 480  | 2.14  |   |
| 8   | 200 | 760  | 3.38  |   |
| 10  | 250 | 1120   | 4.98  | 5. Pipe attachment ratings for temperature ranges between 650°F to 750°F (343°C to 398°C) shall be reduced by the ratio of allowable stress at service temperature to the allowable stress at 650°F (343°C) |
| 12  | 300 | 1480   | 6.58  |   |
| 14  | 350 | 1710   | 7.61  | 6. For services over 750°F (398°C), attachments in direct contact with the pipe shall be designed to allowable stresses listed in Tables 2 and A2.  |
| 16  | 400 | 2130   | 9.47  |   |
| 18  | 450 | 2580   | 11.48 |   |
| 20  | 500 | 3060   | 13.61 |   |
| 24  | 600 | 3060   | 13.61 |   |
| 30  | 750 | 3500   | 15.57 |   |

#### 4. ALLOWABLE STRESSES, LOAD RATINGS, AND TEMPERATURES

4.1 The maximum allowable tensile stress for materials commonly used in the design of pipe hangers and supports are listed in Tables 2 and A2. Allowable values for the types of stress stated in Sections 4.1.1 through 4.1.5 shall be computed by multiplying the maximum allowable tensile stress by the applicable factor. Materials should not be used above the highest temperature for which a stress value appears.

| 4.1.1 <i>Tension:</i>              | Factor    |
|------------------------------------|-----------|
| a) On the gross area               | 1.0       |
| b) On the net section at pin holes | 0.9       |
| 4.1.2 <i>Bending</i>               | 1.0       |
| 4.1.3 <i>Shear</i>                 | 0.8       |
| 4.1.4 <i>Bearing</i>               | 1.5       |
| 4.1.5 <i>Compression</i>           | 1.0 (max) |

Allowable compressive stress must be reduced on the basis of structural stability and buckling (column action).

#### 4.1.6 Combined Stress Check

$$\frac{\text{Stress in Tension or Compression}}{\text{Allowable Tension or Compression}} + \frac{\text{Stress in Bending}}{\text{Allowable Bending}} \leq 1.0$$

#### 4.2 Welds

4.2.1 Maximum allowable shear stress in welds shall be limited to 80% of the maximum allowable stress of the weaker of the base metals being joined. Maximum allowable tension and bending stresses in welds shall be limited to the maximum allowable stress of the weaker of the base metals being joined.

4.3 Higher allowable stresses under well defined short-term loading conditions shall be as designated by the applicable codes.

4.4 Allowable stresses for materials not listed in Tables 2 and A2, produced in accordance with a recognized specification and with known physical properties shall be determined as the lower of the following values:

- a) 29% of minimum tensile strength at service temperature.
- b) 67% of minimum yield strength at service temperature.
- c) Such materials shall not be used where temperatures exceed 650°F (345°C) and shall not be welded to the piping or piping component.
- d) Refer to MSS SP-69 Section 4 for application specific considerations.

4.5 Allowable stresses for cast materials calculated in accordance with Section 4.4 shall be reduced by a casting quality factor of 20%. Allowable stress for gray iron castings shall be limited to 10% of minimum specified tensile strength.

4.6 For steel materials of unknown specification, a stress value of 30% of yield strength (0.2% offset) at room temperature may be used. The yield strength shall be established by tensile testing a sample of material in accordance with

ASTM A 370. The value corresponding to a 0.2% permanent strain (offset) is the material yield strength. The stress value so established shall not exceed 9500 psi (65.5 MPa)

4.7 Load ratings for threaded hanger rods made from carbon steel are shown in Table 3. Hanger rods made from all other materials shall also have a 25% reduction of the allowable stress. Load ratings shall be based on the thread root area (the 25% reduction is to allow for normal installation and service conditions).

4.8 Forged eye rods, and formed and welded eye rods shall have load capacities at least equal to those determined in accordance with Section 4.7 for the same nominal diameter. Formed but not welded eye rods shall have load capacities not greater than 40% of those determined in accordance with Section 4.7 for the same nominal diameter.

4.9 Capacities for U-bolts, loaded in tension, shall be limited to twice the capacity of hanger rods of the same material and diameter.

4.10 All threaded items, both external and internal, not covered by Sections 4.7, 4.8 or 4.9 need not be subjected to the 25% stress reduction.

4.11 Design temperature of hanger components in direct contact with the pipe shall be the temperature of the contained fluid. For conventional high temperature piping installations, a reduction in temperature of 100°F/in (2.2°C/mm) as measured from the outer pipe surfaces may be applied for strength calculations and material requirements. Alloy bolting within insulation may be furnished with ASTM A 194 Grade 2H nuts for line temperatures not exceeding 1050°F (566°C).

4.12 The compressive loading of non-metallic material shall be limited to the compression capacity of the material as rated in accordance with the governing ASTM specification for the specific material utilized with an appropriate safety factor for the specific material used.

**TABLE 2**  
**Materials and Allowable Stresses**

| ASTM Spec        | Grade   | Material Composition | Condition | Minimum Tensile (KSI) | Minimum Yield (KSI) | Maximum Allowable Stress in Tension (KSI) for Metal Temperatures Not Exceeding Degrees F |      |      |      |      |      |      |      |      |      |      |      |      |
|------------------|---------|----------------------|-----------|-----------------------|---------------------|--|------|------|------|------|------|------|------|------|------|------|------|------|
|                  |         |                      |           |                       |                     | -20 to 450   | 650  | 700  | 750  | 800  | 850  | 900  | 950  | 1000 | 1050 | 1100 | 1150 | 1200 |
| STRUCTURAL STEEL |         |                      |           |                       |                     |  |      |      |      |      |      |      |      |      |      |      |      |      |
| A36              | -       | Carbon Steel         | HR        | 58.0                  | 36.0                | 16.6   | 16.6 | 15.6 | 13.0 |      |      |      |      |      |      |      |      |      |
| (1) A500         | B       | Carbon Steel         | CF        | 58.0                  | 46.0                | 16.6   | 16.6 | 15.6 | 13.0 |      |      |      |      |      |      |      |      |      |
| (1) A500         | C       | Carbon Steel         | CF        | 62.0                  | 50.0                | 17.1   | 15.8 | 15.3 | 13.0 |      |      |      |      |      |      |      |      |      |
| (1) A501         | -       | Carbon Steel         | HR        | 58.0                  | 36.0                | 16.6   | 16.6 | 15.6 | 13.0 |      |      |      |      |      |      |      |      |      |
| A572             | 50      | Low Alloy            | -         | 65.0                  | 50.0                | 18.6   | 18.6 | 18.6 |      |      |      |      |      |      |      |      |      |      |
| A992             | -       | Carbon Steel         | -         | 65.0                  | 50.0                | 18.6   | 18.6 | 18.6 |      |      |      |      |      |      |      |      |      |      |
| RODS & BARS      |         |                      |           |                       |                     |  |      |      |      |      |      |      |      |      |      |      |      |      |
| A36              | -       | Carbon Steel         | HR        | 58.0                  | 36.0                | 16.6   | 16.6 | 15.6 | 13.0 |      |      |      |      |      |      |      |      |      |
| (1) A108         | 1018    | Carbon Steel         | CF        | 60.0                  | 40.0                | 17.1   | 17.1 |      |      |      |      |      |      |      |      |      |      |      |
| (1) A108         | 1141    | Carbon Steel         | CF        | 90.0                  | 80.0                | 23.1   | 23.1 |      |      |      |      |      |      |      |      |      |      |      |
| (1) A108         | 12L14   | Carbon Steel         | CF        | 78.0                  | 60.0                | 20.0   | 20.0 |      |      |      |      |      |      |      |      |      |      |      |
| A276             | 304     | 18 CR - 8 Ni         | -         | 75.0                  | 30.0                | 13.3   | 12   | 11.7 | 11.5 | 11.2 | 11   | 10.8 | 10.6 | 10.4 |      |      |      |      |
| A276             | 316     | 16 CR - 12 Ni - 2 Mo | -         | 75.0                  | 30.0                | 13.8   | 12.3 | 12.1 | 11.9 | 11.7 | 11.6 | 11.5 | 11.4 | 11.3 |      |      |      |      |
| A276             | 321     | 18 CR - 10 Ni - Ti   | -         | 75.0                  | 30.0                | 14.8   | 13.2 | 13   | 12.7 | 12.6 | 12.4 | 12.3 | 12.1 | 12   |      |      |      |      |
| A276             | 347     | 18 CR - 10 Ni - Cb   | -         | 75.0                  | 30.0                | 15.5   | 14   | 13.8 | 13.7 | 13.6 | 13.5 | 13.4 | 13.4 |      |      |      |      |      |
| A322             | 4130    | 1 CR - 1/5 Mo        | A         | 81.0                  | 52.0                | 20.8   | 20.8 |      |      |      |      |      |      |      |      |      |      |      |
| A322             | 4140    | 1 CR - 1/5 Mo        | A         | 95.0                  | 70.0                | 24.4   | 24.4 |      |      |      |      |      |      |      |      |      |      |      |
| A331             | 41L40   | 1 CR - 1/5 Mo        | A         | 95.0                  | 70.0                | 24.4   | 24.4 |      |      |      |      |      |      |      |      |      |      |      |
| (2) A479         | 304     | 18 CR - 8 Ni         | -         | 75.0                  | 30.0                | 13.3   | 12   | 11.7 | 11.5 | 11.2 | 11   | 10.8 | 10.6 | 10.4 | 10.1 | 9.8  | 7.7  | 6.1  |
| (2) A479         | 316     | 16 CR - 12 Ni - 2 Mo | -         | 75.0                  | 30.0                | 13.8   | 12.3 | 12.1 | 11.9 | 11.7 | 11.6 | 11.5 | 11.4 | 11.3 | 11.2 | 11   | 9.8  | 7.4  |
| (2) A479         | 321     | 18 CR - 10 Ni - Ti   | -         | 75.0                  | 30.0                | 14.8   | 13.2 | 13   | 12.7 | 12.6 | 12.4 | 12.3 | 12.1 | 12   | 9.6  | 6.9  | 5.0  | 3.6  |
| (2) A479         | 347     | 18 CR - 10 Ni - Cb   | -         | 75.0                  | 30.0                | 15.5   | 14   | 13.8 | 13.7 | 13.6 | 13.5 | 13.4 | 13.4 | 13.4 | 12.1 | 9.1  | 6.1  | 4.4  |
| (6) A564         | 630     | 17-4PH               | AH        | 145.0                 | 125.0               | 34.8   | 33.7 |      |      |      |      |      |      |      |      |      |      |      |
| (1) A575         | M1010   | Carbon Steel         | HR        | 47.0                  | 26.0                | 12.1   | 12.1 |      |      |      |      |      |      |      |      |      |      |      |
| (1) A575         | M1015   | Carbon Steel         | HR        | 50.0                  | 27.0                | 12.9   | 12.9 |      |      |      |      |      |      |      |      |      |      |      |
| (1) A575         | M1020   | Carbon Steel         | HR        | 55.0                  | 30.0                | 14.1   | 14.1 |      |      |      |      |      |      |      |      |      |      |      |
| (1) A575         | M1025   | Carbon Steel         | HR        | 58.0                  | 32.0                | 14.9   | 14.9 |      |      |      |      |      |      |      |      |      |      |      |
| (1) A576         | 1010    | Carbon Steel         | HR        | 47.0                  | 26.0                | 12.1   | 12.1 |      |      |      |      |      |      |      |      |      |      |      |
| (1) A576         | 1015    | Carbon Steel         | HR        | 50.0                  | 25.0                | 13.9   | 12.4 |      |      |      |      |      |      |      |      |      |      |      |
| (1) A576         | 1020    | Carbon Steel         | HR        | 55.0                  | 27.5                | 15.3   | 13.6 |      |      |      |      |      |      |      |      |      |      |      |
| (1) A576         | 1025    | Carbon Steel         | HR        | 60.0                  | 30.0                | 16.7   | 14.8 |      |      |      |      |      |      |      |      |      |      |      |
| A675             | 60      | Carbon Steel         | HR        | 60.0                  | 30.0                | 16.7   | 14.8 | 14.3 | 13.0 |      |      |      |      |      |      |      |      |      |
| A675             | 65      | Carbon Steel         | HR        | 65.0                  | 32.5                | 18.1   | 16.1 | 15.5 | 13.9 |      |      |      |      |      |      |      |      |      |
| A675             | 70      | Carbon Steel         | HR        | 70.0                  | 35.0                | 19.4   | 17.3 | 16.7 | 14.8 |      |      |      |      |      |      |      |      |      |
| PLATE            |         |                      |           |                       |                     |  |      |      |      |      |      |      |      |      |      |      |      |      |
| A36              | -       | Carbon Steel         | HR        | 58.0                  | 36.0                | 16.6   | 16.6 | 15.6 | 13.0 |      |      |      |      |      |      |      |      |      |
| (2,3) A240       | 304     | 18 CR - 8 Ni         | -         | 75.0                  | 30.0                | 13.3   | 12.0 | 11.7 | 11.5 | 11.2 | 11.0 | 10.8 | 10.6 | 10.4 | 10.1 | 9.8  | 7.7  | 6.1  |
| (2,3) A240       | 316     | 16 CR - 12 Ni - 2 Mo | -         | 75.0                  | 30.0                | 13.8   | 12.3 | 12.1 | 11.9 | 11.7 | 11.6 | 11.5 | 11.4 | 11.3 | 11.2 | 11.0 | 9.8  | 7.4  |
| (2,3) A240       | 321     | 18 CR - 10 Ni - Ti   | -         | 75.0                  | 30.0                | 14.8   | 13.2 | 13.0 | 12.7 | 12.6 | 12.4 | 12.3 | 12.1 | 12.0 | 9.6  | 6.9  | 5.0  | 3.6  |
| (2,3) A240       | 347     | 18 CR - 10 Ni - Cb   | -         | 75.0                  | 30.0                | 15.5   | 14.0 | 13.8 | 13.7 | 13.6 | 13.5 | 13.4 | 13.4 | 13.4 | 12.1 | 9.1  | 6.1  | 4.4  |
| A285             | A       | Carbon Steel         | HR        | 45.0                  | 24.0                | 12.9   | 11.9 | 11.5 | 10.7 |      |      |      |      |      |      |      |      |      |
| A285             | B       | Carbon Steel         | HR        | 50.0                  | 27.0                | 14.3   | 13.3 | 12.5 | 11.2 |      |      |      |      |      |      |      |      |      |
| A285             | C       | Carbon Steel         | HR        | 55.0                  | 30.0                | 15.7   | 14.8 | 14.3 | 13.0 |      |      |      |      |      |      |      |      |      |
| (7) A387         | 22      | 2 1/4 CR - 1 Mo      | -         | 60.0                  | 30.0                | 16.6   | 16.6 | 16.6 | 16.6 | 16.6 | 16.6 | 13.6 | 10.8 | 8.0  | 5.7  | 3.8  | 2.4  | 1.4  |
| (14) A387        | 91      | 9 CR - 1 Mo - V      | -         | 85.0                  | 60.0                | 24.1   | 23.4 | 22.9 | 22.2 | 21.3 | 20.3 | 19.1 | 17.8 | 16.3 | 14.0 | 10.3 | 7.0  | 4.3  |
| (15) A387        | 91      | 9 CR - 1 Mo - V      | -         | 85.0                  | 60.0                | 24.1   | 23.4 | 22.9 | 22.2 | 21.3 | 20.3 | 19.1 | 17.8 | 16.3 | 12.9 | 9.6  | 7.0  | 4.3  |
| A514             | t≤2.5in | Alloy Steel          | QT        | 110.0                 | 100.0               | 31.4   | 31.3 | 30.7 |      |      |      |      |      |      |      |      |      |      |
| A514             | t>2.5in | Alloy Steel          | QT        | 100.0                 | 90.0                | 28.5   | 28.4 | 28.0 |      |      |      |      |      |      |      |      |      |      |
| A515             | 60      | Carbon Steel         | HR        | 60.0                  | 32.0                | 17.1   | 15.8 | 15.3 | 13.0 |      |      |      |      |      |      |      |      |      |
| A515             | 65      | Carbon Steel         | HR        | 65.0                  | 35.0                | 18.6   | 17.3 | 16.7 | 13.9 |      |      |      |      |      |      |      |      |      |
| A515             | 70      | Carbon Steel         | HR        | 70.0                  | 38.0                | 20.0   | 18.8 | 18.1 | 14.8 |      |      |      |      |      |      |      |      |      |
| A516             | 60      | Carbon Steel         | HR        | 60.0                  | 32.0                | 17.1   | 15.8 | 15.3 | 13.0 |      |      |      |      |      |      |      |      |      |
| A516             | 65      | Carbon Steel         | HR        | 65.0                  | 35.0                | 18.6   | 17.3 | 16.7 | 13.9 |      |      |      |      |      |      |      |      |      |
| A516             | 70      | Carbon Steel         | HR        | 70.0                  | 38.0                | 20.0   | 18.8 | 18.1 | 14.8 |      |      |      |      |      |      |      |      |      |
| A517             | t≤2.5in | Alloy Steel          | QT        | 115.0                 | 100.0               | 32.8   | 32.7 | 32.2 |      |      |      |      |      |      |      |      |      |      |
| A517             | t>2.5in | Alloy Steel          | QT        | 105.0                 | 90.0                | 30.0   | 29.9 | 29.3 |      |      |      |      |      |      |      |      |      |      |

*Conditions: HR=Hot Rolled, CF=Cold Finished, QT=Quenched and Tempered, A=Annealed, AH=Age Hardened*



**TABLE 2**  
**Materials and Allowable Stresses (continued)**

| ASTM Spec     | Grade                    | Material Composition | Condition | Minimum Tensile (KSI) | Minimum Yield (KSI) | Maximum Allowable Stresses in Tension (KSI) for Metal Temperatures Not Exceeding Degrees F |                    |      |      |      |      |      |      |      |      |      |      |      |  |
|---------------|--------------------------|----------------------|-----------|-----------------------|---------------------|--|--------------------|------|------|------|------|------|------|------|------|------|------|------|--|
|               |                          |                      |           |                       |                     | -20 to 450   | 650                | 700  | 750  | 800  | 850  | 900  | 950  | 1000 | 1050 | 1100 | 1150 | 1200 |  |
| SHEET & STRIP |                          |                      |           |                       |                     |  |                    |      |      |      |      |      |      |      |      |      |      |      |  |
| A109          | #4                       | Carbon Steel         | CF        | 48.0                  | --                  | 12.3   | 12.3               |      |      |      |      |      |      |      |      |      |      |      |  |
| (2,3) A240    | 304                      | 18 CR - 8 Ni         | -         | 75.0                  | 30.0                | 13.3   | 12                 | 11.7 | 11.5 | 11.2 | 11   | 10.8 | 10.6 | 10.4 | 10.1 | 9.8  | 7.7  | 6.1  |  |
| (2,3) A240    | 316                      | 16 CR - 12 Ni - 2 Mo | -         | 75.0                  | 30.0                | 13.8   | 12.3               | 12.1 | 11.9 | 11.7 | 11.6 | 11.5 | 11.4 | 11.3 | 11.2 | 11   | 9.8  | 7.4  |  |
| (2,3) A240    | 321                      | 18 CR - 10 Ni - Ti   | -         | 75.0                  | 30.0                | 14.8   | 13.2               | 13   | 12.7 | 12.6 | 12.4 | 12.3 | 12.1 | 12   | 9.6  | 6.9  | 5    | 3.6  |  |
| (2,3) A240    | 347                      | 18 CR - 10 Ni - Cb   | -         | 75.0                  | 30.0                | 15.5   | 14                 | 13.8 | 13.7 | 13.6 | 13.5 | 13.4 | 13.4 | 13.4 | 12.1 | 9.1  | 6.1  | 4.4  |  |
| (1) A446      | A                        | Carbon Steel         | HR        | 45.0                  | 24.0                | 12.9   | 11.9               |      |      |      |      |      |      |      |      |      |      |      |  |
| (1) A526      | -                        | Carbon Steel         | HR        | 45.0                  | 24.0                | 12.9   | 11.9               |      |      |      |      |      |      |      |      |      |      |      |  |
| (1) A569      | (superceded by A1011 CS) |                      |           |                       |                     |  |                    |      |      |      |      |      |      |      |      |      |      |      |  |
| (1) A570      | (superceded by A1011 SS) |                      |           |                       |                     |  |                    |      |      |      |      |      |      |      |      |      |      |      |  |
| (1) A635      | 1010                     | Carbon Steel         | HR        | 47.0                  | 26.0                | 12.1   | 12.1               |      |      |      |      |      |      |      |      |      |      |      |  |
| A653 SS       | 33                       | Pregalv. Steel       | -         | 45.0                  | 33.0                | 12.9   | 12.9               |      |      |      |      |      |      |      |      |      |      |      |  |
| (1,5) A653 CS | -                        | Pregalv. Steel       | -         | --                    | 30.0                | 11.7   | 11.7               |      |      |      |      |      |      |      |      |      |      |      |  |
| (1) A659      | 1020                     | Carbon Steel         | HR        | 50.0                  | 27.0                | 14.3   | 13.3               |      |      |      |      |      |      |      |      |      |      |      |  |
| (6) A693      | 630                      | 17-4PH               | AH        | 185.0                 | 160.0               | 39.8   | 38.5               |      |      |      |      |      |      |      |      |      |      |      |  |
| (1) A1011 SS  | 33                       | Carbon Steel         | HR        | 52.0                  | 33.0                | 14.9   | 14.9               |      |      |      |      |      |      |      |      |      |      |      |  |
| (1) A1011 SS  | 40                       | Carbon Steel         | HR        | 55.0                  | 40.0                | 15.7   | 15.7               |      |      |      |      |      |      |      |      |      |      |      |  |
| (1) A1011 CS  | -                        | Carbon Steel         | HR        | --                    | 30.0                | 13.5   | 13.5               |      |      |      |      |      |      |      |      |      |      |      |  |
| PIPE & TUBING |                          |                      |           |                       |                     |  |                    |      |      |      |      |      |      |      |      |      |      |      |  |
| A53           | A                        | Carbon Steel         | HR        | 48.0                  | 30.0                | 13.7   | 13.7               | 12.5 | 10.7 |      |      |      |      |      |      |      |      |      |  |
| A53           | B                        | Carbon Steel         | HR        | 60.0                  | 35.0                | 17.1   | 17.1               | 15.6 | 13.0 |      |      |      |      |      |      |      |      |      |  |
| A106          | A                        | Carbon Steel         | HR        | 48.0                  | 30.0                | 13.7   | 13.7               | 12.5 | 10.7 |      |      |      |      |      |      |      |      |      |  |
| A106          | B                        | Carbon Steel         | HR        | 60.0                  | 35.0                | 17.1   | 17.1               | 15.6 | 13.0 |      |      |      |      |      |      |      |      |      |  |
| A106          | C                        | Carbon Steel         | HR        | 70.0                  | 40.0                | 20.0   | 19.8               | 18.3 | 14.8 |      |      |      |      |      |      |      |      |      |  |
| (2) A312      | 304                      | 18 CR - 8 Ni         | -         | 75.0                  | 30.0                | 11.3   | 10.2               | 10   | 9.8  | 9.6  | 9.4  | 9.2  | 9    | 8.8  | 8.6  | 8.3  | 6.6  | 5.2  |  |
| (2) A312      | 316                      | 16 CR - 12 Ni - 2 Mo | -         | 75.0                  | 30.0                | 11.7   | 10.5               | 10.3 | 10.1 | 10   | 9.9  | 9.8  | 9.7  | 9.6  | 9.5  | 9.4  | 8.3  | 6.3  |  |
| (2) A312      | 321                      | 18 CR - 10 Ni - Ti   | -         | 75.0                  | 30.0                | 12.6   | 11.2               | 11   | 10.8 | 10.7 | 10.5 | 10.4 | 10.3 | 10.2 | 8.2  | 5.9  | 4.3  | 3.1  |  |
| (2) A312      | 347                      | 18 CR - 10 Ni - Cb   | -         | 75.0                  | 30.0                | 13.2   | 11.9               | 11.8 | 11.6 | 11.5 | 11.5 | 11.4 | 11.4 | 11.4 | 10.3 | 7.8  | 5.2  | 3.8  |  |
| A335          | P11                      | 1 1/4 CR - 1/2 Mo    | HR        | 60.0                  | 30.0                | 16.5   | 15.4               | 15.1 | 14.8 | 14.4 | 14.0 | 13.6 | 9.3  | 6.3  | 4.2  | 2.8  | 1.9  | 1.2  |  |
| A335          | P22                      | 2 1/4 CR - 1 Mo      | HR        | 60.0                  | 30.0                | 16.6   | 16.6               | 16.6 | 16.6 | 16.6 | 16.6 | 13.6 | 10.8 | 8.0  | 5.7  | 3.8  | 2.4  | 1.4  |  |
| A335          | P91                      | 9 CR - 1 Mo - V      | -         | 85.0                  | 60.0                | 24.1   | 23.4               | 22.9 | 22.2 | 21.3 | 20.3 | 19.1 | 17.8 | 16.3 | 14.0 | 10.3 | 7.0  | 4.3  |  |
| A513          | 1015                     | Carbon Steel         | HR        | 50.0                  | 32.0                | 14.3   | 14.3               |      |      |      |      |      |      |      |      |      |      |      |  |
| A513          | 1020                     | Carbon Steel         | HR        | 50.0                  | 32.0                | 14.3   | 14.3               |      |      |      |      |      |      |      |      |      |      |      |  |
| A513          | 1025                     | Carbon Steel         | HR        | 55.0                  | 35.0                | 15.7   | 15.7               |      |      |      |      |      |      |      |      |      |      |      |  |
| A519          | 1018                     | Carbon Steel         | HR        | 50.0                  | 32.0                | 14.3   | 14.3               |      |      |      |      |      |      |      |      |      |      |      |  |
| CASTINGS      |                          |                      |           |                       |                     |  |                    |      |      |      |      |      |      |      |      |      |      |      |  |
| A47           | 32510                    | Malleable Iron       | A         | 50.0                  | 32.5                | 11.4   |                    |      |      |      |      |      |      |      |      |      |      |      |  |
| A47           | 35018                    | Malleable Iron       | A         | 53.0                  | 35.0                | 12.1   |                    |      |      |      |      |      |      |      |      |      |      |      |  |
| A48           | 20                       | Gray Iron            | -         | 20.0                  | --                  | 2.0  | (limited to 400°F) |      |      |      |      |      |      |      |      |      |      |      |  |
| A48           | 25                       | Gray Iron            | -         | 25.0                  | --                  | 2.5  | (limited to 400°F) |      |      |      |      |      |      |      |      |      |      |      |  |
| A48           | 30                       | Gray Iron            | -         | 30.0                  | --                  | 3.0  | (limited to 400°F) |      |      |      |      |      |      |      |      |      |      |      |  |
| A126          | A                        | Gray Iron            | -         | 21.0                  | --                  | 2.0  | (limited to 400°F) |      |      |      |      |      |      |      |      |      |      |      |  |
| A126          | B                        | Gray Iron            | -         | 31.0                  | --                  | 3.0  | (limited to 400°F) |      |      |      |      |      |      |      |      |      |      |      |  |
| A126          | C                        | Gray Iron            | -         | 41.0                  | --                  | 4.0  | (limited to 400°F) |      |      |      |      |      |      |      |      |      |      |      |  |
| A197          | -                        | Malleable Iron       | A         | 40.0                  | 30.0                | 9.1  |                    |      |      |      |      |      |      |      |      |      |      |      |  |
| A216          | WCA                      | Carbon Steel         | N         | 60.0                  | 30.0                | 16.7   | 14.8               | 14.3 |      |      |      |      |      |      |      |      |      |      |  |
| A216          | WCB                      | Carbon Steel         | N         | 70.0                  | 36.0                | 19.8   | 17.8               | 17.2 |      |      |      |      |      |      |      |      |      |      |  |
| A217          | WC6                      | 1 1/4 CR - 1/2 Mo    | NT        | 70.0                  | 40.0                | 20.0   | 20.0               | 20.0 |      |      |      |      |      |      |      |      |      |      |  |
| A217          | WC9                      | 2 1/4 CR - 1 Mo      | NT        | 70.0                  | 40.0                | 19.3   | 19.1               | 18.8 |      |      |      |      |      |      |      |      |      |      |  |
| A351          | CF8                      | 18 CR - 8 Ni         | -         | 70.0                  | 30.0                | 10.6   | 9.6                | 9.4  | 9.2  | 9.0  |      |      |      |      |      |      |      |      |  |
| A351          | CF8C                     | 18 CR - 10 Ni - Cb   | -         | 70.0                  | 30.0                | 12.4   | 11.2               | 11.0 | 11.0 | 10.9 |      |      |      |      |      |      |      |      |  |
| A351          | CF8M                     | 16 CR - 12 Ni - 2 Mo | -         | 70.0                  | 30.0                | 11.0   | 9.8                | 9.7  | 9.5  | 9.4  |      |      |      |      |      |      |      |      |  |
| A395          | -                        | Ductile Iron         | -         | 60.0                  | 40.0                | 13.7   | 13.7               |      |      |      |      |      |      |      |      |      |      |      |  |
| A536          | 65-45-12                 | Ductile Iron         | -         | 65.0                  | 45.0                | 14.9   | 14.9               |      |      |      |      |      |      |      |      |      |      |      |  |

*Conditions: HR=Hot Rolled, CF=Cold Finished, A=Annealed, AH=Age Hardened, N=Normalized, NT=Normalized and Tempered*

**TABLE 2**  
**Materials and Allowable Stresses (continued)**

| ASTM Spec  | Grade  | Material Composition   | Condition | Minimum Tensile (KSI) | Minimum Yield (KSI) | Maximum Allowable Stresses in Tension (KSI) for Metal Temperatures Not Exceeding Degrees F |      |      |      |      |      |      |      |      |      |      |      |      |  |
|--|--------|------------------------|-----------|-----------------------|---------------------|--|------|------|------|------|------|------|------|------|------|------|------|------|--|
|  |        |                        |           |                       |                     | -20 to 450   | 650  | 700  | 750  | 800  | 850  | 900  | 950  | 1000 | 1050 | 1100 | 1150 | 1200 |  |
| FORGINGS   |        |                        |           |                       |                     |  |      |      |      |      |      |      |      |      |      |      |      |      |  |
| A105   | -      | Carbon Steel           | HT        | 70.0                  | 36.0                | 19.8   | 17.8 | 17.2 |      |      |      |      |      |      |      |      |      |      |  |
| A181   | 70     | Carbon Steel           | -         | 70.0                  | 36.0                | 19.8   | 17.8 | 17.2 |      |      |      |      |      |      |      |      |      |      |  |
| A182   | F11    | 1 1/4 CR - 1/2 Mo - Si | A         | 70.0                  | 40.0                | 20.0   | 20.0 | 20.0 | 19.7 | 19.2 | 18.7 | 13.7 | 9.3  | 6.3  | 4.2  | 2.8  | 1.9  | 1.2  |  |
| A182   | F22    | 2 1/4 CR - 1 Mo        | A         | 75.0                  | 45.0                | 20.5   | 20.2 | 20.0 | 19.7 | 19.3 | 18.7 | 15.8 | 11.4 | 7.8  | 5.1  | 3.2  | 2.0  | 1.2  |  |
| (2) A182   | F304   | 18 CR - 8 Ni           | HT        | 75.0                  | 30.0                | 13.3   | 12.0 | 11.7 | 11.5 | 11.2 | 11.0 | 10.8 | 10.6 | 10.4 | 10.1 | 9.8  | 7.7  | 6.1  |  |
| (2) A182   | F316   | 16 CR - 12 Ni - 2 Mo   | HT        | 75.0                  | 30.0                | 13.8   | 12.3 | 12.1 | 11.9 | 11.8 | 11.6 | 11.5 | 11.4 | 11.3 | 11.2 | 11.0 | 9.8  | 7.4  |  |
| (2) A182   | F321   | 18 CR - 10 Ni - Ti     | HT        | 75.0                  | 30.0                | 14.8   | 13.2 | 13.0 | 12.7 | 12.6 | 12.4 | 12.3 | 12.1 | 12.0 | 9.6  | 6.9  | 5.0  | 3.6  |  |
| (2) A182   | F347   | 18 CR - 10 Ni - Cb     | HT        | 75.0                  | 30.0                | 15.5   | 14.0 | 13.8 | 13.7 | 13.6 | 13.5 | 13.4 | 13.4 | 13.4 | 12.1 | 9.1  | 6.1  | 4.4  |  |
| A668   | A      | Carbon Steel           | -         | 47.0                  | --                  | 13.4   | 13.4 |      |      |      |      |      |      |      |      |      |      |      |  |
| A668   | B      | Carbon Steel           | A         | 60.0                  | 30.0                | 17.1   | 17.1 |      |      |      |      |      |      |      |      |      |      |      |  |
| A668   | C      | Carbon Steel           | A         | 66.0                  | 33.0                | 18.8   | 18.8 |      |      |      |      |      |      |      |      |      |      |      |  |
| A668   | D      | Carbon Steel           | N         | 75.0                  | 37.5                | 21.4   | 21.4 |      |      |      |      |      |      |      |      |      |      |      |  |
| A668   | E      | Carbon Steel           | DNT       | 83.0                  | 43.0                | 23.7   | 23.7 |      |      |      |      |      |      |      |      |      |      |      |  |
| (16) A668  | F      | Carbon Steel           | QT        | 90.0                  | 55.0                | 25.7   | 25.7 |      |      |      |      |      |      |      |      |      |      |      |  |
| BOLTING  |        |                        |           |                       |                     |  |      |      |      |      |      |      |      |      |      |      |      |      |  |
| (10) A193  | B7     | 1 CR - 1/5 Mo          | HT        | 125.0                 | 105.0               | 25   | 25   | 25   | 23.6 | 21   | 17   | 12.5 | 8.5  | 4.5  |      |      |      |      |  |
| (11) A193  | B7     | 1 CR - 1/5 Mo          | HT        | 115.0                 | 95.0                | 23   | 23   | 23   | 22.5 | 20   | 16.3 | 12.5 | 8.5  | 4.5  |      |      |      |      |  |
| (12) A193  | B7     | 1 CR - 1/5 Mo          | HT        | 100.0                 | 75.0                | 18.8   | 18.8 | 18.8 | 18   | 16.3 | 12.5 | 8.5  | 4.5  |      |      |      |      |      |  |
| (2,3,4) A193   | B8     | 18 CR - 8 Ni           | -         | 75.0                  | 30.0                | 13.3   | 12   | 11.8 | 11.5 | 11.2 | 11   | 10.8 | 10.6 | 10.4 | 10.1 | 9.8  | 7.7  | 6    |  |
| (2,3,4) A193   | B8M    | 16 CR - 12 Ni - 2 Mo   | -         | 75.0                  | 30.0                | 13.8   | 12.3 | 12.1 | 11.9 | 11.7 | 11.6 | 11.5 | 11.4 | 11.3 | 11.2 | 11   | 9.8  | 7.4  |  |
| (2,3,4) A193   | B8C    | 18 CR - 10 Ni - Cb     | -         | 75.0                  | 30.0                | 15.2   | 14.1 | 13.8 | 13.7 | 13.6 | 13.5 | 13.5 | 13.4 | 13.4 | 12.1 | 9.1  | 6.1  | 4.4  |  |
| (2,3,4) A193   | B8T    | 18 CR - 10 Ni - Ti     | -         | 75.0                  | 30.0                | 14.8   | 13.3 | 12.9 | 12.7 | 12.5 | 12.4 | 12.3 | 12.1 | 12   | 9.6  | 6.9  | 5    | 3.6  |  |
| A307   | A      | Carbon Steel           | -         | 60.0                  | --                  | 17.1   | 17.1 |      |      |      |      |      |      |      |      |      |      |      |  |
| A307   | B      | Carbon Steel           | -         | 60.0                  | --                  | 17.1   | 17.1 |      |      |      |      |      |      |      |      |      |      |      |  |
| (8) A325   | TYPE 2 | Carbon Steel           | HT        | 120.0                 | --                  | 34.3   | 34.3 |      |      |      |      |      |      |      |      |      |      |      |  |
| (9) A325   | TYPE 2 | Carbon Steel           | HT        | 105.0                 | --                  | 30.0   | 30.0 |      |      |      |      |      |      |      |      |      |      |      |  |
| (8) A449   | -      | Carbon Steel           | QT        | 120.0                 | --                  | 26.2   | 26.2 |      |      |      |      |      |      |      |      |      |      |      |  |
| (9) A449   | -      | Carbon Steel           | QT        | 105.0                 | --                  | 22.8   | 22.8 |      |      |      |      |      |      |      |      |      |      |      |  |
| (13) A449  | -      | Carbon Steel           | QT        | 90.0                  | --                  | 16.5   | 16.5 |      |      |      |      |      |      |      |      |      |      |      |  |
| A490   | -      | Alloy Steel            | QT        | 150.0                 | 130.0               | 42.9   | 42.9 |      |      |      |      |      |      |      |      |      |      |      |  |
| RIVETS & NUTS  |        |                        |           |                       |                     |  |      |      |      |      |      |      |      |      |      |      |      |      |  |
| A194   | ALL    | -                      | -         | Product Specification |                     |  |      |      |      |      |      |      |      |      |      |      |      |      |  |
| A502   | -      | Carbon Steel           | -         | 52.0                  | 28.0                | 14.9   | 14.9 |      |      |      |      |      |      |      |      |      |      |      |  |
| A563   | ALL    | Carbon Steel           | -         | Product Specification |                     |  |      |      |      |      |      |      |      |      |      |      |      |      |  |
| SPRINGS See Figures 2 and 3 for Materials and Stresses |        |                        |           |                       |                     |  |      |      |      |      |      |      |      |      |      |      |      |      |  |

*Conditions: A=Annealed, N=Normalized, DNT=Double Normalized and Tempered, QT=Quenched and Tempered, HT=Heat Treated*

**NOTES:**

- Allowable stresses for these materials are based upon those of comparable materials of similar chemical properties.
- For temperatures above 1000°F, these stress values apply only when the carbon content is 0.04% or higher based on heat analysis.
- For temperatures above 1000°F, these stress values may be used only if the material is heat treated by treating it to a minimum temperature of 1900°F and quenching in water or rapidly cooling by other means.
- Class 1 only.
- Type B only.
- Age hardened at 1075°F.
- For temperatures above 850°F, these stress values apply only when the carbon content is 0.05% or higher based on heat analysis.
- For bolt diameters 1 inch and less.
- For bolt diameters greater than 1 inch through 1 1/2 inch.
- For bolt diameters 2 1/2 inch and less.
- For bolt diameters greater than 2 1/2 inch through 4 inch.
- For diameters greater than 4 inch.
- For bolt diameters greater than 1 1/2 inch through 3 inch.
- For material thickness 3 inch and less.
- For material thickness greater than 3 inch.
- For diameters 4 inch and less.

**TABLE A2**  
**Materials and Allowable Stresses, Metric Units**

| Maximum Allowable Stresses in Tension (MPa) for Metal Temperatures Not Exceeding Degrees C |            |                      |           |                       |                     |            |       |       |       |       |       |       |       |       |      |      |      |      |
|--|------------|----------------------|-----------|-----------------------|---------------------|------------|-------|-------|-------|-------|-------|-------|-------|-------|------|------|------|------|
| ASTM Spec  | Grade      | Material Composition | Condition | Minimum Tensile (MPa) | Minimum Yield (MPa) | -29 to 232 | 343   | 371   | 399   | 427   | 454   | 482   | 510   | 538   | 566  | 593  | 621  | 649  |
|  |            |                      |           |                       |                     |            |       |       |       |       |       |       |       |       |      |      |      |      |
| STRUCTURAL STEEL   |            |                      |           |                       |                     |            |       |       |       |       |       |       |       |       |      |      |      |      |
| A36  | -          | Carbon Steel         | HR        | 399.9                 | 248.2               | 114.5      | 114.5 | 107.6 | 89.6  |       |       |       |       |       |      |      |      |      |
| (1) A500   | B          | Carbon Steel         | CF        | 399.9                 | 317.2               | 114.5      | 114.5 | 107.6 | 89.6  |       |       |       |       |       |      |      |      |      |
| (1) A500   | C          | Carbon Steel         | CF        | 427.5                 | 344.7               | 117.9      | 108.9 | 105.5 | 89.6  |       |       |       |       |       |      |      |      |      |
| (1) A501   | -          | Carbon Steel         | HR        | 399.9                 | 248.2               | 114.5      | 114.5 | 107.6 | 89.6  |       |       |       |       |       |      |      |      |      |
| A572   | 50         | Low Alloy            | -         | 448.2                 | 344.7               | 128.2      | 128.2 | 128.2 |       |       |       |       |       |       |      |      |      |      |
| A992   | -          | Carbon Steel         | -         | 448.2                 | 344.7               | 128.2      | 128.2 | 128.2 |       |       |       |       |       |       |      |      |      |      |
| RODS & BARS  |            |                      |           |                       |                     |            |       |       |       |       |       |       |       |       |      |      |      |      |
| A36  | -          | Carbon Steel         | HR        | 399.9                 | 248.2               | 114.5      | 114.5 | 107.6 | 89.6  |       |       |       |       |       |      |      |      |      |
| (1) A108   | 1018       | Carbon Steel         | CF        | 413.7                 | 275.8               | 117.9      | 117.9 |       |       |       |       |       |       |       |      |      |      |      |
| (1) A108   | 1141       | Carbon Steel         | CF        | 620.5                 | 551.6               | 159.3      | 159.3 |       |       |       |       |       |       |       |      |      |      |      |
| (1) A108   | 12L14      | Carbon Steel         | CF        | 537.8                 | 413.7               | 137.9      | 137.9 |       |       |       |       |       |       |       |      |      |      |      |
| A276   | 304        | 18 CR - 8 Ni         | -         | 517.1                 | 206.8               | 91.7       | 82.7  | 80.7  | 79.3  | 77.2  | 75.8  | 74.5  | 73.1  | 71.7  |      |      |      |      |
| A276   | 316        | 16 CR - 12 Ni - 2 Mo | -         | 517.1                 | 206.8               | 95.1       | 84.8  | 83.4  | 82.0  | 80.7  | 80.0  | 79.3  | 78.6  | 77.9  |      |      |      |      |
| A276   | 321        | 18 CR - 10 Ni - Ti   | -         | 517.1                 | 206.8               | 102.0      | 91.0  | 89.6  | 87.6  | 86.9  | 85.5  | 84.8  | 83.4  | 82.7  |      |      |      |      |
| A276   | 347        | 18 CR - 10 Ni - Cb   | -         | 517.1                 | 206.8               | 106.9      | 96.5  | 95.1  | 94.5  | 93.8  | 93.1  | 92.4  | 92.4  | 92.4  |      |      |      |      |
| A322   | 4130       | 1 CR - 1/5 Mo        | A         | 558.5                 | 358.5               | 143.4      | 143.4 |       |       |       |       |       |       |       |      |      |      |      |
| A322   | 4140       | 1 CR - 1/5 Mo        | A         | 655.0                 | 482.6               | 168.2      | 168.2 |       |       |       |       |       |       |       |      |      |      |      |
| A331   | 41L40      | 1 CR - 1/5 Mo        | A         | 655.0                 | 482.6               | 168.2      | 168.2 |       |       |       |       |       |       |       |      |      |      |      |
| (2) A479   | 304        | 18 CR - 8 Ni         | -         | 517.1                 | 206.8               | 91.7       | 82.7  | 80.7  | 79.3  | 77.2  | 75.8  | 74.5  | 73.1  | 71.7  | 69.6 | 67.6 | 53.1 | 42.1 |
| (2) A479   | 316        | 16 CR - 12 Ni - 2 Mo | -         | 517.1                 | 206.8               | 95.1       | 84.8  | 83.4  | 82.0  | 80.7  | 80.0  | 79.3  | 78.6  | 77.9  | 77.2 | 75.8 | 67.6 | 51.0 |
| (2) A479   | 321        | 18 CR - 10 Ni - Ti   | -         | 517.1                 | 206.8               | 102.0      | 91.0  | 89.6  | 87.6  | 86.9  | 85.5  | 84.8  | 83.4  | 82.7  | 66.2 | 47.6 | 34.5 | 24.8 |
| (2) A479   | 347        | 18 CR - 10 Ni - Cb   | -         | 517.1                 | 206.8               | 106.9      | 96.5  | 95.1  | 94.5  | 93.8  | 93.1  | 92.4  | 92.4  | 92.4  | 83.4 | 62.7 | 42.1 | 30.3 |
| (6) A564   | 630        | 17-4PH               | AH        | 999.7                 | 861.8               | 239.9      | 232.4 |       |       |       |       |       |       |       |      |      |      |      |
| (1) A575   | M1010      | Carbon Steel         | HR        | 324.1                 | 179.3               | 82.7       | 82.7  |       |       |       |       |       |       |       |      |      |      |      |
| (1) A575   | M1015      | Carbon Steel         | HR        | 344.7                 | 186.2               | 88.3       | 88.3  |       |       |       |       |       |       |       |      |      |      |      |
| (1) A575   | M1020      | Carbon Steel         | HR        | 379.2                 | 206.8               | 97.2       | 97.2  |       |       |       |       |       |       |       |      |      |      |      |
| (1) A575   | M1025      | Carbon Steel         | HR        | 399.9                 | 220.6               | 102.7      | 102.7 |       |       |       |       |       |       |       |      |      |      |      |
| (1) A576   | 1010       | Carbon Steel         | HR        | 324.1                 | 179.3               | 82.7       | 82.7  |       |       |       |       |       |       |       |      |      |      |      |
| (1) A576   | 1015       | Carbon Steel         | HR        | 344.7                 | 172.4               | 95.8       | 85.5  |       |       |       |       |       |       |       |      |      |      |      |
| (1) A576   | 1020       | Carbon Steel         | HR        | 379.2                 | 189.6               | 105.5      | 93.8  |       |       |       |       |       |       |       |      |      |      |      |
| (1) A576   | 1025       | Carbon Steel         | HR        | 413.7                 | 206.8               | 115.1      | 102.0 |       |       |       |       |       |       |       |      |      |      |      |
| A675   | 60         | Carbon Steel         | HR        | 413.7                 | 206.8               | 115.1      | 102.0 | 98.6  | 89.6  |       |       |       |       |       |      |      |      |      |
| A675   | 65         | Carbon Steel         | HR        | 448.2                 | 224.1               | 124.8      | 111.0 | 106.9 | 95.8  |       |       |       |       |       |      |      |      |      |
| A675   | 70         | Carbon Steel         | HR        | 482.6                 | 241.3               | 133.8      | 119.3 | 115.1 | 102.0 |       |       |       |       |       |      |      |      |      |
| PLATE  |            |                      |           |                       |                     |            |       |       |       |       |       |       |       |       |      |      |      |      |
| A36  | -          | Carbon Steel         | HR        | 399.9                 | 248.2               | 114.5      | 114.5 | 107.6 | 89.6  |       |       |       |       |       |      |      |      |      |
| (2,3) A240   | 304        | 18 CR - 8 Ni         | -         | 517.1                 | 206.8               | 91.7       | 82.7  | 80.7  | 79.3  | 77.2  | 75.8  | 74.5  | 73.1  | 71.7  | 69.6 | 67.6 | 53.1 | 42.1 |
| (2,3) A240   | 316        | 16 CR - 12 Ni - 2 Mo | -         | 517.1                 | 206.8               | 95.1       | 84.8  | 83.4  | 82.0  | 80.7  | 80.0  | 79.3  | 78.6  | 77.9  | 77.2 | 75.8 | 67.6 | 51.0 |
| (2,3) A240   | 321        | 18 CR - 10 Ni - Ti   | -         | 517.1                 | 206.8               | 102.0      | 91.0  | 89.6  | 87.6  | 86.9  | 85.5  | 84.8  | 83.4  | 82.7  | 66.2 | 47.6 | 34.5 | 24.8 |
| (2,3) A240   | 347        | 18 CR - 10 Ni - Cb   | -         | 517.1                 | 206.8               | 106.9      | 96.5  | 95.1  | 94.5  | 93.8  | 93.1  | 92.4  | 92.4  | 92.4  | 83.4 | 62.7 | 42.1 | 30.3 |
| A285   | A          | Carbon Steel         | HR        | 310.3                 | 165.5               | 88.9       | 82.0  | 79.3  | 73.8  |       |       |       |       |       |      |      |      |      |
| A285   | B          | Carbon Steel         | HR        | 344.7                 | 186.2               | 98.6       | 91.7  | 86.2  | 77.2  |       |       |       |       |       |      |      |      |      |
| A285   | C          | Carbon Steel         | HR        | 379.2                 | 206.8               | 108.2      | 102.0 | 98.6  | 89.6  |       |       |       |       |       |      |      |      |      |
| (7) A387   | 22         | 2 1/4 CR - 1 Mo      | -         | 413.7                 | 206.8               | 114.5      | 114.5 | 114.5 | 114.5 | 114.5 | 114.5 | 93.8  | 74.5  | 55.2  | 39.3 | 26.2 | 16.5 | 9.7  |
| (14) A387  | 91         | 9 CR - 1 Mo - V      | -         | 586.1                 | 413.7               | 166.2      | 161.3 | 157.9 | 153.1 | 146.9 | 140.0 | 131.7 | 122.7 | 112.4 | 96.5 | 71.0 | 48.3 | 29.6 |
| (15) A387  | 91         | 9 CR - 1 Mo - V      | -         | 586.1                 | 413.7               | 166.2      | 161.3 | 157.9 | 153.1 | 146.9 | 140.0 | 131.7 | 122.7 | 112.4 | 88.9 | 66.2 | 48.3 | 29.6 |
| A514   | t ≤ 6.35cm | Alloy Steel          | QT        | 758.4                 | 689.5               | 216.5      | 215.8 | 211.7 |       |       |       |       |       |       |      |      |      |      |
| A514   | t > 6.35cm | Alloy Steel          | QT        | 689.5                 | 620.5               | 196.5      | 195.8 | 193.1 |       |       |       |       |       |       |      |      |      |      |
| A515   | 60         | Carbon Steel         | HR        | 413.7                 | 220.6               | 117.9      | 108.9 | 105.5 | 89.6  |       |       |       |       |       |      |      |      |      |
| A515   | 65         | Carbon Steel         | HR        | 448.2                 | 241.3               | 128.2      | 119.3 | 115.1 | 95.8  |       |       |       |       |       |      |      |      |      |
| A515   | 70         | Carbon Steel         | HR        | 482.6                 | 262.0               | 137.9      | 129.6 | 124.8 | 102.0 |       |       |       |       |       |      |      |      |      |
| A516   | 60         | Carbon Steel         | HR        | 413.7                 | 220.6               | 117.9      | 108.9 | 105.5 | 89.6  |       |       |       |       |       |      |      |      |      |
| A516   | 65         | Carbon Steel         | HR        | 448.2                 | 241.3               | 128.2      | 119.3 | 115.1 | 95.8  |       |       |       |       |       |      |      |      |      |
| A516   | 70         | Carbon Steel         | HR        | 482.6                 | 262.0               | 137.9      | 129.6 | 124.8 | 102.0 |       |       |       |       |       |      |      |      |      |
| A517   | t ≤ 6.35cm | Alloy Steel          | QT        | 792.9                 | 689.5               | 226.1      | 225.5 | 222.0 |       |       |       |       |       |       |      |      |      |      |
| A517   | t > 6.35cm | Alloy Steel          | QT        | 723.9                 | 620.5               | 206.8      | 206.2 | 202.0 |       |       |       |       |       |       |      |      |      |      |

*Conditions: HR=Hot Rolled, CF=Cold Finished, QT=Quenched and Tempered, A=Annealed, AH=Age Hardened*

**TABLE A2**  
**Materials and Allowable Stresses, Metric Units (continued)**

| ASTM Spec     | Grade                    | Material Composition | Condition | Minimum Tensile (MPa) | Minimum Yield (MPa) | Maximum Allowable Stresses in Tension (MPa) for Metal Temperatures Not Exceeding Degrees C |                    |       |       |       |       |       |       |       |       |       |       |       |       |       |
|---------------|--------------------------|----------------------|-----------|-----------------------|---------------------|--|--------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|               |                          |                      |           |                       |                     | -29 to 232   | 343                | 371   | 399   | 427   | 454   | 482   | 510   | 538   | 566   | 593   | 621   | 649   |       |       |
| SHEET & STRIP |                          |                      |           |                       |                     |  |                    |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A109          | #4                       | Carbon Steel         | CF        | 330.9                 | --                  | 84.8   | 84.8               |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (2,3) A240    | 304                      | 18 CR - 8 Ni         | -         | 517.1                 | 206.8               | 91.7   | 82.7               | 80.7  | 79.3  | 77.2  | 75.8  | 74.5  | 73.1  | 71.7  | 69.6  | 67.6  | 53.1  | 42.1  |       |       |
| (2,3) A240    | 316                      | 16 CR - 12 Ni - 2 Mo | -         | 517.1                 | 206.8               | 95.1   | 84.8               | 83.4  | 82.0  | 80.7  | 80.0  | 79.3  | 78.6  | 77.9  | 77.2  | 75.8  | 67.6  | 51.0  |       |       |
| (2,3) A240    | 321                      | 18 CR - 10 Ni - Ti   | -         | 517.1                 | 206.8               | 102.0  | 91.0               | 89.6  | 87.6  | 86.9  | 85.5  | 84.8  | 83.4  | 82.7  | 82.0  | 81.3  | 78.6  | 67.6  | 51.0  |       |
| (2,3) A240    | 347                      | 18 CR - 10 Ni - Nb   | -         | 517.1                 | 206.8               | 106.9  | 96.5               | 95.1  | 94.5  | 93.8  | 93.1  | 92.4  | 92.4  | 92.4  | 92.4  | 92.4  | 83.4  | 62.7  | 42.1  | 30.3  |
| (1) A446      | A                        | Carbon Steel         | HR        | 310.3                 | 165.5               | 88.9   | 82.0               |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (1) A526      | -                        | Carbon Steel         | HR        | 310.3                 | 165.5               | 88.9   | 82.0               |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (1) A569      | (superceded by A1011 CS) |                      |           |                       |                     |  |                    |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (1) A570      | (superceded by A1011 SS) |                      |           |                       |                     |  |                    |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (1) A635      | 1010                     | Carbon Steel         | HR        | 324.1                 | 179.3               | 83.4   | 83.4               |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A653 SS       | 33                       | Pregalv. Steel       | -         | 310.3                 | 227.5               | 88.9   | 88.9               |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (1,5) A653 CS | -                        | Pregalv. Steel       | -         | --                    | 206.8               | 80.7   | 80.7               |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (1) A659      | 1020                     | Carbon Steel         | HR        | 344.7                 | 186.2               | 98.6   | 91.7               |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (6) A693      | 630                      | 17-4PH               | AH        | 1275.5                | 1103.2              | 274.4  | 265.4              |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (1) A1011 SS  | 33                       | Carbon Steel         | HR        | 358.5                 | 227.5               | 102.7  | 102.7              |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (1) A1011 SS  | 40                       | Carbon Steel         | HR        | 379.2                 | 275.8               | 108.2  | 108.2              |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (1) A1011 CS  | -                        | Carbon Steel         | HR        | --                    | 206.8               | 93.1   | 93.1               |       |       |       |       |       |       |       |       |       |       |       |       |       |
| PIPE & TUBING |                          |                      |           |                       |                     |  |                    |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A53           | A                        | Carbon Steel         | HR        | 330.9                 | 206.8               | 94.5   | 94.5               | 86.2  | 73.8  |       |       |       |       |       |       |       |       |       |       |       |
| A53           | B                        | Carbon Steel         | HR        | 413.7                 | 241.3               | 117.9  | 117.9              | 107.6 | 89.6  |       |       |       |       |       |       |       |       |       |       |       |
| A106          | A                        | Carbon Steel         | HR        | 330.9                 | 206.8               | 94.5   | 94.5               | 86.2  | 73.8  |       |       |       |       |       |       |       |       |       |       |       |
| A106          | B                        | Carbon Steel         | HR        | 413.7                 | 241.3               | 117.9  | 117.9              | 107.6 | 89.6  |       |       |       |       |       |       |       |       |       |       |       |
| A106          | C                        | Carbon Steel         | HR        | 482.6                 | 275.8               | 137.9  | 136.5              | 126.2 | 102.0 |       |       |       |       |       |       |       |       |       |       |       |
| (2) A312      | 304                      | 18 CR - 8 Ni         | -         | 517.1                 | 206.8               | 77.9   | 70.3               | 68.9  | 67.6  | 66.2  | 64.8  | 63.4  | 62.1  | 60.7  | 59.3  | 57.2  | 45.5  | 35.9  |       |       |
| (2) A312      | 316                      | 16 CR - 12 Ni - 2 Mo | -         | 517.1                 | 206.8               | 80.7   | 72.4               | 71.0  | 69.6  | 68.9  | 68.3  | 67.6  | 66.9  | 66.2  | 65.5  | 64.8  | 57.2  | 43.4  |       |       |
| (2) A312      | 321                      | 18 CR - 10 Ni - Ti   | -         | 517.1                 | 206.8               | 86.9   | 77.2               | 75.8  | 74.5  | 73.8  | 72.4  | 71.7  | 71.0  | 70.3  | 69.6  | 68.9  | 62.7  | 47.6  |       |       |
| (2) A312      | 347                      | 18 CR - 10 Ni - Nb   | -         | 517.1                 | 206.8               | 91.0   | 82.0               | 81.4  | 80.0  | 79.3  | 79.3  | 78.6  | 78.6  | 78.6  | 78.6  | 78.6  | 71.0  | 53.8  | 26.2  |       |
| A335          | P11                      | 1 1/4 CR - 1/2 Mo    | HR        | 413.7                 | 206.8               | 113.8  | 106.2              | 104.1 | 102.0 | 99.3  | 96.5  | 93.8  | 93.8  | 93.8  | 93.8  | 93.8  | 93.8  | 93.8  | 93.8  | 93.8  |
| A335          | P22                      | 2 1/4 CR - 1 Mo      | HR        | 413.7                 | 206.8               | 114.5  | 114.5              | 114.5 | 114.5 | 114.5 | 114.5 | 114.5 | 114.5 | 114.5 | 114.5 | 114.5 | 114.5 | 114.5 | 114.5 | 114.5 |
| A335          | P91                      | 9 CR - 1 Mo - V      | -         | 586.1                 | 413.7               | 166.2  | 161.3              | 157.9 | 153.1 | 146.9 | 140.0 | 131.7 | 122.7 | 112.4 | 96.5  | 71.0  | 48.3  | 29.6  |       |       |
| A513          | 1015                     | Carbon Steel         | HR        | 344.7                 | 220.6               | 98.6   | 98.6               |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A513          | 1020                     | Carbon Steel         | HR        | 344.7                 | 220.6               | 98.6   | 98.6               |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A513          | 1025                     | Carbon Steel         | HR        | 379.2                 | 241.3               | 108.2  | 108.2              |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A519          | 1018                     | Carbon Steel         | HR        | 344.7                 | 220.6               | 98.6   | 98.6               |       |       |       |       |       |       |       |       |       |       |       |       |       |
| CASTINGS      |                          |                      |           |                       |                     |  |                    |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A47           | 32510                    | Malleable Iron       | A         | 344.7                 | 224.1               | 78.6   |                    |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A47           | 35018                    | Malleable Iron       | A         | 365.4                 | 241.3               | 83.4   |                    |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A48           | 20                       | Gray Iron            | -         | 137.9                 | --                  | 13.8   | (limited to 204°C) |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A48           | 25                       | Gray Iron            | -         | 172.4                 | --                  | 17.2   | (limited to 204°C) |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A48           | 30                       | Gray Iron            | -         | 206.8                 | --                  | 20.7   | (limited to 204°C) |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A126          | A                        | Gray Iron            | -         | 144.8                 | --                  | 13.8   | (limited to 204°C) |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A126          | B                        | Gray Iron            | -         | 213.7                 | --                  | 20.7   | (limited to 204°C) |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A126          | C                        | Gray Iron            | -         | 282.7                 | --                  | 27.6   | (limited to 204°C) |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A197          | -                        | Malleable Iron       | A         | 275.8                 | 206.8               | 62.7   |                    |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A216          | WCA                      | Carbon Steel         | N         | 413.7                 | 206.8               | 115.1  | 102.0              | 98.6  |       |       |       |       |       |       |       |       |       |       |       |       |
| A216          | WCB                      | Carbon Steel         | N         | 482.6                 | 248.2               | 136.5  | 122.7              | 118.6 |       |       |       |       |       |       |       |       |       |       |       |       |
| A217          | WC6                      | 1 1/4 CR - 1/2 Mo    | NT        | 482.6                 | 275.8               | 137.9  | 137.9              | 137.9 |       |       |       |       |       |       |       |       |       |       |       |       |
| A217          | WC9                      | 2 1/4 CR - 1 Mo      | NT        | 482.6                 | 275.8               | 133.1  | 131.7              | 129.6 |       |       |       |       |       |       |       |       |       |       |       |       |
| A351          | CF8                      | 18 CR - 8 Ni         | -         | 482.6                 | 206.8               | 73.4   | 66.2               | 64.5  | 63.4  | 61.8  |       |       |       |       |       |       |       |       |       |       |
| A351          | CF8C                     | 18 CR - 10 Ni - Nb   | -         | 482.6                 | 206.8               | 85.5   | 77.2               | 76.1  | 75.6  | 75.0  |       |       |       |       |       |       |       |       |       |       |
| A351          | CF8M                     | 16 CR - 12 Ni - 2 Mo | -         | 482.6                 | 206.8               | 75.6   | 67.8               | 66.7  | 65.6  | 64.5  |       |       |       |       |       |       |       |       |       |       |
| A395          | -                        | Ductile Iron         | -         | 413.7                 | 275.8               | 94.5   | 94.5               |       |       |       |       |       |       |       |       |       |       |       |       |       |
| A536          | 65-45-12                 | Ductile Iron         | -         | 448.2                 | 310.3               | 102.7  | 102.7              |       |       |       |       |       |       |       |       |       |       |       |       |       |

*Conditions: HR=Hot Rolled, CF=Cold Finished, A=Annealed, AH=Age Hardened, N=Normalized, NT=Normalized and Tempered*

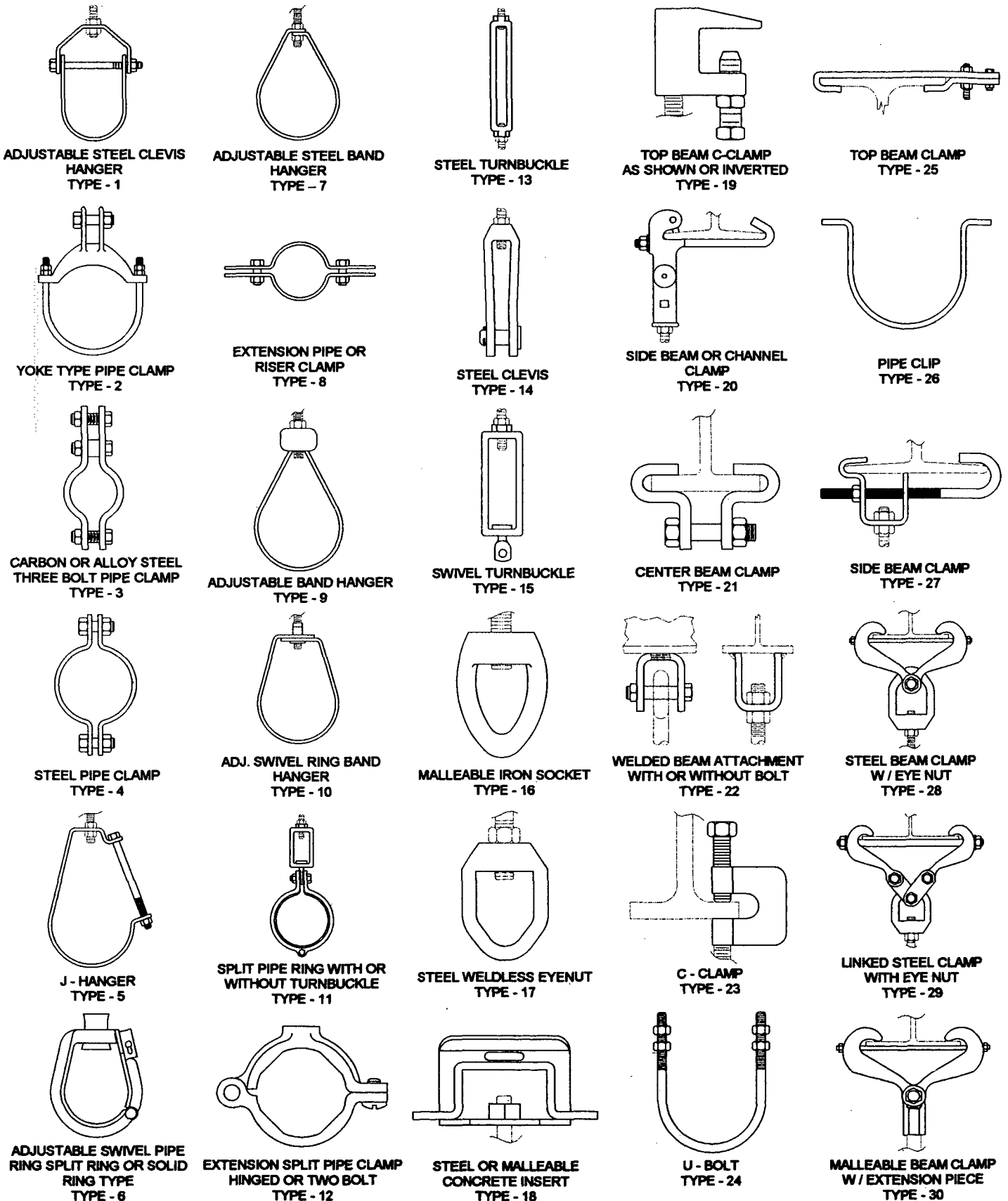
**TABLE A2**  
**Materials and Allowable Stresses, Metric Units (continued)**

| Materials and Allowable Stresses, Metric Units (Continued) |        |                        |           |                       |                     |  |       |       |       |       |       |       |      |      |      |      |      |      |
|--|--------|------------------------|-----------|-----------------------|---------------------|--|-------|-------|-------|-------|-------|-------|------|------|------|------|------|------|
| ASTM Spec  | Grade  | Material Composition   | Condition | Minimum Tensile (MPa) | Minimum Yield (MPa) | Maximum Allowable Stresses in Tension (MPa) for Metal Temperatures Not Exceeding Degrees C |       |       |       |       |       |       |      |      |      |      |      |      |
|  |        |                        |           |                       |                     | -29 to 232   | 343   | 371   | 399   | 427   | 454   | 482   | 510  | 538  | 566  | 593  | 621  | 649  |
| FORGINGS   |        |                        |           |                       |                     |  |       |       |       |       |       |       |      |      |      |      |      |      |
| A105   | -      | Carbon Steel           | HT        | 482.6                 | 248.2               | 136.5  | 122.7 | 118.6 |       |       |       |       |      |      |      |      |      |      |
| A181   | 70     | Carbon Steel           | -         | 482.6                 | 248.2               | 136.5  | 122.7 | 118.6 |       |       |       |       |      |      |      |      |      |      |
| A182   | F11    | 1 1/4 CR - 1/2 Mo - Si | A         | 482.6                 | 275.8               | 137.9  | 137.9 | 137.9 | 135.8 | 132.4 | 128.9 | 94.5  | 64.1 | 43.4 | 29.0 | 19.3 | 13.1 | 8.3  |
| A182   | F22    | 2 1/4 CR - 1 Mo        | A         | 517.1                 | 310.3               | 141.3  | 139.3 | 137.9 | 135.8 | 133.1 | 128.9 | 108.9 | 78.6 | 53.8 | 35.2 | 22.1 | 13.8 | 8.3  |
| (2) A182   | F304   | 18 CR - 8 Ni           | HT        | 517.1                 | 206.8               | 91.7   | 82.7  | 80.7  | 79.3  | 77.2  | 75.8  | 74.5  | 73.1 | 71.7 | 69.6 | 67.6 | 53.1 | 42.1 |
| (2) A182   | F316   | 16 CR - 12 Ni - 2 Mo   | HT        | 517.1                 | 206.8               | 95.1   | 84.8  | 83.4  | 82.0  | 81.4  | 80.0  | 79.3  | 78.6 | 77.9 | 77.2 | 75.8 | 67.6 | 51.0 |
| (2) A182   | F321   | 18 CR - 10 Ni - Ti     | HT        | 517.1                 | 206.8               | 102.0  | 91.0  | 89.6  | 87.6  | 86.9  | 85.5  | 84.8  | 83.4 | 82.7 | 66.2 | 47.6 | 34.5 | 24.8 |
| (2) A182   | F347   | 18 CR - 10 Ni - Cb     | HT        | 517.1                 | 206.8               | 106.9  | 96.5  | 95.1  | 94.5  | 93.8  | 93.1  | 92.4  | 92.4 | 92.4 | 83.4 | 62.7 | 42.1 | 30.3 |
| A668   | A      | Carbon Steel           | -         | 324.1                 | --                  | 92.4   | 92.4  |       |       |       |       |       |      |      |      |      |      |      |
| A668   | B      | Carbon Steel           | A         | 413.7                 | 206.8               | 117.9  | 117.9 |       |       |       |       |       |      |      |      |      |      |      |
| A668   | C      | Carbon Steel           | A         | 455.1                 | 227.5               | 129.6  | 129.6 |       |       |       |       |       |      |      |      |      |      |      |
| A668   | D      | Carbon Steel           | N         | 517.1                 | 258.6               | 147.5  | 147.5 |       |       |       |       |       |      |      |      |      |      |      |
| A668   | E      | Carbon Steel           | DNT       | 572.3                 | 296.5               | 163.4  | 163.4 |       |       |       |       |       |      |      |      |      |      |      |
| (16) A668  | F      | Carbon Steel           | QT        | 620.5                 | 379.2               | 177.2  |       |       |       |       |       |       |      |      |      |      |      |      |
| BOLTING  |        |                        |           |                       |                     |  |       |       |       |       |       |       |      |      |      |      |      |      |
| (10) A193  | B7     | 1 CR - 1/5 Mo          | HT        | 861.8                 | 723.9               | 172.4  | 172.4 | 172.4 | 162.7 | 144.8 | 117.2 | 86.2  | 58.6 | 31.0 |      |      |      |      |
| (11) A193  | B7     | 1 CR - 1/5 Mo          | HT        | 792.9                 | 655.0               | 158.6  | 158.6 | 158.6 | 155.1 | 137.9 | 112.4 | 86.2  | 58.6 | 31.0 |      |      |      |      |
| (12) A193  | B7     | 1 CR - 1/5 Mo          | HT        | 689.5                 | 517.1               | 129.6  | 129.6 | 129.6 | 129.6 | 124.1 | 112.4 | 86.2  | 58.6 | 31.0 |      |      |      |      |
| (2,3,4) A193   | B8     | 18 CR - 8 Ni           | -         | 517.1                 | 206.8               | 91.7   | 82.7  | 81.4  | 79.3  | 77.2  | 75.8  | 74.5  | 73.1 | 71.7 | 69.6 | 67.6 | 53.1 | 41.4 |
| (2,3,4) A193   | B8M    | 16 CR - 12 Ni - 2 Mo   | -         | 517.1                 | 206.8               | 95.1   | 84.8  | 83.4  | 82.0  | 80.7  | 79.3  | 78.6  | 77.9 | 77.2 | 75.8 | 67.6 | 51.0 |      |
| (2,3,4) A193   | B8C    | 18 CR - 10 Ni - Cb     | -         | 517.1                 | 206.8               | 104.8  | 97.2  | 95.1  | 94.5  | 93.8  | 93.1  | 93.1  | 92.4 | 92.4 | 83.4 | 62.7 | 42.1 | 30.3 |
| (2,3,4) A193   | B8T    | 18 CR - 10 Ni - Ti     | -         | 517.1                 | 206.8               | 102.0  | 91.7  | 88.9  | 87.6  | 86.2  | 85.5  | 84.8  | 83.4 | 82.7 | 66.2 | 47.6 | 34.5 | 24.8 |
| A307   | A      | Carbon Steel           | -         | 413.7                 | --                  | 117.9  | 117.9 |       |       |       |       |       |      |      |      |      |      |      |
| A307   | B      | Carbon Steel           | -         | 413.7                 | --                  | 117.9  | 117.9 |       |       |       |       |       |      |      |      |      |      |      |
| (8) A325   | TYPE 2 | Carbon Steel           | HT        | 827.4                 | --                  | 236.5  | 236.5 |       |       |       |       |       |      |      |      |      |      |      |
| (9) A325   | TYPE 2 | Carbon Steel           | HT        | 723.9                 | --                  | 206.8  | 206.8 |       |       |       |       |       |      |      |      |      |      |      |
| (8) A449   | -      | Carbon Steel           | QT        | 827.4                 | --                  | 180.6  | 180.6 |       |       |       |       |       |      |      |      |      |      |      |
| (9) A449   | -      | Carbon Steel           | QT        | 723.9                 | --                  | 157.2  | 157.2 |       |       |       |       |       |      |      |      |      |      |      |
| (13) A449  | -      | Carbon Steel           | QT        | 620.5                 | --                  | 113.8  | 113.8 |       |       |       |       |       |      |      |      |      |      |      |
| A490   | -      | Alloy Steel            | QT        | 1034.2                | 896.3               | 295.8  | 295.8 |       |       |       |       |       |      |      |      |      |      |      |
| RIVETS & NUTS  |        |                        |           |                       |                     |  |       |       |       |       |       |       |      |      |      |      |      |      |
| A194   | ALL    | -                      | -         | Product Specification |                     |  |       |       |       |       |       |       |      |      |      |      |      |      |
| A502   | -      | Carbon Steel           | -         | 358.5                 | 193.1               | 102.7  | 102.7 |       |       |       |       |       |      |      |      |      |      |      |
| A563   | ALL    | Carbon Steel           | -         | Product Specification |                     |  |       |       |       |       |       |       |      |      |      |      |      |      |
| SPRINGS See Figures 2 and 3 for Materials and Stresses     |        |                        |           |                       |                     |  |       |       |       |       |       |       |      |      |      |      |      |      |

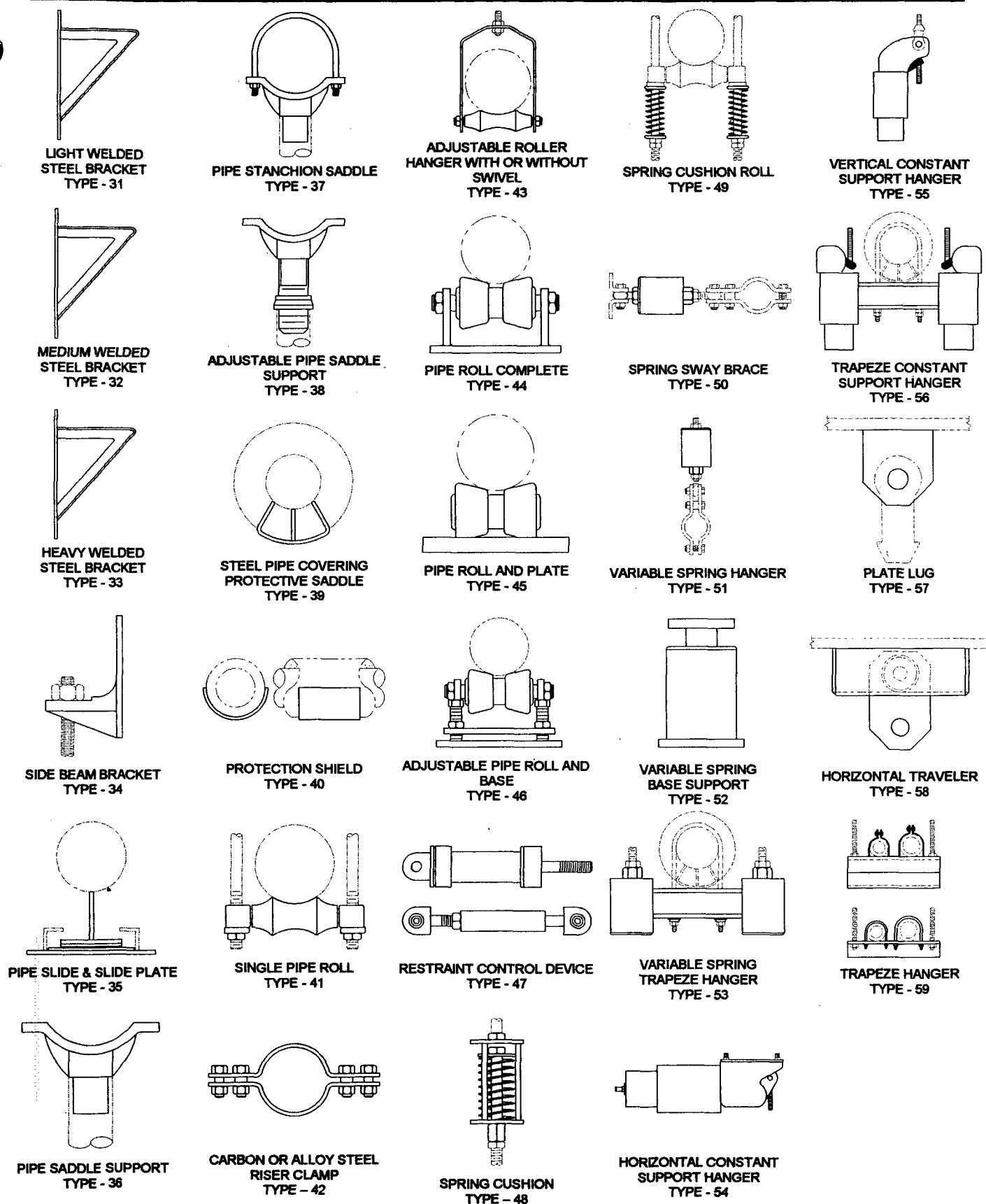
*Conditions: A=Annealed, N=Normalized, DNT=Double Normalized and Tempered, QT=Quenched and Tempered, HT=Heat Treated*

**NOTES:**

- Allowable stresses for these materials are based upon those of comparable materials of similar chemical properties.
- For temperatures above 538°C, these stress values apply only when the carbon content is 0.04% or higher based on heat analysis.
- For temperatures above 538°C, these stress values may be used only if the material is heat treated by treating it to a minimum temperature of 1038°C and quenching in water or rapidly cooling by other means.
- Class 1 only.
- Type B only.
- Age hardened at 579°C.
- For temperatures above 454°C, these stress values apply only when the carbon content is 0.05% or higher based on heat analysis.
- For bolt diameters 2.54 cm and less.
- For bolt diameters greater than 2.54 cm through 3.81 cm.
- For bolt diameters 6.35 cm and less.
- For bolt diameters greater than 6.35 cm through 10.16 cm.
- For diameters greater than 10.16 cm.
- For bolt diameters greater than 3.81 cm through 7.62 cm.
- For material thickness 7.62 cm and less.
- For material thickness greater than 7.62 cm.
- For diameters 10.16 cm and less.



**FIGURE 1**  
**Type Chart**



**FIGURE 1**  
**Type Chart (continued)**

**TABLE 3**  
**Load Ratings of Carbon Steel Threaded Hanger Rods**  
 (For metric rod sizes see Table A3.)

| Nominal Rod Diameter | Root Area of Thread | Maximum Safe Load at Rod Temperature of 650°F (343°C) |      |   |
|----------------------|---------------------|---|------|---|
|                      |                     | Pounds  | kN   |   |
| 3/8                  | .0678               | 730   | 3.23 | <b>Notes:</b><br><br>1. For materials other than carbon steel, see requirements of Section 4.7 and Table 2.<br><br>2. Tabulated loads are based on a minimum actual tensile stress of 50 ksi. (345 MPa) divided by a safety factor of 3.5, reduced by 25% resulting in an allowable stress of 10.7 ksi. (The 25% reduction is to allow for normal installation and service conditions.)<br><br>3. Root areas of thread are based upon the following thread series:<br>dia. 4" and below— coarse thread (UNC)<br>dia. above 4"—4 thread (4-UN) |
| 1/2                  | .126                | 1350  | 5.98 |   |
| 5/8                  | .202                | 2160  | 9.61 |   |
| 3/4                  | .302                | 3230  | 14.4 |   |
| 7/8                  | .419                | 4480  | 19.9 |   |
| 1                    | .551                | 5900  | 26.2 |   |
| 1 1/4                | .890                | 9500  | 42.4 |   |
| 1 1/2                | 1.29                | 13800   | 61.6 |   |
| 1 3/4                | 1.74                | 18600   | 82.8 |   |
| 2                    | 2.30                | 24600   | 109  |   |
| 2 1/4                | 3.02                | 32300   | 144  |   |
| 2 1/2                | 3.72                | 39800   | 177  |   |
| 2 3/4                | 4.62                | 49400   | 220  |   |
| 3                    | 5.62                | 60100   | 267  |   |
| 3 1/4                | 6.72                | 71900   | 320  |   |
| 3 1/2                | 7.92                | 84700   | 377  |   |
| 3 3/4                | 9.21                | 98500   | 438  |   |
| 4                    | 10.6                | 114000  | 505  |   |
| 4 1/4                | 12.1                | 129000  | 576  |   |
| 4 1/2                | 13.7                | 146000  | 652  |   |
| 4 3/4                | 15.4                | 165000  | 733  |   |
| 5                    | 17.2                | 184000  | 819  |   |



**TABLE A3**  
**Load Ratings of Carbon Steel Metric Threaded Hanger Rods**  
 (For inch rod sizes see Table 3.)

| Nominal Rod Diameter | Root Area of Thread | Maximum Safe Load at Rod Temperature of 343°C (650°F) |        |  |
|----------------------|---------------------|---|--------|--|
|                      |                     | kN  | Pounds |  |
| mm                   | Sq. mm *            |   |        |  |
| M10                  | 49.49               | 3.66  | 820    | <b>Notes:</b><br><br>1. For materials other than carbon steel, see requirements of Section 4.7 and Table A2.<br><br>2. Tabulated loads are based on a minimum actual tensile strength of 345 MPa divided by a safety factor of 3.5, reduced by 25% resulting in an allowable stress of 73.9 MPa. (The 25% reduction is to allow for normal installation and service conditions.) |
| M12                  | 72.40               | 5.35  | 1200   |  |
| M16                  | 138.3               | 10.2  | 2300   |  |
| M20                  | 217.1               | 16.0  | 3610   |  |
| M24                  | 312.8               | 23.1  | 5200   |  |
| M30                  | 503.0               | 37.2  | 8300   |  |
| M36                  | 738.0               | 54.5  | 12300  |  |
| M42                  | 1018                | 75.2  | 16900  |  |
| M48                  | 1343                | 99.2  | 22300  |  |
| M56x4                | 2014                | 149   | 33500  |  |
| M64x4                | 2701                | 200   | 44900  |  |
| M68x4                | 3082                | 228   | 51200  |  |
| M72x4                | 3488                | 258   | 58000  |  |
| M80x4                | 4376                | 323   | 72700  |  |

\* M10-M48 are based on minimum root diameters for standard coarse thread class 6g. Taken from ASME B1.13M for metric thread forms.

## 5. FABRICATION REQUIREMENTS FOR STEEL HANGERS

### 5.1 *Cold Forming*

5.1.1 Cold forming of plate and flat bars may be performed on materials 0.5 inch (12.7mm) thick or less to a minimum inside radius of one times the stock thickness. Cold forming may be performed on material over 0.5 inch (12.7mm) thick to a minimum inside radius of 2.5 times the stock thickness. Material over 0.5 inch (12.7mm) thick may be cold formed to an inside radius less than 2.5 times but not less than one times the stock thickness provided heat treatment is performed as prescribed in Section 5.3 and a case history is established showing that forming or a subsequent process does not have a damaging effect detrimental to the strength or function of the product.

5.1.2 Round bars 0.75 inch (19mm) diameter and smaller may be cold formed to a minimum inside radius of 0.5 times the bar diameter. Round bars greater than 0.75 inch (19mm) diameter may be cold formed to a minimum inside radius of 2.5 times bar diameter. Forming is not permitted on threaded areas.

5.1.3 Heating material to less than minimum temperature shown in Section 5.2.1, to facilitate the forming operation, shall be considered cold forming.

### 5.2 *Hot Forming*

5.2.1 Hot forming of plate and flat bars may be performed on materials of any thickness to an inside radius not less than one times the stock thickness within the following surface temperature ranges (no holding time required):

|                            |                        |                         |
|----------------------------|------------------------|-------------------------|
| Carbon Steel               | 1400°F Min.<br>(760°C) | 2000°F Max.<br>(1093°C) |
| Chrome-Moly Alloy Steel    | 1550°F Min.<br>(843°C) | 2000°F Max.<br>(1093°C) |
| Austenitic Stainless Steel | 1400°F Min.<br>(760°C) | 2100°F Max.<br>(1148°C) |

Material shall not be heated in bundles or closed stacks in other than induction type furnaces but shall be separated to allow good circulation within the furnaces.

Materials should not be heated above the maximum temperature shown. No hot forming operation shall be performed below the minimum temperature shown. Carbon steel and chrome-moly alloy steel shall be cooled in still air. Water quenching is not permitted. Cooling of stainless steel other than still-air cooling, may be accomplished as per ASTM A 403, Paragraph 6.

5.2.2 Round bars of any diameter may be hot formed to a minimum inside radius of 0.5 times the bar diameter within the temperature ranges given in Section 5.2.1. Forming is not permitted on threaded areas.

### 5.3 *Heat Treatment After Forming*

5.3.1 Stress relieving, when required of carbon steel and chrome-moly steel, shall be done within the temperature ranges shown below. The material is to be held at temperature for one hour per inch (25.4 mm) of thickness, but not less than one hour, followed by slow cooling in furnace. Carbon steel may be cooled in still air.

|                         |                        |                        |
|-------------------------|------------------------|------------------------|
| Carbon Steel            | 1100°F Min.<br>(593°C) | 1250°F Max.<br>(676°C) |
| Chrome-Moly Alloy Steel | 1300°F Min.<br>(704°C) | 1400°F Max.<br>(760°C) |

5.3.2 A carbide solution heat treatment of austenitic stainless steel, when required by design specification, shall be performed as prescribed by ASTM A 403, Paragraph 6.

5.4 Incremental bending by braking is an acceptable method of forming.

5.5 Formed components may be furnished in "as formed" condition without any further mechanical work.

## 5.6 *Welding*

5.6.1 Unless otherwise specified by the design specification, welders and welding procedures shall be qualified in accordance with the ASME Boiler and Pressure Vessel Code, Section IX. AWS D1.1 may also be used.

5.6.2 When qualifying a welding procedure for materials listed in Table 2, which do not have a Section IX P-Number or S-Number and Group Number from ASME Section III, Code Case N-71-16 qualifies that material to corresponding P-Number/S-Number and Group Number in Section IX. Welder's performance test results and Welding Procedure Qualification Records shall be available upon request, to authorized inspection personnel.

5.6.3 When tack welds are to become a part of the finished weld, they shall be visually examined and ground or feathered, if necessary. Defective tack welds and tack welds made by unqualified welders shall be removed.

5.6.4 Attachments welded directly to the pipe shall be of appropriate chemical composition, compatible for welding, and able to withstand the anticipated loads at the piping temperature. The method of attachment to the pipe shall meet all the preheating, welding, and post-weld heat treating requirements of the applicable piping code.

5.6.5 Welded cold-finished steels of a specific classification, grade, and/or type should be evaluated with the mechanical properties for its hot rolled counterpart in the heat affected zone.

5.6.6 Preheating and post-weld heat treating (PWHT) requirements for pipe hangers shall be as outlined in Tables 4 and A4.

5.6.7 Unacceptable welds shall be removed by flame or arc gouging, grinding, chipping, or machining. Welds requiring repair shall be welded in accordance with the requirements of the original weld procedure. Base metal irregularities requiring repair by welding shall be repaired in accordance with the material specification or ASTM A 6, as applicable. Welders and welding procedures used in making repair welds shall be qualified in accordance with Section 5.6.1.

## 5.7 *Surface Discontinuities*

5.7.1 Surface discontinuities of welds shall be evaluated in accordance with the applicable code or job specification requirements.

5.7.2 Only those surface discontinuities that are detrimental to the strength or function of a product shall be cause for rejection.

**TABLE 4**  
**Preheat and Post-Weld Heat Treatment (PWHT) Requirements**

| Material Designation  | Base Material Size | Thickness of Weld (Equal Leg Fillet Weld)* | Other Requirements         | Minimum Preheat Temperature | Post-Weld Heat Treatment (See Note 4) |
|---|--------------------|--|----------------------------|-----------------------------|---------------------------------------|
| P-1<br>Carbon Steel   | 3/4" & Less        | All Welds                                  | None                       | 50 °F                       | Not Required                          |
|   | Over 3/4" to 1"    | 1/16" to 3/4" (1/8" to 1" Fillet)          |                            |                             |                                       |
|   |                    | Over 3/4" (Over 1" Fillet)                 |                            |                             | 1100 - 1200 °F (See Note 6)           |
|   | Over 1"            | 3/4" & Less (1" & Less Fillet)             | 0.3% Carbon or Less        | 50 °F                       | 1100 - 1200 °F (See Note 6)           |
|   |                    |  | Greater Than 0.3% Carbon   | 175 °F                      |                                       |
|   |                    |  | Or as an Option, None      | 200 °F                      | Not Required                          |
|   |                    | Over 3/4" (Over 1" Fillet)                 | 0.3% Carbon or Less        | 50 °F                       | 1100 - 1200 °F (See Note 6)           |
|   |                    |  | Greater Than 0.3% Carbon   | 175 °F                      |                                       |
| P-4<br>Chrome/Moly Alloy Steel  | 1/2" & Less        | All Weld Sizes                             | Not Mandatory (See Note 9) | 250 °F                      | 1300 - 1375 °F (See Note 6)           |
|   | Over 1/2"          |  | None                       |                             |                                       |
| P-5A<br>Chrome/Moly Alloy Steel   | 1/2" & Less        | All Weld Sizes                             | Not Mandatory (See Note 9) | 300 °F                      | 1300 - 1400 °F (See Note 6)           |
|   | Over 1/2"          |  | None                       |                             |                                       |
| P-5B<br>Chrome/Moly Alloy Steel   | All Sizes          | All Weld Sizes                             | None                       |                             |                                       |
| P-8<br>Stainless Steel  | All Sizes          | All Weld Sizes                             | None                       | 50 °F                       | (See Note 7)                          |
| * Size of equivalent equal leg fillet weld shown for convenience. The weld thickness of all other types of welds needs to be determined by an acceptable conventional method. |                    |  |                            |                             |                                       |

**TABLE A4**  
**Preheat and Post-Weld Heat Treatment (PWHT) Requirements, Metric Units**

| Material Designation            | Base Material Size | Thickness of Weld (Equal Leg Fillet Weld)* | Other Requirements         | Minimum Preheat Temperature | Post-Weld Heat Treatment (See Note 4) |
|---------------------------------|--------------------|--|----------------------------|-----------------------------|---------------------------------------|
| P-1<br>Carbon Steel             | 20mm & Less        | All Welds                                  | None                       | 10 °C                       | Not Required                          |
|                                 | Over 20mm to 25mm  | 2mm to 20mm (3mm to 25mm Fillet)           |                            |                             |                                       |
|                                 |                    | Over 20mm (Over 25mm Fillet)               |                            |                             | 593 - 649 °C (See Note 6)             |
|                                 | Over 25mm          | 20mm & Less (25mm & Less Fillet)           | 0.3% Carbon or Less        | 10 °C                       | 593 - 649 °C (See Note 6)             |
|                                 |                    |  | Greater Than 0.3% Carbon   | 79 °C                       |                                       |
|                                 |                    |  | Or as an Option, None      | 93 °C                       | Not Required                          |
|                                 |                    | Over 20mm (Over 25mm Fillet)               | 0.3% Carbon or Less        | 10 °C                       | 593 - 649 °C (See Note 6)             |
|                                 |                    |  | Greater Than 0.3% Carbon   | 79 °C                       |                                       |
| P-4<br>Chrome/Moly Alloy Steel  | 13mm & Less        | All Weld Sizes                             | Not Mandatory (See Note 9) | 121 °C                      | 704 - 746 °C (See Note 6)             |
|                                 | Over 13mm          |  | None                       |                             |                                       |
| P-5A<br>Chrome/Moly Alloy Steel | 13mm & Less        | All Weld Sizes                             | Not Mandatory (See Note 9) | 149 °C                      | 704 - 760 °C (See Note 6)             |
|                                 | Over 13mm          |  | None                       |                             |                                       |
| P-5B<br>Chrome/Moly Alloy Steel | All Sizes          | All Weld Sizes                             | None                       |                             |                                       |
| P-8<br>Stainless Steel          | All Sizes          | All Weld Sizes                             | None                       | 10 °C                       | (See Note 7)                          |

\* Size of equivalent equal leg fillet weld shown for convenience. The weld thickness of all other types of welds needs to be determined by an acceptable conventional method.

**TABLES 4 and A4**  
**Preheat and Post-Weld Heat Treatment (PWHT) Requirements (continued)**

**NOTES:**

1. When joining carbon steel and alloy steel by welding, the higher preheat and PWHT temperatures of the two materials shall apply.
2. When joining stainless steel to either carbon steel or alloy steel, caution shall be exercised as the stainless steel material may not be suited for the preheat or PWHT temperatures required by the other materials.
3. When carbide solution heat treatment of stainless steel is required by the design specification, heat treatment shall be in accordance with ASTM A 403, Paragraph 6.
4. PWHT Requirements:
  - a. PWHT may be by full furnace heat treatment or by local heating. When local heating is used, the width of the heated band shall be at least three (3) times the thickness of the thickest section at the joint.
  - b. For Table 4- Above 600°F the rate of heating and cooling shall not exceed 600°F per hour divided by one-half (1/2) the maximum thickness of material in inches at the weld, but in no case shall the rate exceed 600°F per hour.
  - c. For Table A4- Above 315°C the approximate rate of heating and cooling shall not exceed 315°C per hour divided by 0.02 times the maximum thickness of material in mm at the weld, but in no case shall the rate exceed 315°C per hour.
5. Base material size refers to the thickness at the weld of thicker part being joined.
6. Hold Time Requirements:
  - a. For Table 4- Hold time shall be one (1) hour/ in. up to 2" thick with fifteen (15) minutes minimum. For 2" and over; two (2) hours plus fifteen (15) minutes for each inch over 2".
  - b. For Table A4- Hold time shall be one (1) hour/ 25mm up to 50mm thick with fifteen (15) minutes minimum. For 50mm and over; two (2) hours plus fifteen (15) minutes for each 25mm over 50mm.
7. Post weld heat treatment of stainless steel is neither required nor prohibited (Notes 2 and 3).
8. These tables, which cover materials commonly used in the manufacture of pipe hangers and supports, have been consolidated from ASME B31.1-1998 edition.
9. PWHT is not mandatory for P-4 & P-5A material when welds comply with all the following conditions :
  - a. Nominal pipe size is NPS 4 or less.
  - b. Nominal material thickness is 1/2" (13mm) or less.
  - c. Specified carbon content of material to be welded is 0.15% or less.
  - d. A minimum preheat of 250°F (120°C) is maintained for P-4 material during welding.
  - e. A minimum preheat of 300°F (150°C) is maintained for P-5A material during welding.

## 6. PROTECTIVE COATINGS FOR CORROSION, ABRASION, AND ELECTROLYTIC RESISTANCE

### 6.1 *Metallic Coatings*

6.1.1 Metallic coatings for corrosion resistance may be applied by electroplating, pre-galvanizing, hot dip galvanizing, or mechanical plating.

6.1.2 Electroplating shall be in accordance with ASTM B 633 or B 766 for the specific coating used. To avoid difficulty in assembling threaded parts that are plated, female machine threads may be tapped oversize. It is not permissible to rethread male parts after plating. It is acceptable for female threads to be uncoated.

6.1.3 Pre-galvanized sheet shall meet the requirements of ASTM A 653.

6.1.4 Hot dip galvanizing shall be in accordance with ASTM A 153 or A 123. To avoid difficulty in assembling threaded parts, it is recommended that male parts be shaken, spun, or hand brushed to remove spelter lumps from the threads. It is recommended that female machine threads be tapped oversize to accommodate the male thread. It is acceptable for female threads to be uncoated. Any process, including galvanizing, that is performed by parties other than the manufacturer may affect performance of the product, therefore the manufacturer shall be consulted.

6.1.5 Mechanical plating shall be done in accordance with ASTM B 695.

6.1.6 Repair of metallic protective coatings may be performed in accordance with coating manufacturer's recommendations.

6.1.7 Superficial copper plating or other superficial coatings are not intended to provide corrosion protection and are applied for identification purposes only.

### 6.2 *Non-Metallic Coatings*

6.2.1 Non-metallic coatings shall be the types selected for specific purposes. Application of coatings shall be in accordance with the coating manufacturer's recommendations. In general, only such coatings with good adhesive quality that will withstand reasonably rough handling should be used.

6.2.2 Non-metallic coatings that are suitable for threaded products may be applied before assembly.

6.2.3 Non-metallic coatings, jackets, and liners to prevent abrasion of glass or plastic pipe, etc., shall be applied in accordance with manufacturer's recommendations.

6.2.4 Non-metallic coatings, jackets, and liners for electrolytic resistance shall have dielectric strength suitable for the intended use.

## 7. DIMENSIONS

7.1 Unprotected flat steel shall have a minimum thickness of 0.120 inch (3.2mm) and a minimum width of 1 inch (25.4mm). The minimum cross section for unprotected hangers (Types 1, 5, 7, 9, and 10) shall be 0.105 inch (2.7mm) x 0.88 inch (22.4mm). As an exception for pipe NPS 1 (DN25) and smaller, the minimum cross section shall be 0.060 inch (1.6mm) x 0.75 inch (19.1mm). Equivalent cross sections may be substituted provided the minimum thickness is not decreased.

7.2 Hangers that meet the tabulated load requirements of Table 1 and that have protective coatings in accordance with Section 6 need not conform to minimum dimensional requirements of Section 7.1.

7.3 Hanger rods shall be a minimum of 3/8 inch (9.6mm) diameter. The use of 3/8 inch rod is limited to pipe or tubing NPS 4 (DN100) and less. For pipe and tubing greater than NPS 4 (DN100), the rod diameter shall not be less than 1/2" (12.7mm) and sized for the design load per Table 3. In addition, the minimum rod diameter for rigid hangers must be sized for the loads shown in Table 1, subject to the above restrictions.

7.4 Hanger rods utilizing rolled threads must be threaded full length.

7.5 Eye rods shall have a minimum inside diameter of eye 0.12 inch (3.2mm) larger than the rod size.

7.5.1 Forged eye rods shall have a metal area across the eye equal to or greater than 1.25 times the area of the rod.

7.5.2 Formed and welded eye rods shall have a circumferential length of weld not less than twice the rod diameter.

## 8. THREADS

8.1 Inch screw threads shall be in conformance with ASME B1.1 or Federal Standard H28, UNC 2A/2B for the coarse thread series and 8UN 2A/2B for the eight thread series. Metric screw threads shall be in conformance with ASME B1.13M 6H/6g.

8.2 Pipe that is threaded for adjustment means shall be in accordance with ANSI B1.20-1 NPSM and NPSL for Standard Straight Pipe Threads.

8.3 Special thread forms and fits other than specified by Sections 8.1 and 8.2 shall be used only when both male and female members are furnished as part of a permanent assembly or in cases listed in Section 6.1.4.

## 9. PROTECTION SADDLES AND SHIELDS

9.1 Pipe covering protection saddles (Type 39) shall be made of material as follows: For pipe NPS 5 (DN125) and smaller, the minimum metal thickness shall be 0.12 inch (3.2mm); for pipe NPS 6 (DN150) and larger, the minimum metal thickness shall be 0.19 inch (4.8mm). Saddles shall have sufficient depth for the insulation thickness required and the ribs shall be notched so that the rib contact with pipe is between 25% and 50% of each rib length. All standard saddles shall be 12 inch (305mm) in axial length and shall span an arc of approximately 60°. Saddles for pipe NPS 12 (DN300) and larger shall have a center rib. Standard saddles shall accommodate nominal

insulation thicknesses 1", 1-1/2", 2", 2-1/2", 3", 4", and 5-1/2" (25mm, 38mm, 51mm, 64mm, 76mm, 102mm and 140mm).

9.2 Pipe covering protection shields (Type 40) are used to prevent crushing of insulation at the hanger point. They can be used with or without high-strength compressive inserts.

9.2.1 When used without high-strength compressive inserts, pipe covering protection shields shall be in accordance with Table 5 and shall span an arc of 180°.

9.2.2 When pipe covering protection shields are used with high-strength compressive inserts, the shield length and thickness shall be appropriate for the compressive strength of the insert material. The insert shall be at least as long as the shield and where a vapor barrier is required, the vapor barrier shall extend 2 inches (51mm) beyond the shield and overlap the outside circumference by 2 inches (51mm).

9.2.3 It is recommended that provision be made to hold shields and saddles in place.

9.2.4 Protection shield gages listed in Table 5 are for use with band type hangers only. For point loading, increase shield thickness and length. When shields are used with rollers, shield thickness may be adjusted accordingly and shield lengths shall be increased to keep rolling point of contact within the middle one-third of the shield length.

**TABLE 5**  
**Dimensions for Pipe Covering Protection Shields**

| Nominal Pipe or Tubing Size |           | Length |     | Thickness |      |      |
|-----------------------------|-----------|--------|-----|-----------|------|------|
| in                          | mm        | in     | mm  | gage      | in   | mm   |
| 1/4 - 3 1/2                 | 7-90      | 12     | 305 | 18        | .048 | 1.22 |
| 4                           | 100       | 12     | 305 | 16        | .060 | 1.52 |
| 5 & 6                       | 125 & 150 | 18     | 457 | 16        | .060 | 1.52 |
| 8 - 14                      | 200-350   | 24     | 610 | 14        | .075 | 1.91 |
| 16 - 24                     | 400-600   | 24     | 610 | 12        | .105 | 2.67 |

Table 5 is based on 15 psi (103 kPa) compressive strength insulation. For compressive strengths other than 15 psi (103 kPa), dimensions may be adjusted accordingly.



## 10. SPRING SUPPORTS AND SWAY BRACES

**10.1 *Spring Supports.*** Spring supports are divided into three classes; Spring Cushion, Variable Support, and Constant Support.

**10.1.1 *Spring Cushion Supports (Types 48 and 49).*** This class is limited to those using springs having a 2 inch (51mm) or less total deflection and which are not provided with load or travel indicators. Springs shall be confined so that accidental release of load is impossible. Travel limit stops need not be provided.

**10.1.2 *Variable Supports (Types 51, 52, and 53).*** This class applies to all variable-effort spring supports. Supports in this class shall have travel scales with provisions for marking "hot" and "cold" settings. Unit load rating shall be in the form of load scales or indicated operating load and spring rate. Limit stops shall be provided to prevent excessive travel from overstressing the spring or release of load. A properly designed confined compression spring will serve as such a stop. Where stops for hydrostatic test purposes are provided, the unit shall be capable of supporting up to 2 times the normal operating load. Spring supports for this class shall have characteristics so that use at the maximum recommended pipe travel results in a variability factor of not more than 25%. (See Equation 1.)

Equation 1:

$$\text{Variability Factor} = \frac{\text{Pipe Travel in (mm)} \times \text{Spring rate lbs/in (N/mm)}}{\text{Operating Load lbs (N)}}$$

### 10.1.3 *Constant Supports (Types 54, 55, and 56).*

This class applies to all constant-effort spring supports where the variable spring force is compensated either mechanically or by auxiliary springs to result in a mean variability (deviation from specified load)<sup>(a)</sup>, including friction, of not more than 6% throughout total travel range. These supports shall be provided with a travel scale, a load adjustment scale, provisions for field load adjustment of at least  $\pm 10\%$ , provisions for "hot" and "cold" settings, limit stops to prevent over travel or release of load, and auxiliary stops (where required) for erection and hydrostatic test purposes. The unit shall be capable of supporting up to 2 times the normal operating load. All constant supports shall be calibrated by the manufacturer. Special consideration shall be given to the possible effects of calibrating the unit in other than the intended installed position. The user is advised to specify a unit with sufficient total travel to provide adequate travel reserve.

**10.2 *Spring Sway Brace (Type 50).*** This class includes spring devices designed to control undesirable pipe movement and also provide forces to restore pipe to normal operating position. They shall consist of one or more springs, suitably confined, and may be either single or double acting.

<sup>(a)</sup> Deviation from specified load is the sum of kinematic friction and manufacturing tolerance factor. Determination of deviation is by load test machine and is calculated in Equation 2.

Equation 2:

Deviation

$$\text{From Specified Load} = \frac{\text{Max. reading moving down} - \text{Min. reading moving up}}{\text{Max. reading moving down} + \text{Min. reading moving up}}$$

Maximum reading moving down and minimum reading moving up shall be within 6% of specified load.

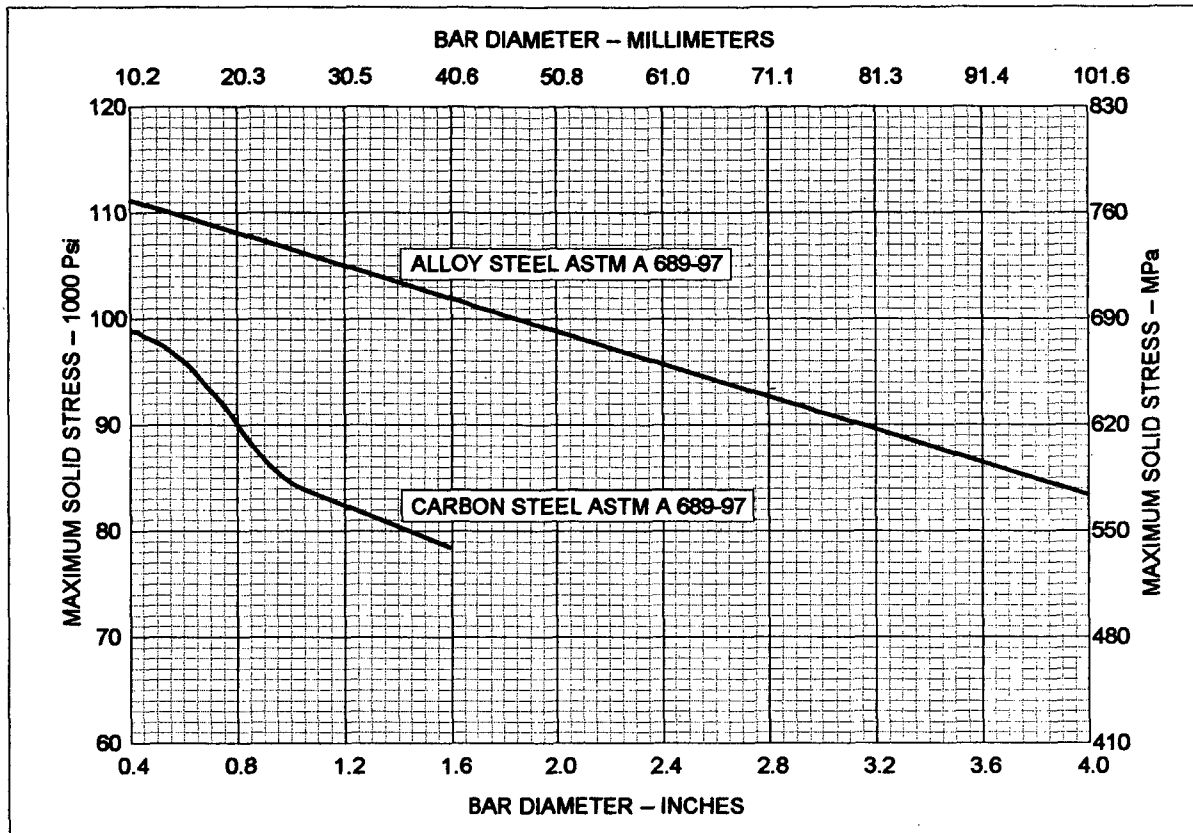


FIGURE 2

### Solid Design Stress (Uncorrected) for Helical Hot Wound Quenched and Tempered or Helical Cold Wound Springs Tempered After Forming

#### 11. SPRING DESIGN

11.1 Structural components of all classes of spring supports and sway braces noted in Section 10 shall be designed as specified elsewhere in this standard except that the spring shall be designed as stated in Sections 11.2 through 11.5.

11.2 Springs for pipe supports are generally of the helical type. Compression springs, unless suitably guided, shall have a free length to coil diameter (O.D.) ratio not greater than 4:1. For spring coils with a ratio greater than 4:1 and stacked coils provided with spacer plates, the spring casing serves as a guide. Special forms of springs such as leaf, disc, volute, involute, torsion, extension springs, and the like may be used. Such forms, when used, are to be designed and manufactured in accordance with acceptable commercial practices.

#### 11.3 Helical Hot Wound Quenched and Tempered or Helical Cold Wound Springs Tempered After Forming

11.3.1 Springs shall be designed so that maximum uncorrected solid stress<sup>(a)</sup> for compression springs shall not exceed those shown on the chart, Figure 2, by more than 20%. Working stresses (uncorrected) for compression springs shall be limited to 90% of the chart values.

11.3.2 Springs shall be manufactured and tested in accordance with ASTM A 125.

(a) Maximum uncorrected solid stress is a calculated stress without correction for curvature.

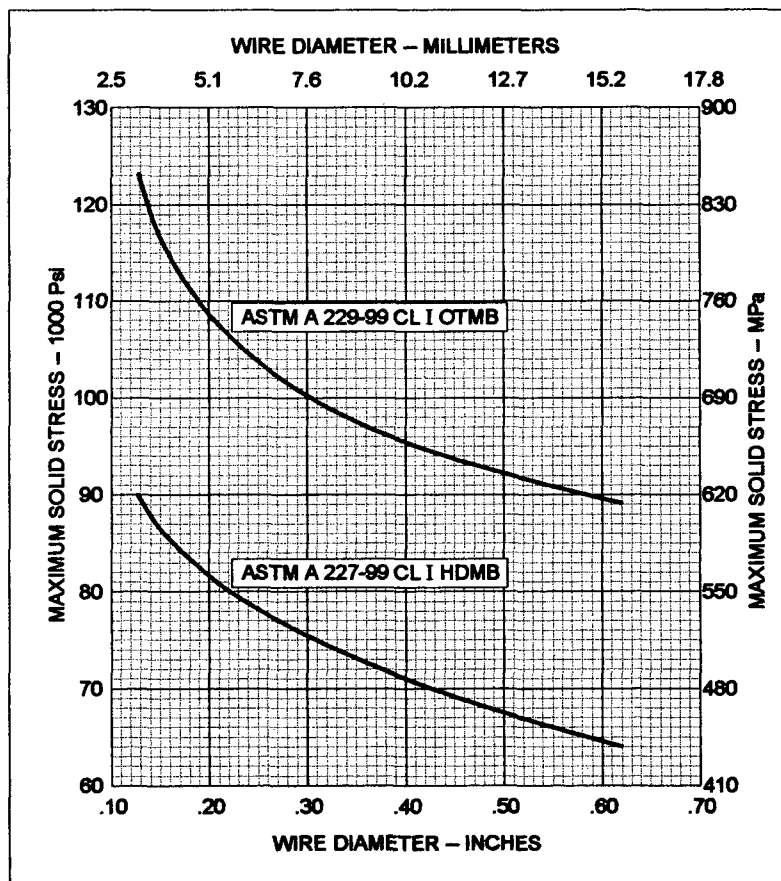
11.3.3 Alloy springs of 1.5 inch (38.1mm) and larger bar diameter shall be inspected after heat treatment by magnetic particle or equivalent method. Springs with seams, slits, or quench cracks deeper than 3% of bar diameter shall be rejected. The depth of discontinuity may be determined by grinding and blending, and measuring the minimum diameter of the remaining bar.

#### 11.4 Helical Cold Wound Springs

11.4.1 Compression springs shall be designed so that the maximum uncorrected solid stress shall not exceed those shown on the chart, Figure 3. Working stresses (uncorrected) for compression springs shall be limited to 80% of chart values. For other materials, refer to publication referenced in Section 11.4.2.

11.4.2 Springs shall be manufactured in accordance with Spring Manufacturers Institute, Inc., Standard for Compression, Extension, Torsion and Garter Springs.

11.5 Springs may be electroplated for corrosion protection provided proper procedures to avoid embrittlement are observed in accordance with ASTM B 242. Maximum allowable working stress shall be reduced 15% for electroplated springs. Non-metallic coatings shall be applied for corrosion protection whenever possible to avoid inherent electroplating difficulties.



**FIGURE 3**  
**Solid Design Stress (Uncorrected) for Cold Wound Compression Springs**

**12. RESTRAINT CONTROL DEVICES**

12.1 Hydraulic devices for the control of vibration or dynamic loads shall be designed in accordance with proven commercial practice and the requirements of Section 4. It is recommended that a non-flammable fluid be used. These devices shall accommodate thermal movement.

12.2 Mechanical devices for the control of vibration and dynamic forces shall be designed in accordance with the requirements of Section 4. Materials shall be suitable for the intended service and ambient conditions. These devices shall accommodate thermal movement.

12.3 Rigid struts or sway braces used for the control of vibration and dynamic forces shall be designed in accordance with the requirements of Section 4. Materials shall be suitable for the intended service and ambient conditions. Rigid struts cannot accommodate thermal movement in the primary direction (tension or compression).

**13. MARKING**

13.1 On cast hangers and supports, the name, initial or other identifying mark may be legibly cast on

each piece. On fabricated hangers and supports, the name or mark may be die stamped on a main member. This marking may be omitted if it cannot be incorporated into the regular production process without additional operational steps, and should be omitted where it may impair the strength.

13.2 Hanger components specifically sized for use on copper tubing or copper pipe are normally identified by the manufacturer by a color system; this may not be intended to provide corrosion protection. The user should consult with the manufacturer when corrosion protection is required. (See Section 6.1.7).

**14. INSPECTION**

14.1 Units shall be inspected in accordance with the established quality control procedures of the manufacturer.

**15. TESTING**

15.1 Any physical or non-destructive testing of units or parts thereof, beyond that required for normal production control, shall be the responsibility of the purchaser.

## ANNEX A

### Referenced Standards and Applicable Dates

This Annex is an integral part of this Standard Practice and is placed after the main text for convenience.

#### ANSI

B1.20.1-1983      Pipe Threads, General Purpose (Inch)

#### ASME

B1.1-1989 (R 2001)    Unified Inch Screw Threads (UN and UNR Thread Form)  
B1.13M-2001      Metric Screw Threads—M Profile  
B31.1-2001      Power Piping  
B31.3-2002      Process Piping  
B31.4-2002      Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids  
B31.5-2001      Refrigeration Piping and Heat Transfer Components  
B31.8-2000      Gas Transmission and Distribution Piping Systems  
B31.9-1996      Building Services Piping Code  
ASME-2001      Boiler and Pressure Vessel Code

#### ASTM

A 6/ A 6M-02      General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling  
A 125-96 (2001)    Steel Springs, Helical, Heat-Treated  
A 194/A 194M-01a   Carbon and Alloy Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both  
A 370-02e1      Standard Test Methods and Definitions for Mechanical Testing of Steel Products  
A 403/A 403M-02    Wrought Austenitic Stainless Steel Piping Fittings  
A 653/A 653M-02a   Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process  
B 242-99      Preparation of High-Carbon Steel for Electroplating  
B 633-98e1      Electrodeposited Coatings of Zinc on Iron and Steel  
B 695-00      Coatings of Zinc Mechanically Deposited on Iron and Steel  
B 766-86 (1998)    Electrodeposited Coatings of Cadmium

#### AWS

D1.1/D1.1M-2002    Structural Welding Code Steel

#### Federal Standard

H28-2001      Screw Thread Standards for Federal Services

**ANNEX A**  
**Referenced Standards and Applicable Dates (continued)**

**FM**

FM1951/1952  
/1953-1975

Approval Standard for Pipe Hanger Components for Automatic Sprinkler Systems

**MSS**

SP-69-2002  
SP-89-1998  
SP-127-2001

Pipe Hangers and Supports – Selection and Application  
Pipe Hangers and Supports – Fabrication and Installation Practices  
Bracing For Piping Systems Seismic – Wind – Dynamic Design, Selection, Application

**SMI**

n/a-2000

Compression, Extension, Torsion and Garter Springs

**UL**

UL203-1996

Pipe Hanger Equipment for Fire Protection Service

**ANNEX A**  
**Referenced Standards and Applicable Dates (continued)**

Publications of the following organizations appear in the preceding list:

|      |  |
|------|--|
| ANSI | American National Standards Institute<br>25 West 43rd Street, New York, NY 10036, Phone: (212) 354-3300  |
| ASME | The American Society of Mechanical Engineers<br>Three Park Avenue, New York, NY 10016-5990, Phone: (800) 843-2763  |
| ASTM | American Society for Testing and Materials<br>100 Bar Harbor Drive, West Conshohocken, PA 19428, Phone: (610) 832-9500   |
| AWS  | American Welding Society<br>550 NW LeJeune Road, Miami, FL 33126, Phone: (800) 443-9353  |
| FM   | Factory Mutual Research<br>1151 Boston-Providence Turnpike, Norwood, MA 02062, Phone: (617) 762-4300   |
| GSA  | Federal Standards care of the General Services Administration<br>Federal Supply Service, FSS Acquisition Management Center, Environmental Programs &<br>Engineering Policy Division, Washington, DC 20406, Phone: (703) 305-5682 |
| MSS  | Manufacturers Standardization Society of the Valve and Fittings Industry, Inc.<br>127 Park Street, N.E., Vienna, VA 22180, Phone: (703) 281-6613   |
| SMI  | Spring Manufacturers Institute, Inc.<br>2001 Midwest Road, Suite 106, Oak Brook, IL 60523, Phone: (630) 495-8588   |
| UL   | Underwriters Laboratories<br>333 Pfingsten Road, Northbrook, IL 60062, Phone: (708) 272-8800   |

# List of MSS Standard Practices (Price List Available Upon Request)

| Number      |  |
|-------------|--|
| SP-6-2001   | Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings  |
| SP-9-2001   | Spot Facing for Bronze, Iron and Steel Flanges   |
| SP-25-1998  | Standard Marking System For Valves, Fittings, Flanges and Unions   |
| SP-42-1999  | Class 150 Corrosion Resistant Gate, Globe, Angle and Check Valves with Flanged and Butt Weld Ends  |
| SP-43-1991  | (R 01) Wrought Stainless Steel Butt-Welding Fittings   |
| SP-44-1996  | (R 01) Steel Pipeline Flanges  |
| SP-45-1998  | Bypass and Drain Connections   |
| SP-51-2000  | Class 150LW Corrosion Resistant Flanges and Cast Flanged Fittings  |
| SP-53-1999  | (R 02) Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components - Magnetic Particle Examination Method   |
| SP-54-1999  | (R 02) Quality Standard for Steel Castings for Valves, Flanges, and Fittings and Other Piping Components - Radiographic Examination Method   |
| SP-55-2001  | Quality Standard for Steel Castings for Valves, Flanges, Fittings, and Other Piping Components - Visual Method for Evaluation of Surface Irregularities  |
| SP-58-2002  | Pipe Hangers and Supports - Materials, Design, and Manufacture   |
| SP-60-1999  | Connecting Flange Joint Between Tapping Sleeves and Tapping Valves   |
| SP-61-2003  | Pressure Testing of Steel Valves   |
| SP-65-1999  | High Pressure Chemical Industry Flanges and Threaded Stubs for Use with Lens Gaskets   |
| SP-67-2002  | Butterfly Valves   |
| SP-68-1997  | High Pressure Butterfly Valves with Offset Design  |
| SP-69-2002  | Pipe Hangers and Supports - Selection and Application  |
| SP-70-1998  | Cast Iron Gate Valves, Flanged and Threaded Ends   |
| SP-71-1997  | Gray Iron Swing Check Valves, Flanged and Threaded Ends  |
| SP-72-1999  | Ball Valves with Flanged or Butt Welding Ends for General Service  |
| SP-73-1991  | (R 96) Brazing Joints for Copper and Copper Alloy Pressure Fittings  |
| SP-75-1998  | Specification for High Test Wrought Butt Welding Fittings  |
| SP-77-1995  | (R 00) Guidelines for Pipe Support Contractual Relationships   |
| SP-78-1998  | Cast Iron Plug Valves, Flanged and Threaded Ends   |
| SP-79-1999a | Socket-Welding Reducer Inserts   |
| SP-80-1997  | Bronze Gate, Globe, Angle and Check Valves   |
| SP-81-2001  | Stainless Steel, Bonnetless, Flanged Knife Gate Valves   |
| SP-82-1992  | Valve Pressure Testing Methods   |
| SP-83-2001  | Class 3000 Steel Pipe Unions, Socket Welding and Threaded  |
| SP-85-2002  | Gray Iron Globe & Angle Valves, Flanged and Threaded Ends  |
| SP-86-2002  | Guidelines for Metric Data in Standards for Valves, Flanges, Fittings, and Actuators   |
| SP-88-1993  | (R 01) Diaphragm Valves  |
| SP-89-1998  | Pipe Hangers and Supports - Fabrication and Installation Practices   |
| SP-90-2000  | Guidelines on Terminology for Pipe Hangers and Supports  |
| SP-91-1992  | (R 96) Guidelines for Manual Operations of Valves  |
| SP-92-1999  | MSS Valve User Guide   |
| SP-93-1999  | Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components-Liquid Penetrant Examination Method   |
| SP-94-1999  | Quality Std for Ferritic and Martensitic Steel Castings for Valves, Flanges, and Fittings and Other Piping Components-Ultrasonic Examination Method  |
| SP-95-2000  | Swage(d) Nipples and Bull Plugs  |
| SP-96-2001  | Guidelines on Terminology for Valves and Fittings  |
| SP-97-2001  | Integrally Reinforced Forged Branch Outlet Fittings-Socket Welding, Threaded, and Buttwelding Ends   |
| SP-98-2001  | Protective Coatings for the Interior of Valves, Hydrants, and Fittings   |
| SP-99-1994  | (R 01) Instrument Valves   |
| SP-100-2002 | Qualification Requirements for Elastomer Diaphragms for Nuclear Service Diaphragm Valves   |
| SP-101-1989 | (R 01) Part-Turn Valve Actuator Attachment-Flange and Driving Component Dimensions and Performance Characteristics   |
| SP-102-1989 | (R 01) Multi-Turn Valve Actuator Attachment - Flange and Driving Component Dimensions and Performance Characteristics  |
| SP-103-1995 | (R 00) Wrought Copper and Copper Alloy Insert Fittings for Polybutylene Systems  |
| SP-104-1995 | Wrought Copper Solder Joint Pressure Fittings  |
| SP-105-1996 | (R 01) Instrument Valves for Code Applications   |
| SP-106-1990 | (R 96) Cast Copper Alloy Flanges and Flanged Fittings, Class 125, 150 and 300  |
| SP-107-1991 | (R 00) Transition Union Fittings for Joining Metal and Plastic Products  |
| SP-108-2002 | Resilient-Seated Cast-Iron Eccentric Plug Valves   |
| SP-109-1997 | Welded Fabricated Copper Solder Joint Pressure Fittings  |
| SP-110-1996 | Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends  |
| SP-111-2001 | Gray-Iron and Ductile-Iron Tapping Sleeves   |
| SP-112-1999 | Quality Standard for Evaluation of Cast Surface Finishes - Visual and Tactile Method. This SP must be sold with a 10-surface, three dimensional Cast Surface Comparator, which is a necessary part of the Standard. Additional Comparators may be sold separately at \$25.00 each. Same quantity discounts apply on total order. |
| SP-113-2001 | Connecting Joint between Tapping Machines and Tapping Valves   |
| SP-114-2001 | Corrosion Resistant Pipe Fittings Threaded and Socket Welding, Class 150 and 1000  |
| SP-115-1999 | Excess Flow Valves 1 1/4 NPS and Smaller, for Fuel Gas Service   |
| SP-116-1996 | Service Line Valves and Fittings for Drinking Water Systems  |
| SP-117-2002 | Bellows Seals for Globe and Gate Valves  |
| SP-118-2002 | Compact Steel Globe & Check Valves - Flanged, Flangeless, Threaded, & Welding Ends (Chemical & Petroleum Refinery Service)   |
| SP-119-2003 | Factory-Made Wrought Belled End Socket-Welding Fittings  |
| SP-120-2002 | Flexible Graphite Packing System for Rising Stem Steel Valves (Design Requirements)  |
| SP-121-1997 | (R 02) Qualification Testing Methods for Stem Packing for Rising Stem Steel Valves   |
| SP-122-1997 | Plastic Industrial Ball Valves   |
| SP-123-1998 | Non-Ferrous Threaded and Solder-Joint Unions for Use With Copper Water Tube  |
| SP-124-2001 | Fabricated Tapping Sleeves   |
| SP-125-2000 | Gray Iron and Ductile Iron In-Line, Spring-Loaded, Center-Guided Check Valves  |
| SP-126-2000 | Steel In-Line Spring-Assisted Center Guided Check Valves   |
| SP-127-2001 | Bracing for Piping Systems Seismic-Wind-Dynamic Design, Selection, Application   |
| SP-129-2003 | Copper-Nickel Socket-Welding Fittings and Unions   |
| (R YEAR)    | Indicates year standard reaffirmed without substantive changes   |

A large number of former MSS Practices have been approved by the ANSI or ANSI Standards, published by others. In order to maintain a single source of authoritative information, the MSS withdraws its Standard Practice in such cases.